A Conceptual Framework for Devising Adaptive User Interfaces to Improve the Usability of Mobile ERP

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Abstract

One of the major types of enterprise applications is enterprise resource planning systems (ERP systems), and many research works have pointed out that ERP systems suffer from poor usability due to their complex, rigid, and bloated user interfaces.

Nowadays, the increasing demands to access ERP systems via mobile devices, such as smart phones, mobile full-screen phones, tablet computers, and mobile handheld computers are noted. Thus, mobile applications that are able to manipulate ERP functionalities, to perform flexible actions and reactions are called mobile ERP applications.

Mobile ERP has become a core requirement for enterprises that have ERP systems, due to the benefits that can be reaped from this model, such as higher operational efficiencies and effectiveness, reducing some costs, real-time visibility and traceability, and better decision making.

However, mobile ERP is still a young topic in research and practice, and there is a knowledge gap in the literature regarding the usability of the mobile ERP, while usability is considered a critical success factor for any software application.

Mobile ERP is an extension of ERP systems, and thus, several potential usability challenges might hinder the sustainability of the mobile ERP model, due to the usability challenges that could be inherited from ERP systems, and the impact of the mobile context of use.

Consequently, this research study aims to improve the usability of mobile ERP apps by addressing their potential usability challenges. Therefore, five research studies were conducted in order to construct a conceptualisation of the usability challenges of mobile ERP apps through:

1. Identifying the usability challenges of mobile HCI and ERP systems.
2. Identifying the usability challenges of mobile ERP apps from the reality of business practices.
3. Identifying a usability evaluation method that can be used to evaluate the usability of mobile ERP apps.

Adaptive user interfaces (AUIs) have been exploited in several research works as a means to improve the usability of software applications. Therefore, these types of user interfaces (UIs) have been exploited in this research study to address the identified usability challenges of mobile ERP apps, which have been identified from the aforementioned research studies. Consequently, a computational framework was developed for devising AUIs for mobile ERP apps by determining the following components regarding the context of this research study:

1. The adapted constituents that can be exploited.
2. The information that is considered for the adaptation processes.
3. The adaptation methods and techniques that can be exploited for mobile ERP apps.
4. The adaptive system architecture that can operate the determined adaptation processes for mobile ERP apps.

The final phase of this research study aims to evaluate the usability improvements of the prototypical implementation after incorporating the developed computational framework and its components.

Zusammenfassung

Einer der wichtigsten Unternehmensanwendungen sind Enterprise-Resource-Planning Systeme (ERP-Systeme). Viele wissenschaftliche Arbeiten haben gezeigt, dass ERP-Systeme aufgrund Ihrer komplexen, starren und aufgeblähten Benutzeroberflächen unter einer schlechten Benutzerfreundlichkeit leiden.

Dabei wird heutzutage ein ansteigender Bedarf wahrgenommen, auf ERP-Systeme mit mobilen Endgeräten, wie Smartphones, Tablets und mobilen Handhelds, zuzugreifen. Mobile Anwendungen, die in der Lage sind ERP-Funktionalitäten, durch flexible Aktionen und Reaktionen, auszuführen, werden Mobile ERP-Anwendungen genannt.

Mobile ERP ist für Unternehmen, die ERP-Systeme einsetzen, zu einer Kernanforderung an die ERP-Systeme geworden. Das Resultiert aus den Vorteilen, die sich durch diesen Ansatz ergeben. Als Vorteile zeichnen sich insbesondere eine höhere operationale Effizienz und Effektivität, die Reduzierung einiger Kosten, Echtzeit Sichtbarkeit sowie die Nachverfolgbarkeit und Entscheidungsfindung, aus.

Dabei ist Mobile ERP immer noch ein neues Thema in Wissenschaft und Praxis und es existiert eine Wissenslücke in der Literatur in Bezug auf die Benutzerfreundlichkeit von Mobile ERP. Dabei ist die Benutzerfreundlichkeit ein kritischer Erfolgsfaktor für jede Software.

Als Erweiterung von ERP-Systemen sind Herausforderungen an die Benutzerfreundlichkeit von Mobile ERP für die Nachhaltigkeit dieses Ansatzes ebenfalls von entscheidender Bedeutung. Dabei sind insbesondere auch die geerbten Anforderungen an die Benutzerfreundlichkeit von ERP-Systemen für den mobilen Einsatzzweck relevant.

Deshalb hat sich diese Arbeit zum Ziel gesetzt die Benutzerfreundlichkeit von Mobile ERP Apps zu verbessern. Dafür werden die potentiellen Herausforderungen untersucht. Es wurden 5 Forschungsstudien durchgeführt, mit dem Ziel eine Konzeptionierung der Anforderungen an Benutzerfreundlichkeit für Mobile ERP Apps zu konstruieren. Dafür sind folgende Teilziele erreicht worden:

1. Identifizierung der Herausforderungen zur Benutzerfreundlichkeit bei Mobilen HCI- (Mensch Computer Interaktion) und ERP-Systemen.
2. Identifizierung der Herausforderungen zur Benutzerfreundlichkeit bei Mobile ERP Apps anhand von realen Gegebenheiten in Unternehmen.
3. Identifizieren einer Methode für die Evaluierung der Benutzerfreundlichkeit von Mobile ERP Apps.

Adaptive User Interfaces (AUIs) sind in verschiedenen Forschungsarbeiten als Mittel zur Verbesserung der Benutzerfreundlichkeit von Software identifiziert worden. Deshalb sind in dieser Arbeit verschieden Typen von Benutzeroberflächen (UIs) untersucht worden, um diese auf die identifizierten Herausforderungen zur Benutzerfreundlichkeit von Mobilen ERP Apps zu überprüfen. Es ist ein rechnergestütztes Framework entwickelt worden, um AUIs für Mobile ERP Apps zu entwickeln. Dafür werden die folgenden Komponenten entsprechend der Vorgaben dieser Arbeit festgelegt:

1. Die anpassbaren der Bestandteile die ausgewertet werden können.
2. Die Informationen, die für den Anpassungsprozess beachtet werden müssen.

3. Die Anpassungsmethoden und -techniken, die für Mobile ERP Apps genutzt werden können.
4. Die Adaptive Systemarchitektur, die den festgelegten Anpassungsprozess für Mobile ERP Apps, ausführen kann.

Die finale Phase dieser Forschungsarbeit befasst sich mit der Evaluation der Benutzerfreundlichkeitsverbesserungen bei einer prototypischen Implementierung nach Anwendung des rechnergestützten Frameworks und seiner Komponenten.

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List of Abbreviations and Acronyms

AI	Artificial Intelligence
AH	Adaptive Hypermedia
AISeL	AIS Electronic Library
API	Application Program Interface
APM	Abstract Presentation Model
APS	Advance Planning and Scheduling
AUIs	Adaptive User Interfaces
BI	Business Intelligence
BOM	Bill of Material
CC/PP	Composite Capabilities/Preferences Profile
CMS	Content Management System
CPM	Concrete Presentation Model
CRM	Customer Relation Management
CSS	Cascading Style Sheets
CTT	Concurtasktrees
DBMS	Database Management Systems
DDR	Device Description Repository
DDWG	Device Description Working Group
DS	Design Science
DSRM	The Design Science Research Methodology
ECA	Event-Condition-Action
ERP	Enterprise Resource Planning
GPL	General Public License
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GUI	Graphical User Interface
HCI	Human Computer Interaction
HCM	Human Capital Management
HR	Human Resources
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
ICT	Information and Communications Technology
IDE	Integrated Development Environment
IHS	Intelligent Help System
IJHCI	The International Journal of Human-Computer Interaction
IJHCS	The International Journal of Human-Computer Studies
IJMHCI	The International Journal of Mobile Human Computer Interaction
IS	Information Systems
ISO	International Organisation for Standardisation
ITs	Interaction Techniques
ITS	Intelligent Tutoring System

IUIs	Intelligent User Interfaces
JSON	Javascript Object Notation
KSA	Kingdom of Saudi Arabia
MFU	Most Frequently Used Item
MPS	Master Production Schedule
MRP	Material Requirements Planning
MRP II	Manufacturing Resource Planning
MRU	Most Recently Used Item
MSS	Mobile Satellite Services
MVC	Model-View-Controller
ORM	Object Relational Mapping
OS	Operating System
PACMAD	People At The Centre Of Mobile Application Development
PC	Personal Computer
PDA	Personal Digital Assistant
POS	Point of Sale
PUC	The Personal and Ubiquitous Computing Journal
R&D	Research and Development
RDBMS	Relational Database Management Systems
RDF	The Resource Description Framework
RFQ	Request For Quotation
RPC	Remote Procedure Call
SaaS	Software As A Service
SCM	Supply Chain Management
SDLC	Systems Development Life Cycle
SFA	Sales Force Automation
SOA	Service Oriented Architecture
SOUPA	Standard Ontologies for Ubiquitous and Pervasive Applications
SQL	Structured Query Language
SRM	Supplier Relationship Management
TLX	Task Load Index
TOCHI	Transactions On Computer-Human Interaction
TOCs	Table Of Contents
UAProf	User Agent Profile
UI	User Interface
UML	Unified Modelling Language
W3C	World Wide Web Consortium
WLANs	Wireless Local Area Networks
WSGI	Web Server Gateway Interface
WURFL	Wireless Universal Resource File
WWW	World Wide Web
XML	Extensible Markup Language

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1 Introduction

The introduction begins by presenting a brief background to this research study and the motivations behind it. Afterwards, it presents the research problem, research objectives, and the research questions. Thereafter, the employed research methodology that has been followed to answer the identified research questions for achieving the main objective of this research is presented. Finally, the dissertation structure will be outlined in the final section of this chapter.

The introductory concepts in this chapter were published and presented in the doctoral symposium on the 45-annual meeting of the society for computer science, Informatik 2015, Cottbus, Germany (Omar, 2015).

1.1 Background

At present, information systems (IS) are considered a critical component of successful enterprises[1] (Motiwalla & Thompson, 2012), and these types of systems aim to improve the effectiveness and efficiency of numerous enterprises through providing a high level of computer automation to support their business processes and functions (Hevner, March, Park, & Ram, 2004; Motiwalla & Thompson, 2012). The applications of IS that support this kind of computer automation are called enterprise applications (Laudon & Laudon, 2014).

Enterprise applications aim to support enterprises to become more flexible and productive, due to their ability to span over many enterprises' functional areas, to focus on executing business processes across the enterprise, and to include all levels of management (Laudon & Laudon, 2014).

One of the major types of enterprise applications is ERP systems (Laudon & Laudon, 2014). These types of systems have many benefits in case they have been realised correctly within an enterprise. For instance, ERP systems have the ability to integrate and process a large amount of information from different resources and make them available in real-time (Motiwalla & Thompson, 2012).

In recent years, the spreading of mobile devices such as smart phones, mobile full-screen phones, mobile handheld computers, and tablet computers has increased significantly (Stieglitz & Brockmann, 2012). This is confirmed in the Gartner's 2012 annual CIO survey by stating that mobility is one of the directions that pulls CIOs to invest in it in the near future, due to the new business priorities (McDonald & Aron, 2012). Furthermore, the demands of enterprises' employees to employ mobile applications (mobile apps) to support general business activities have increased, due to the constant advances in mobile computing, and the ubiquitous availability of information through mobile devices (Stieglitz & Brockmann, 2012).

Consequently, enterprises have begun adopting the mobility strategy with the aim of meeting the new requirements and expectations of their customers and business partners (Dabkowski & Jankowska, 2003). Therefore, the term "mobile enterprise" emerged and can be defined as an enterprise that enables access to its enterprise applications via wireless mobile devices, such as smart phones or tablet computers (Stieglitz & Brockmann, 2012).

[1] Leon defines an enterprise as a group of people with a common objective, and this group has certain resources at its disposal to achieve this objective. Thus, it could be a business enterprise, a non-profit enterprise, a government enterprise, and others (Leon, 2008b).

Regarding ERP systems, a significant number of enterprises employ a strategy of "best of the breed" for their ERP systems, in order to create and maintain a competitive advantage (Gelogo & Kim, 2014). Therefore, ERP vendors strive to improve and extend the features of their ERP products, such as enabling access to their ERP system via mobile devices, and this is what is known as mobile ERP (Gelogo & Kim, 2014).

Mobile ERP has become a core requirement for the enterprises that have ERP systems (Castellina, 2014), due to the benefits that can be reaped from the mobile ERP model, such as higher operational efficiencies and effectiveness, reducing some costs, real-time visibility and traceability, achieving better decision making, among other benefits (Castellina, 2014; Gelogo & Kim, 2014; Pavin & Klein, 2015). Therefore, enterprises have started considering the role of mobile apps in the evaluation and selection processes of ERP systems (Gelogo & Kim, 2014).

However, despite the aforementioned benefits, there are several potential usability challenges that might hinder the sustainability of the mobile ERP model, and these challenges stem from two main sources. On the one hand, the usability challenges which could be inherited from ERP systems, where several researchers have pointed out that ERP systems plague from usability challenges, such as (Akiki, Bandara, & Yu, 2015), (Parks, 2012), (Scholtz, Cilliers, & Calitz, 2010), (Singh & Wesson, 2009), and (Topi, Lucas, & Babaian, 2005). These usability challenges of ERP systems stem from their complex, rigid, and bloated UIs, because these systems integrate and process a large amount of data (Singh & Wesson, 2009). On the other hand, there are distinctive aspects of user interaction with mobile ERP apps that impose some usability challenges; and these aspects stem from the mobile context of use, such as screen size limitation, environment variability, and the unreliability of mobile data connection in addition to other challenges.

AUIs were employed by many researchers in different research domains as a means to improve the usability of software applications. Therefore, mobile ERP apps could benefit from these types of UIs to address their potential usability challenges.

Therefore, the following research aims at improving the usability of mobile ERP apps by attempting to identify a number of probable usability challenges in such applications and examines to what extent the AUIs approach can be used in overcoming these challenges.

Throughout the chapters of this dissertation, a series of scientific contributions and demonstrations will be presented to assist the target audiences of this research study, which are the enterprises that develop mobile ERP apps, and the researchers in the domain of the usability of mobile ERP apps.

1.2 Motivation

The motivation for this research study is six-fold. First of all, the importance of enterprise applications and ERP systems in today's businesses. Second, the high rates of adopting mobile ERP apps in business practices. Third, the identified knowledge gap in the literature regarding the usability of mobile ERP apps in the mobile ERP research domain. Fourth, the potential usability challenges of mobile ERP apps. The fifth reason is the ability of AUIs to improve the usability of software applications, and finally, the immaturity of the development of mobile ERP apps. Therefore, these motivations will be discussed in the following sub-sections.

1.2.1 Importance of Enterprise Applications

Enterprise applications play a key role in enterprises (Laudon & Laudon, 2014), and their yearly revenues are expected to grow in the upcoming years as it can be seen in Figure 1.1. In particular,

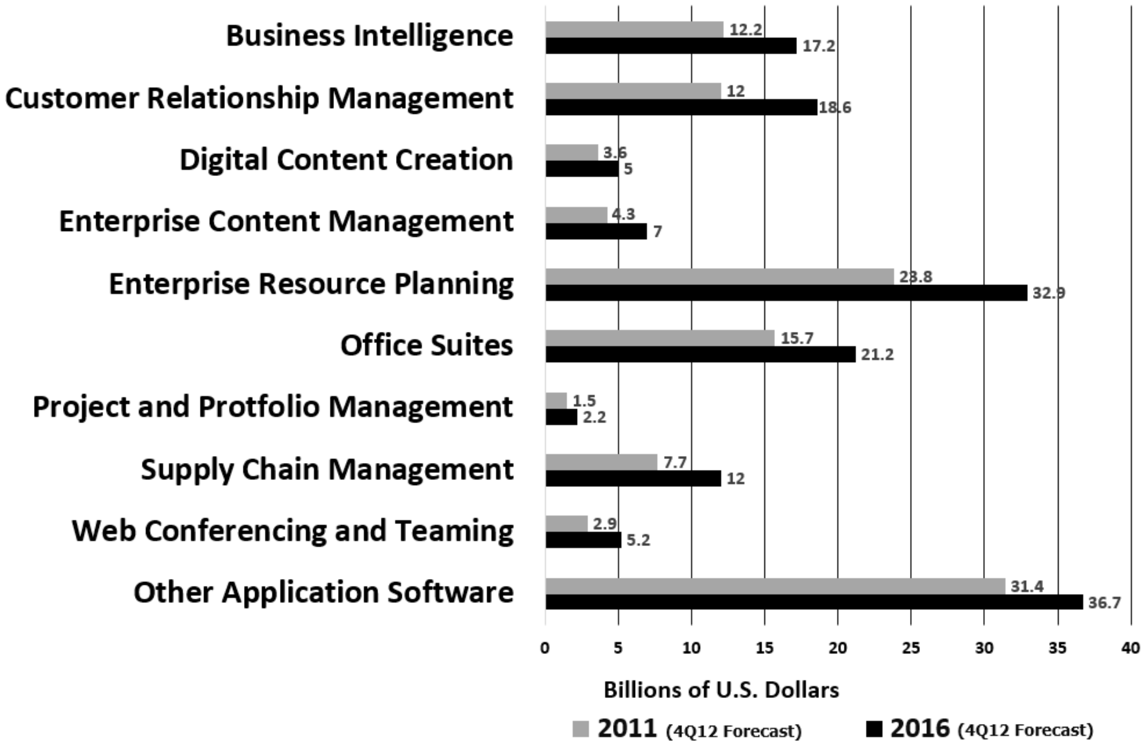

Fig. 1.1: Worldwide revenues forecast for enterprise application software, comparison by segment between the years 2011 and 2016 adapted from (Akiki, 2014; Columbus, 2013; Gartner, 2013)

the expected yearly revenue of ERP systems as can be seen from Figure 1.1 motivates conducting research on these types of enterprise applications and their extensions, such as mobile ERP apps, and this is what has been confirmed in the plethora of research studies in the domain of ERP systems in the last two decades.

1.2.2 High Rates of Adopting Mobile ERP Apps

Presently, the high rate of adopting mobile ERP model in enterprises that employ ERP systems to conduct their business processes is noticed, and this adoption is expected to take centre stage in the future (Trefis Team, 2014), due to the following reasons (Castellina, 2014):

1. The changes in the way of conducting businesses.
2. The rapid increase of pressures on business management, such as managing growth expectations, delays in decision-making, and high costs. Thus, these pressures impose on businesses to be more reactive, agile, and efficient.

Based on the abovementioned reasons, the tendency to share data and collaborate outside traditional office boundaries has increased with an instant access to information (Castellina, 2014).

Furthermore, the current evaluation and selection processes of ERP systems tend to consider the role of mobility as a crucial requirement in these processes (Gelogo & Kim, 2014; Haddara, 2014), due to the benefits that can be realised from incorporating mobility into the ERP systems.

At present, there are several examples that show the proliferation of mobile ERP apps in business.

For instance, the recent report from Aberdeen Group[2] based on a survey of 201 organisations has revealed that 58 percent of Best-in-Class organisations enable access to their ERP systems via mobile devices for their employees, and another 37 percent of all organisations plan to implement this type of access in the near future (Castellina, 2014). Figure 1.2 depicts the percentages of adopting mobile ERP in best-in-class, industry average, and laggard organisations that were reported on the Aberdeen Group survey.

Another example is the online survey that was conducted by interviewing 1500 business professionals in 10 countries. This survey revealed that 65 percent of the respondents perceive mobility as crucial to enable access to information and support the communication for virtual workers. In addition, only 1 in every 2 respondents have any form of remote access to their ERP systems, and only 25 percent of the respondents can access their ERP via smart phones or tablet computers. Moreover, 43 percent of the respondents want to access ERP via their smart phones in the near future, and 38 percent of the respondents want to access ERP via tablet computers (Epicor Software Corporation, 2014). This survey was conducted by Redshift Research Ltd.[3] commissioned by Epicor Software Corporation[4].

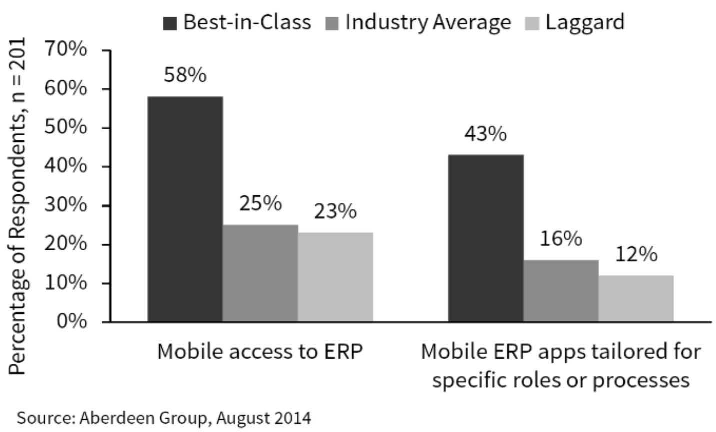

Fig. 1.2: Percentages of adopting mobile ERP in different enterprise classes that were reported on Aberdeen Group survey (Castellina, 2014, p. 4)

Based on the revealed results from the two abovementioned surveys, there is a promising future for mobile ERP apps, and there will be a time where mobile ERP becomes ubiquitous in businesses. Therefore, tremendous research efforts are required towards this trend which is considered one of the fertile research domains, and this will be justified in the next sub-section.

1.2.3 Usability of Mobile ERP Apps in Research

Mobile ERP is still a young topic in research and practice (Căilean & Sharifi, 2013; Pavin & Klein, 2015), and this is noted from the rareness of research works in this domain. (Căilean & Sharifi, 2013) have classified the topics of mobile ERP that can be found in the literature between the years 1998 and 2013 with the number of publications that belong to each classification. Table 1.1 depicts this classification with the number of publications that have been found of each topic.

[2] Aberdeen Group is a technology and services company that helps tech sales and marketing executives distil smart data science into actionable moments. Further information about Aberdeen Group can be found online at http://www.aberdeen.com.

[3] Redshift Research Ltd. is a research company that provides designing and managing research to analysing data sets, working with senior management, and taking care of market research function in its entirety. Further information about Redshift Research Ltd. can be found online at http://redshiftresearch.co.uk.

[4] Epicor is a Software Corporation that provides business software solutions to the manufacturing, distribution, retail and services industries, such as ERP, retail management software, supply chain management (SCM), and human capital management (HCM). Further information about Epicor can be found online at: http://www.epicor.com.

Topic	Addressed issues and description	Number of publications
Implementation of mobile ERP	"How the Mobile ERP system can be introduced into the organisation-including papers concerning selection, the various steps of implementation and related problems, critical success factors, business process alignment during the implementation and organisational diffusion"(Căilean & Sharifi, 2013, p. 20)	10
Optimisation of mobile ERP	"How mobile ERP can be used better in the organisation-including papers concerning post-implementation, usefulness, achievement of competitive advantage through mobile ERP, mobile ERP users, financial benefits of mobile ERP in an organisational context" (Căilean & Sharifi, 2013, p. 20)	15
Management and mobile ERP issues	"How the implementation of mobile ERP affects the management and the organisation-including papers concerning managerial issues of implementation, the mobile ERP impact on the organisation, organisational changes, mobile ERP and best practices, cultural issues in mobile ERP use and finally papers concerning understanding mobile ERP as an phenomenon" (Căilean & Sharifi, 2013, p. 20)	5
The mobile ERP tool	"What are mobile ERP systems and mobile ERP modules and applications? Papers concerning with system architecture, systems language and integration norms, customization, add-ons to mobile ERP systems and mobile ERP as a tool" (Căilean & Sharifi, 2013, p. 20)	46
Mobile ERP and supply chain management	"How mobile ERP systems can be used in the context of a group of companies-papers concerning the use of mobile ERP systems in the system integration with other information technologies and systems and mobile ERP contribution to cooperation in supply chains are included in this category" (Căilean & Sharifi, 2013, p. 20)	2
Studying mobile ERP	"How mobile ERP systems may be studied-papers concerning how mobile ERP systems can and should be studied, using various frameworks, and included in this category" (Căilean & Sharifi, 2013, p. 20)	1
The mobile ERP market and industry	"How the mobile ERP systems market evolves-papers concerning market demands, market share of different vendors, macro diffusion of mobile ERP in the particular industries and/or geo-graphic areas are included in this category" (Căilean & Sharifi, 2013, p. 20)	4
Other	"Papers that do not fit into any of the above categories or very general articles that do not refer to a specific topic" (Căilean & Sharifi, 2013, p. 20)	21

Tab. 1.1: Classified topics of mobile ERP that can be found in the literature adapted from (Căilean & Sharifi, 2013)

According to the classified topics and their description in Table 1.1, a wide knowledge gap exists in the literature regarding the usability in the mobile ERP research domain. Therefore, this research study attempts to bridge this knowledge gap and extends the IS knowledge base through the obtained results from the conducted research works in this research study.

1.2.4 Usability Challenges of ERP Systems and Mobile ERP

Several research works have pointed out that ERP systems suffer from poor usability, due to their complex, rigid, and bloated UIs, such as (Akiki et al., 2015), (Parks, 2012), (Scholtz et al., 2010), (Singh & Wesson, 2009), and (Topi et al., 2005). The reasons behind these deficiencies stem from the nature of the functions that are carried out by these types of IS systems that aim to integrate and process a large amount of data from different resources (Singh & Wesson, 2009).

Mobile ERP is considered an instance and extension of ERP systems (Căilean & Sharifi, 2013; Willis & Willis-Brown, 2002), and thus, some of the usability challenges of ERP systems could be inherited into mobile ERP apps. Besides, there are distinctive aspects of user interaction with mobile ERP apps that lead to some usability challenges; and these aspects stem from the mobile context of use, such as screen size limitation, environment variability, the unreliability of mobile data connection and others, and these aspects and issues will be discussed in detail in Chapter 3 of this dissertation. Consequently, a motivation was established to research the usability of mobile ERP apps in order to sustain these types of promising applications. Especially, the issue of usability, since it is considered one of the most important quality attributes for mobile apps (Nayebi, Desharnais, & Abran, 2012), and a critical success factor for all software applications (Mayhew, 1999).

Moreover, the following knowledge gaps were identified based on an intensive literature review:

1. Identifying the usability challenges of mobile ERP apps.
2. Identifying an appropriate usability evaluation method to evaluate the usability of mobile ERP apps.
3. A solution that assists in improving the usability of mobile ERP apps.

Therefore, the conducted research works in this research study aimed to bridge these gaps.

1.2.5 AUIs as a Means to Improve the Usability of Mobile ERP Apps

AUIs have demonstrated their abilities in improving the usability of software applications in numerous research works, such as (Akiki, 2014), (Reichenbacher, 2004), and (Singh, 2011). The role of these types of UIs is to be aware of the context of use, and in turn, their components are automatically adapted in a continuous way without the end-user’s intervention (Fonseca, José Manuel Cantera, 2010).

According to (Dieterich, Malinowski, Kühme, & Schneider-Hufschmidt, 1993), AUIs aim to:

1. Present an interface to the end-user that is easy, efficient, and effective to use.
2. Make complex systems usable.
3. Present what the end-user wants to see.
4. Speed up and simplify the use of the application.
5. Present a UI that fits heterogeneous end-user groups.
6. Present a UI that considers the increasing experience of the end-users.

Consequently, mobile ERP apps could benefit from these types of UIs to address their potential usability challenges.

1.2.6 Immaturity of the Development of Mobile ERP Apps

According to Van Baker[5], the developers of enterprise apps employ traditional practices to develop desktop apps, and most of these practices and approaches are not suitable for mobile apps development (Cynthia Lee, 2014).

In addition, the deployment of ERP systems on mobile devices faces many challenges, due to the rapid improvement of mobile devices and expanding the app landscape. Furthermore, most of ERP vendors provide generic mobile to enterprise data with technologies, such as HTML5, iOS, and Android. However, their developed apps poorly present the standard ERP on mobile devices, which only boost the complexity and frustration for the end-users (Rimini-Street, 2014).

[5] Van Baker is the research vice president at Gartner. Gartner, is an information technology research and advisory company.

Consequently, this research study attempts to explain how AUIs can be exploited for mobile ERP apps in order to assist mobile ERP developers to develop and deploy usable products.

1.3 Problem Definition

The UI component is an important component of a software application, due to its essential role in bridging the end-user with the application's functionalities (Akiki et al., 2015). Usability is considered a critical success factor for any software application (Mayhew, 1999), and thus, many software applications would eventually fail to be deployed, due to the weakness of their UIs which only negatively impacts the application usability (Akiki et al., 2015; Mayhew, 1999).

> "*In the aftermath of the September 11, 2001 terrorist attacks, some members of the U.S. Congress blamed the inadequacies of user interfaces for the failure to detect the terrorists*" (Shneiderman & Plaisant, 2004, p. 5).

Several researchers have pointed out that ERP systems suffer from poor usability, due to their complex, rigid, and bloated UIs, such as (Akiki et al., 2015), (Parks, 2012), (Scholtz et al., 2010), (Singh & Wesson, 2009), and (Topi et al., 2005). Therefore, there is a high possibility of encountering further usability challenges when ERP systems are accessed via mobile devices. This assumption originates from the following two facts:

1. The usability challenges of ERP systems that could be inherited into mobile ERP apps.
2. The impact of the mobile context of use.

Therefore, this research study attempts to assess the usability of mobile ERP apps, and thus, to construct a conceptualisation of the usability challenges of mobile ERP apps. Thus, this construct can be used to increase the awareness of the developers, regarding the usability challenges of mobile ERP apps when developing such apps. Furthermore, this construct will be constructed through different research methods to ensure its effectiveness, and to assist the developers of mobile ERP apps in assessing the usability of such apps.

AUIs is another concept this research study aims to handle. These types of UIs have been exploited in numerous research works as a means to improve the usability of software applications. Therefore, mobile ERP apps have the opportunity to improve their usability by addressing their potential usability challenges through employing these types of UIs. Furthermore, ERP vendors have not utilised AUIs in their developed mobile ERP apps, due to the lack of existence of a computational framework that has the ability to transfer the AUIs approach to the mobile ERP domain.

Consequently, this research study attempts to provide a conceptual framework that is composed of the construct of the usability challenges of mobile ERP apps and the computational framework for devising AUIs for mobile ERP apps.

1.4 Research Objectives

This research study aims to improve the usability of mobile ERP apps by addressing their potential usability challenges. In order to achieve this main objective, the following sub-objectives were identified:

1. To select an appropriate ERP system for experimental purposes.
    1.1 To develop a model that is able to assist in the selection process of ERP system for experimental purposes and appropriate to the context of this research study.

2. To select a mobile ERP app for experimental purposes and appropriate to the context of this research study. In addition, the selected mobile ERP app must have the ability to access the selected ERP system in research sub-objective 1.
3. To construct a conceptualisation of the usability challenges of mobile ERP apps by achieving the following sub-objectives:
   - 3.1 To conduct an extensive literature review to identify the usability challenges of mobile human-computer interaction (HCI).
   - 3.2 To conduct an extensive literature review to identify the usability challenges of ERP systems.
   - 3.3 To conduct structured interviews with different mobile ERP vendors in order to identify the usability challenges that have been reported by their customers.
   - 3.4 To extract the first conceptions of the usability challenges of mobile ERP apps by mapping the identified usability challenges in research sub-objectives 3.1, 3.2, and 3.3.
   - 3.5 To identify an appropriate usability evaluation method that can assess the usability of mobile ERP apps.
   - 3.6 To identify the usability challenges of the selected mobile ERP app in research sub-objective 2 through:
     - 3.6.1 Applying the identified usability evaluation method in research sub-objective 3.5 to evaluate the usability of the selected mobile ERP app in research sub-objective 2.
     - 3.6.2 Conducting a survey questionnaire that targets the end-users of the selected mobile ERP app in sub-objective 2. In addition, the extracted conceptions of the usability challenges of mobile ERP apps in sub-objective 3.4 will be exploited to develop a questionnaire for this survey.
4. To develop a computational framework for devising AUIs for mobile ERP apps, and this framework should have the ability to address the identified usability challenges in the resulting construct from the achievement of sub-objective 3. Therefore, the following sub-objectives were identified to develop such framework:
   - 4.1 To determine the adapted constituents in AUIs that can be used for mobile ERP apps.
   - 4.2 To map the determined adapted constituents from research sub-objective 4.1 as a means to address the identified usability challenges that will be contained in the resulting construct from the achievement of sub-objective 3.
   - 4.3 To determine the knowledge models that can be used in the adaptation processes in the proposed computational framework.
   - 4.4 To determine the adaptation methods and techniques that have the ability to realise the determined adapted constituents as a solution in sub-objective 4.2.
   - 4.5 To determine an adaptive system architecture that can employ the determined components from sub-objectives 4.2, 4.3, and 4.4 (the adapted constituents, the

determined knowledge models, and the determined methods and techniques) to realise the adaptation processes successfully.

5. To evaluate the usability improvements after incorporating the identified computational framework's components in research sub-objective 4 with the selected mobile ERP app in research sub-objective 2. Therefore, the following sub-objectives were identified to achieve this evaluation process:

    5.1 To demonstrate through a prototype as proof of concept that incorporates the identified computational framework's components with the selected mobile ERP app.

    5.2 To evaluate the usability improvements of the developed prototype.

Figure 1.3 depicts the main sub-objectives of this research study.

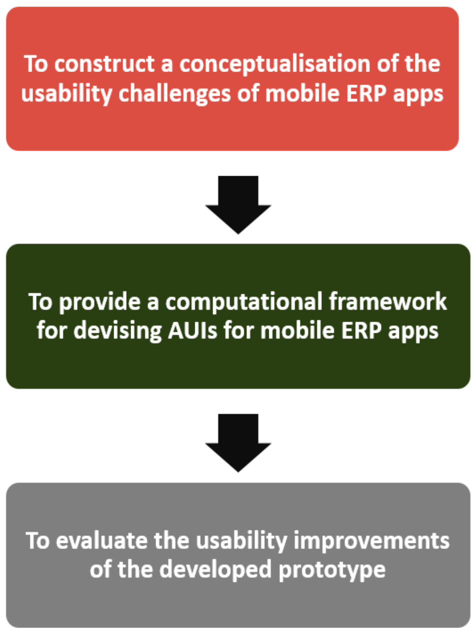

Fig. 1.3: Research sub-objectives

According to the abovementioned research main objective and sub-objectives, a set of research questions was derived that will be presented in the next section.

1.5 Research Questions

The main objective of this research study will be achieved by answering the following main research question:

How can AUIs be designed to improve the usability of mobile ERP apps?

Based on the identified main objective and sub-objectives in section 1.4, a number of research questions were derived and listed in Table 1.2. In addition, Figure 1.4 depicts the flow of the conducted research processes that followed to achieve the main objective and sub-objectives of the following research study. Besides, these processes were mapped to the identified research questions in this figure.

No	Research question
1	What is the appropriate ERP system that can be used for experimental purposes in the context of this research study?
2	What is the appropriate mobile ERP app that can be used for experimental purposes in the context of this research study and can connect with the selected ERP system?
3	What are the potential usability challenges of mobile ERP apps?
3.1	What are the usability challenges of mobile HCI?
3.2	What are the usability challenges of ERP systems?
3.3	What is the appropriate usability evaluation method that can be used to evaluate the usability of mobile ERP apps?
3.4	How can the identified usability evaluation method in question 3.3 be applied?
3.5	What are the usability challenges of the selected mobile ERP app?
4	How can the AUIs approach be exploited to address the identified usability challenges of mobile ERP apps?
4.1	What are the adapted constituents in AUIs that can be used for mobile ERP apps?
4.2	How can the determined adapted constituents in research question 4.1 be exploited as a means to address the identified usability challenges of mobile ERP apps from research question 3?
4.3	What is the information required for realising the adaptation processes successfully in the context of this research study?
4.4	What are the adaptation methods and techniques that can be used to realise the determined adapted constituents as a solution in research question 4.1?
4.5	What is the appropriate adaptive systems architecture that can be employed to realise adaptation processes successfully in the context of this research study?
5	How can the identified computational framework be implemented for the selected mobile ERP app?
6	What are the usability improvements after incorporating the identified computational framework for the selected mobile ERP app?

Tab. 1.2: Research questions

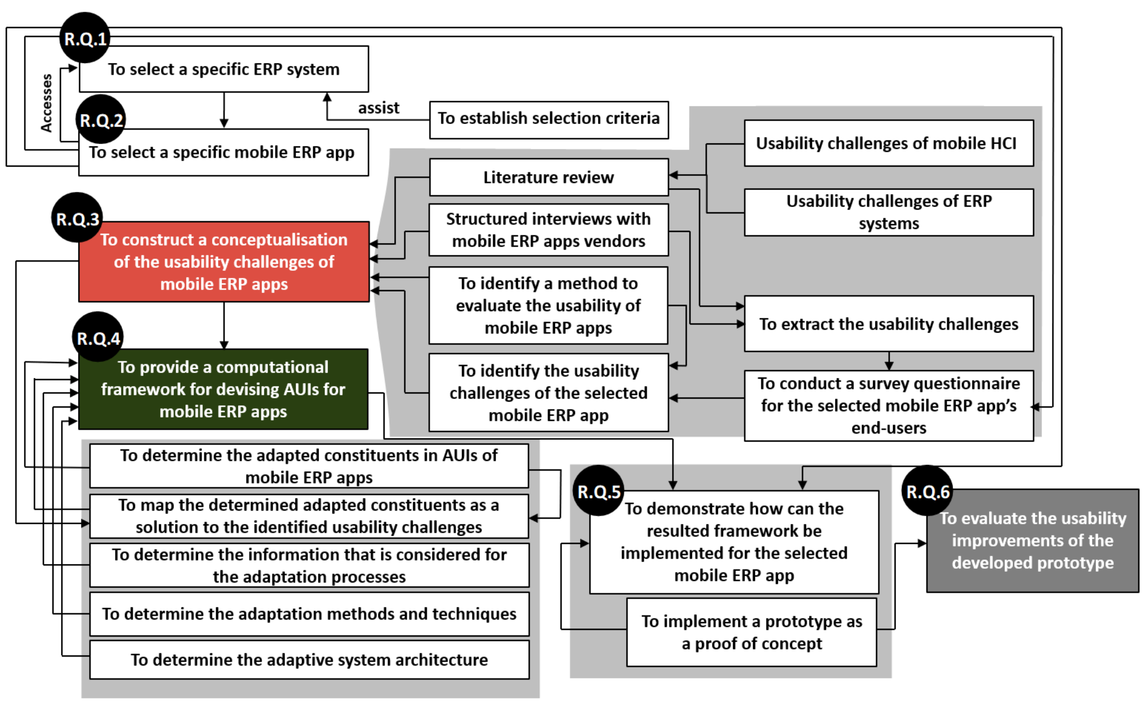

Fig. 1.4: Research sub-objectives, questions, and processes

1.6 Research Methodology

Information systems (IS) is an applied research discipline, where researchers frequently apply theory from other disciplines, such as economics, computer science, and the social sciences in order to solve problems at the intersection of IT and organisations (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007).

Two complementary but distinct research paradigms characterise much of the research in the IS discipline, namely behavioural science and design science (Hevner et al., 2004). The behavioural science paradigm is mainly rooted in natural science research methods, and it aims to develop and justify theories that explain or predict human or organisational phenomena surrounding the analysis, design, implementation, management, and use of IS (Hevner et al., 2004). Whereas design science paradigm is considered a problem solving paradigm (Hevner et al., 2004), and it is mainly rooted in engineering and the sciences of the artificial (Simon, 1996).

The design science paradigm is accepted as an adequate and useful research methodology in the engineering disciplines, because the engineering research culture establishes an explicit value on incrementally effective applicable solutions for problems (Peffers et al., 2007). In addition, the design science paradigm aims to extend the boundaries of human and organisational capabilities by creating new and innovative artefacts. Such artefacts may include constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations (implemented and prototype systems) (Hevner et al., 2004). Therefore, this research study employs the design science research methodology (DSRM) that was proposed by (Peffers et al., 2007), and the design science (DS) approach in the IS discipline that was proposed by (Hevner et al., 2004).

The following sub-sections demonstrate the two selected research processes and by what means they have been followed in this research study.

1.6.1 DSRM Process Model

The design science research methodology (DSRM) was proposed by (Peffers et al., 2007) for the production and presentation of DS research in IS. The DSRM process model is composed of six activities as depicted in Figure 1.5.

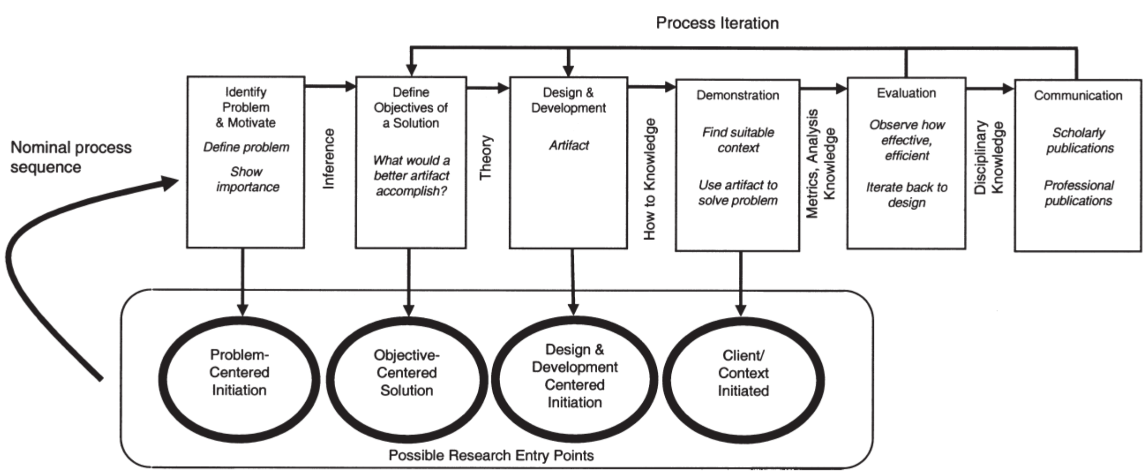

Fig. 1.5: DSRM process model (Peffers et al., p. 54)

The first activity in the DSRM process model is the *problem identification and motivation*. This activity aims to define the research problem, and the value of a solution is justified. The importance of this activity resides in guiding the researchers to develop a useful artefact, which is able to effectively provide a solution. Justifying the value of a solution motivates the researchers and the audience in the targeted research domain to pursue the solution and accept the results of that research. In addition, the justification supports understanding the reasoning associated with the researcher's understanding of the problem. Therefore, the resources that are needed in this activity are a solid knowledge of the state of the problem and the importance of the proposed solution (Peffers et al., 2007).

The second activity in the DSRM process model is *defining the objectives for a solution*. These objectives are inferred from the problem definition and knowledge of what is possible and feasible. The objectives can be quantitative if the desirable solution would be better than existing ones or qualitative if the solution would support solutions to problems that still not addressed by other solutions. These objectives should be inferred rationally from the problem specification that derived from the first activity. Therefore, the resources that are needed in this activity are an in-depth knowledge of the state of problems and current solutions, if any, and their efficacy (Peffers et al., 2007).

The third activity in the DSRM process model is the *design and development*. This activity aims to create the artefact that can be constructs, models, methods, and instantiations (Hevner et al., 2004). In addition, the artefact can also be "new properties of technical, social, and/or informational resources" (Järvinen, 2007, p. 49). According to (Peffers et al., 2007), "*Conceptually, a design research artifact can be any designed object in which a research contribution is embedded in the design*" (Peffers et al., 2007, p. 55). Therefore, this activity determines the desired functionality of an artefact and its architecture and eventually creating the actual artefact. The resources that are needed in this activity are the knowledge of theory in order to move from objectives to design and eventually the development of an artefact (Peffers et al., 2007).

The fourth activity in the DSRM process model is the *demonstration*. In this activity, the use of the artefact is demonstrated by solving one or more instances of the problem. This can be done through experimentation, simulation, case study, proof, and any other proper demonstration. Therefore, an effective knowledge of how to use the artefact to solve the problem is required as a resource for this activity in order to successfully demonstrate the value of the artefact (Peffers et al., 2007).

The fifth activity in the DSRM process model is the *evaluation*. This activity aims to observe and measure how well the artefact supports the solution to the problem. Therefore, the objectives of the solution are compared to actual observed results from use of the artefact in the demonstration. This activity requires knowledge of relevant metrics and analysis techniques. In addition, the determination of the appropriate evaluation method depends on the nature of the problem venue and artefact. Therefore, there are different methods that can be utilised for this activity, such as comparing the artefact's functionality with the defined solution objectives in the second activity, the results of satisfaction surveys, client feedback, or simulations. An evaluation activity could also include quantifiable measures of the system's performance (e.g. response time or availability), or any other empirical evidence or logical proof. As can be seen in Figure 1.5, at the completion of this activity, the researcher can determine whether to revisit the second and third activity again in attempt to improve the effectiveness and functionalities of the artefact; or otherwise, continue to the sixth activity of the DSRM process model (Peffers et al., 2007).

The final activity in the DSRM process model is the *communication*. This activity aims to communicate the problem and its importance, its utility and novelty, the rigor of its design, and its effectiveness to the scientific community in the targeted research domain or practicing professionals. This communication could be achieved through scholarly research publications. The resources required for this activity are knowledge and understanding of the disciplinary culture (Peffers et al., 2007).

As depicted in Figure 1.5, there are four available research entry points, namely problem-centred initiation, objective-centred solution, design- and development-centred initiation, and client-/context-initiated solution.

In the problem-centred approach, the researchers might proceed through the aforementioned six activities in sequential order, if the idea for the research resulted from observing a research problem or from suggested future research trends in prior researches (this case is the entry point of this research study).

Regarding the objective-centred solution, the researcher starts with the second activity of the DSRM process model, and this case could be raised by an industry or research need that can be addressed by developing an artefact.

Regarding the design- and development-centred approach, the researcher would start with the third activity of the DSRM process model, and this approach would result from the existence of an artefact that has not yet been formally applied as a solution for the explicit problem domain to which it can be applied. Such an artefact might have resulted from another research domain, or it might have already been applied to solve a different problem, or it might have appeared as a similar idea.

Finally, the client-/context-initiated solution might be originated from observing a practical solution that worked, and thus, the researcher starts with the fourth activity of the DSRM process model and works backwards to produce a more rigor solution after considering the shortcomings of the current solution and making the optimum use of a consulting experience (Peffers et al., 2007).

According to the abovementioned explanation, Figure 1.6 depicts how the DSRM process model is mapped to this research study.

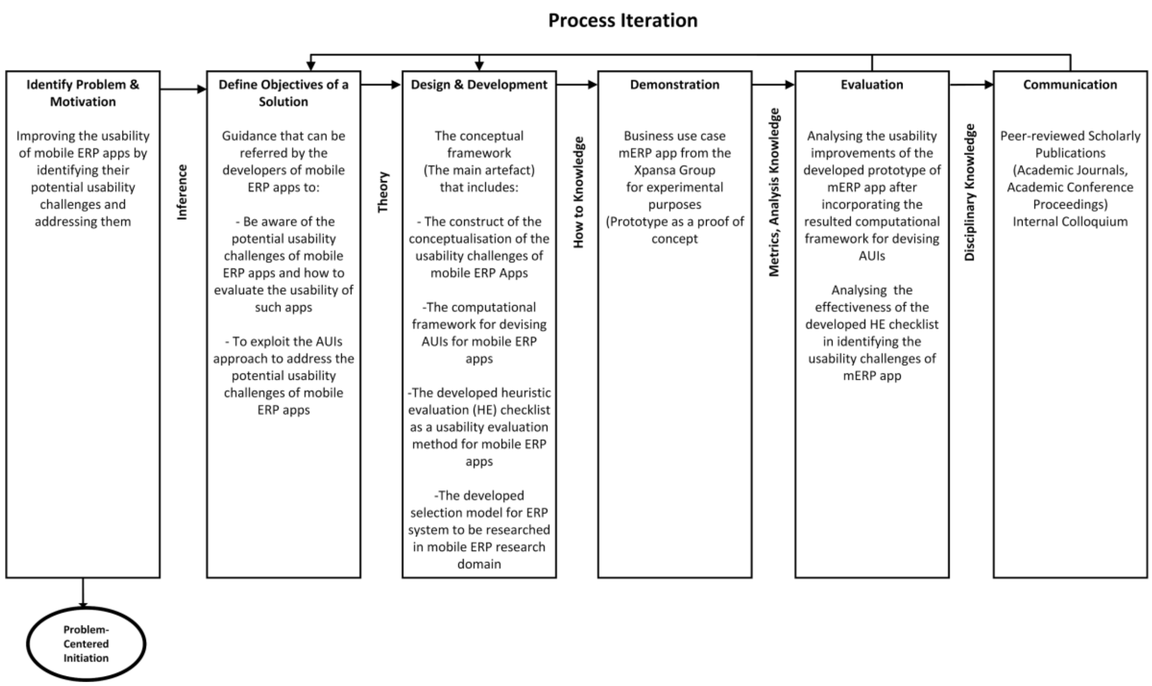

Fig. 1.6: DSRM process for this research study adapted from (Peffers et al., 2007)

1.6.2 Information Systems Research Framework

In addition to the DSRM process model that was explained in the previous section, the design science approach in IS discipline that was proposed by (Hevner et al., 2004) is followed in this research study. This duality in employing those research methodologies aims at maintaining the effectiveness of the resulted artefacts from this research study.

Figure 1.7 presents the IS research conceptual framework that was proposed by (Hevner et al., 2004) for understanding, executing, and evaluating IS research.

According to (Hevner et al., 2004), IS research can be conducted through two complementary phases, namely behavioural and design sciences. These phases address the articulated business needs that are identified in the environment section. The goal of behavioural science is truth through developing and justifying theories that explain or predict phenomena related to the realised business needs. While the goal of design science is utility through building and evaluating artefacts that are designed to meet the realised business needs.

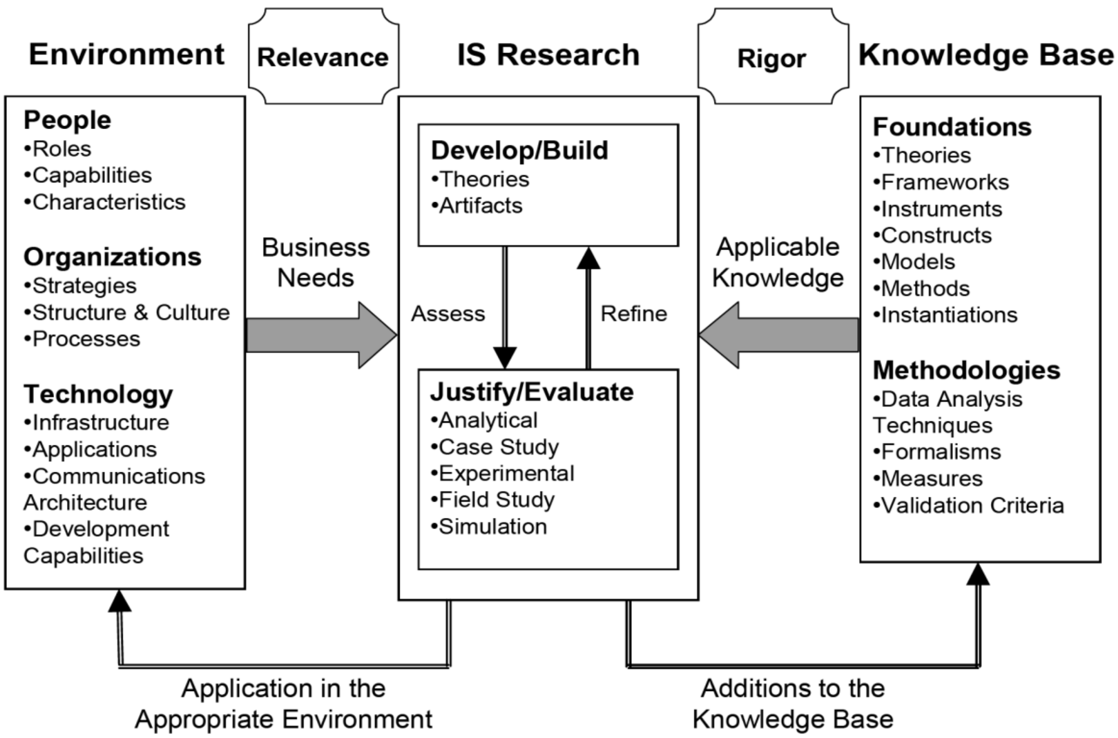

Fig. 1.7: Information systems research framework (Hevner et al., 2004, p. 80)

As can be seen from Figure 1.7, the justification/evaluation activities aim to identify the weaknesses in the theory or artefact, in order to be refined and reassessed. The evaluation of the designed artefacts typically uses methods that are available in the knowledge base, such as observational, analytical, experimental, testing and descriptive methods (Hevner et al., 2004).

The knowledge base provides the raw materials to accomplish the IS research, which is composed of foundations and methodologies. The foundations are used in the development/building phase of the IS research that include foundational theories, frameworks, instruments, constructs, models, methods, and instantiations. These foundations are provided from prior IS research and the obtained results from reference disciplines. Whereas the methodologies provide guidelines that are used in the justification/evaluation phase of the IS research that include data analysis techniques, formalisms, measures, and validation criteria. Therefore, the rigor of IS research can be achieved by appropriately applying the existing foundations and methodologies of the knowledge base (Hevner et al., 2004).

According to the abovementioned explanation of the IS research framework, the remainder of this sub-section will explain how this research framework is applied in this research study.

To ensure the critical goal of relevance is achieved in this research study, the process began with identifying the business needs to a relevant business problem. Therefore, the organisational strategies toward mobility, structures, culture, and business processes were assessed and evaluated in order to understand the business needs for improving the usability of mobile ERP apps. This assessment has revealed that the current evaluation and selection processes for ERP system in businesses impose to consider the role of mobility in its overall business solutions. In addition, some CIOs remain reluctant to invest in more mobility, due to the complexity concerns and usability challenges of mobile ERP apps. Moreover, the developers of mobile ERP apps lack the presence of a conceptual framework that able to guide them in order to develop highly usable applications. Thus, the target organisations for this research study are organisations that are developing mobile ERP apps. Besides, the purchasing module was selected for the demonstration and to deliver the resulted computational framework artefact in this research study. This selection was determined based on the results of the conducted research studies on: a sample of the determined target organisations of this research study, and the end-users of the selected mobile ERP app.

The necessity for improving the usability of mobile ERP apps is shaped by the following existing technologies:

1. The system architecture of mobile ERP apps.
2. The system architecture of ERP systems.
3. The mobile data communications and networks.
4. The mobile development capabilities and technologies.
5. UIs development approaches and principles.

The applicable knowledge for this research study was extracted from the foundational knowledge and methodologies to ensure that this research study is rigorous. The foundational knowledge is important for the development/building phase in this research study, and it was extracted through the exhaustive review of the literature from the relevant frameworks, instruments, models, and methods. This literature review was conducted through the relevant work that was published in scholarly publications about the usability models, usability evaluation methods, the usability of mobile apps, the usability of ERP systems, mobile computing, context-aware computing, mobile HCI, mobile UIs patterns, AUIs frameworks, AUIs system architectures, and AUIs methods and techniques. While the knowledge that was extracted for the applied methodologies in this research study was used as guidelines for the justification/evaluation phase, such as the performed statistical analysis for the collected data from questionnaires and the conducted interview studies, the usability measures and evaluation metrics that were used, and the validation criteria that were used in this research study to ensure the representational fidelity and implementability of the resulted artefacts from this research study.

The development/building activity in this research study provides five clear contributions in the in the areas of the design artefact, design construction knowledge (i.e. foundations), and design evaluation knowledge (i.e. methodologies), and these developed artefacts are briefly explained as follows:

1. Firstly, the conceptual framework for devising AUIs that aims to improve the usability of mobile ERP apps. According to (Hevner et al., 2004), the research artefact must enable a solution of the heretofore unsolved problems. Therefore, this framework aims to guide the developers of the mobile ERP apps through its components in solving the following problems:

    1. Developing highly usable applications by incorporating AUIs in them.
    2. Increasing the developers' awareness regarding the potential usability challenges of mobile ERP apps.
    3. Evaluating the usability of mobile ERP apps.

    Therefore, this framework provided a link between the experiential knowledge (i.e. technical knowledge, research background, and personal experience) and the literature review (i.e. the related theories and research from different disciplines). Thus, this framework is composed of:

    1. The construct of the potential usability challenges of mobile ERP apps.
    2. The computational framework for devising AUIs that has been engineered for mobile ERP apps as a solution to improve their usability.
    3. The applied usability evaluation methods and techniques.

2. Secondly, the construct of the conceptualisation of the usability challenges of mobile ERP apps. This construct extended the foundations of the IS knowledge base by identifying and classifying the potential usability challenges of mobile ERP apps.
3. Thirdly, the developed heuristic evaluation checklist that extended the IS knowledge base with a usability inspection method which is dedicated to evaluate the usability of mobile ERP apps.
4. Fourthly, the developed computational framework for devising AUIs that extended the IS knowledge base through its allocated components for the mobile ERP context of use.
5. Finally, the developed selection model that assists the researchers in their selection process of an appropriate ERP system in order to be researched by following the design science research paradigm in the domain of the mobile ERP research.

The abovementioned artefacts were justified and evaluated in order to ensure their rigorousness and relevance for the community of IS researchers and practitioners. Regarding the conceptual framework, this artefact was justified and evaluated through achieving the main objective and sub-objectives of this research study. While the second artefact (i.e. the construct) was evaluated and justified through employing several data analysis techniques and scientific research methods in the conducted research studies to evaluate its quality and effectiveness. The developed heuristic evaluation checklist was utilised in a real case study through utilising it to identify the usability problems of mERP[6] app (the selected mobile ERP app) which was developed by Xpansa[7] group.

[6] mERP is a mobile native application that enables access to Odoo ERP system and it's developed by Xpansa Group. Further information about mERP can be found online at https://merpapp.com.

[7] Xpansa is a multinational group of companies specialised in delivering IT Business Services and Data Analysis. it provides ERP, BI, DMS implementation and consulting as well as development services for Mobile and Standalone business applications.

(Hevner et al., 2004) state that IT artefacts can be evaluated in terms of usability, and the selection of evaluation methods must be appropriate with the designed artefact. Therefore, the developed computational framework for devising AUIs was evaluated through assessing the developed prototype, and this assessment was achieved by applying the empirical evaluation methodology, which is considered the most predominant methodology for evaluating AUIs. The developed prototype incorporates the identified and developed components of the proposed computational framework, and this prototype was evaluated in a form of a controlled experiment to identify any realised usability improvements after incorporating the developed computational framework and its components to it.

Furthermore, several justifications were made during the developing phase of the resulted artefacts, based on the constant assessments and feedbacks from the scientific research community for the submitted publications during this research study, and the recommendations from the targeted practitioners.

In addition, this research study followed the seven guidelines that were proposed by (Hevner et al., 2004) in order to ensure the effectiveness of this research study. Table 1.3 summarises these seven guidelines.

Guideline	Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

Tab. 1.3: Design-Science research guidelines proposed by (Hevner et al., 2004, p. 83)

1.7 Dissertation Structure

The structure of this dissertation consists of five parts, the first four parts represent the identified activities in the DSRM model, which attempt to achieve the determined research sub-objectives. While the final part is the conclusion. As can be seen from the depicted Figure 1.8, these five parts consist of 6 chapters, in addition to the conclusion and outlook.

Chapter one has provided the introductory concepts of this research study, starting by presenting a brief background to this research study. Followed by presenting the motivation behind this research study, problem definition, research objectives, research questions, which are followed by the research methodology, and dissertation structure.

Chapter two provides an integrated overview of ERP systems and their evolution over a period of time. This will be followed by an explanation of the methodology that has been followed in selecting an appropriate ERP system for experimental purposes in the context of this research study. Finally, an integrated overview of the selected ERP system will be presented.

Chapter three provides an overview of mobile computing in addition to an integrated overview of mobile ERP apps with highlighting the selected mobile ERP app for experimental purposes. This will be followed by presenting an overview of the usability of mobile apps. Finally, five research studies will be discussed that were conducted in order to identify the usability challenges of mobile ERP apps.

Chapter four presents an overview of the adapted systems. This is followed by an integrated overview of AUIs. Thereafter, the developed computational framework and its components for devising AUIs to address the identified usability challenges will be discussed.

Chapter five demonstrates the prototypical implementation to show how the developed computational framework can be implemented for the selected mobile ERP app.

Chapter six evaluates objectively and subjectively the resulted prototypical implementation from Chapter five.

Chapter seven presents the main contributions of this research study with future work directions.

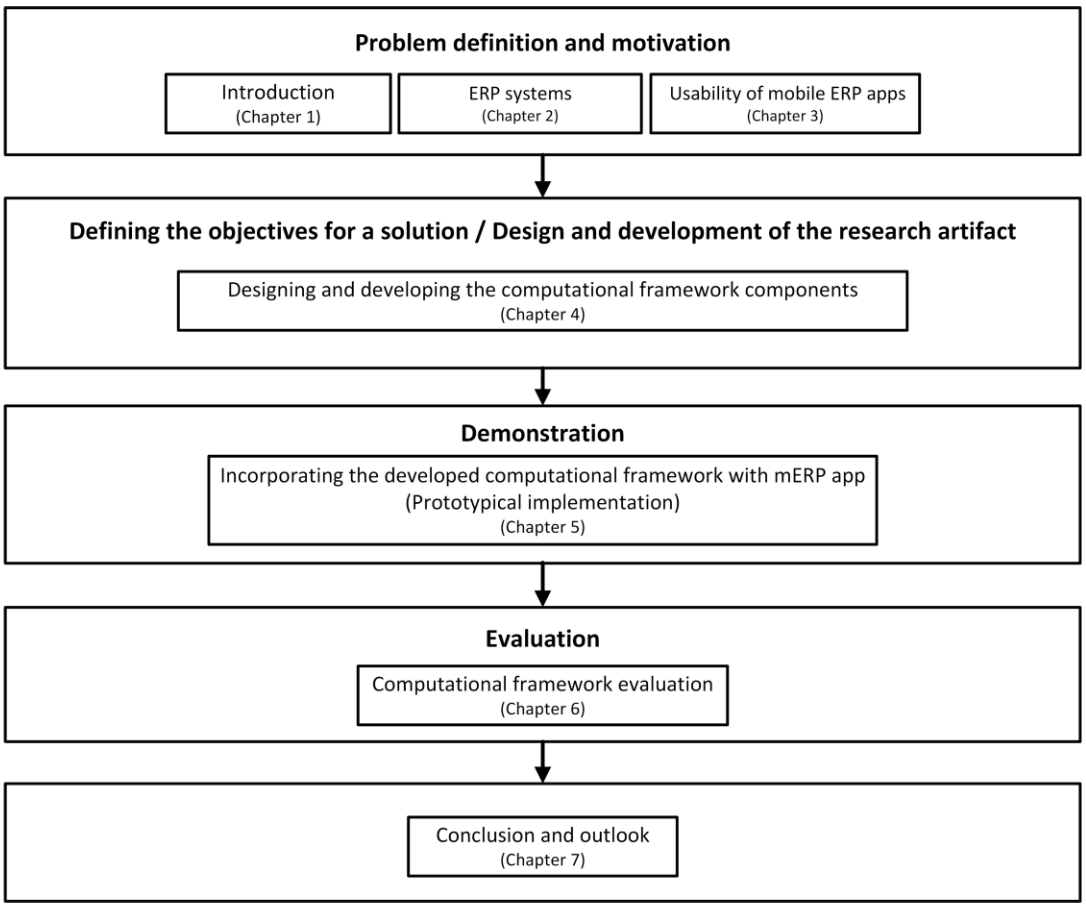

Fig. 1.8: Structure of the dissertation mapped to the DSRM process model

2 ERP Systems

This chapter of the research study aims at clarifying the followed process in selecting an appropriate ERP system for experimental purposes, and this goal has originated from the huge numbers of ERP systems that can be found in the software market. This flood of ERP systems makes the selection process of one of these products, in order to be researched, extremely difficult. In addition, the product that will be selected must be consistent with the context of this research study.

Consequently, this chapter consists of three main sections that aim at assisting to achieve the objective of this chapter gradually. The first of which consists of an integrated overview of ERP systems and their evolution over a period of time that ultimately led to the emergence of the mobile ERP model. This integrated overview aims to achieve a further understanding of ERP systems, and thus, it assisted in the selection process of an appropriate ERP system, whereas, the second section provides an explanation of the methodology that has been followed in selecting an appropriate ERP system for experimental purposes in the context of this research. Finally, an integrated overview of the selected ERP system is presented.

In this chapter, a selection model of an ERP system in mobile ERP design science research was developed, and it was published in the proceedings of The ACS/IEEE International Conference on Computer Systems and Applications (AICCSA), Agadir, Morocco (Omar & Marx Gómez, 2016b).

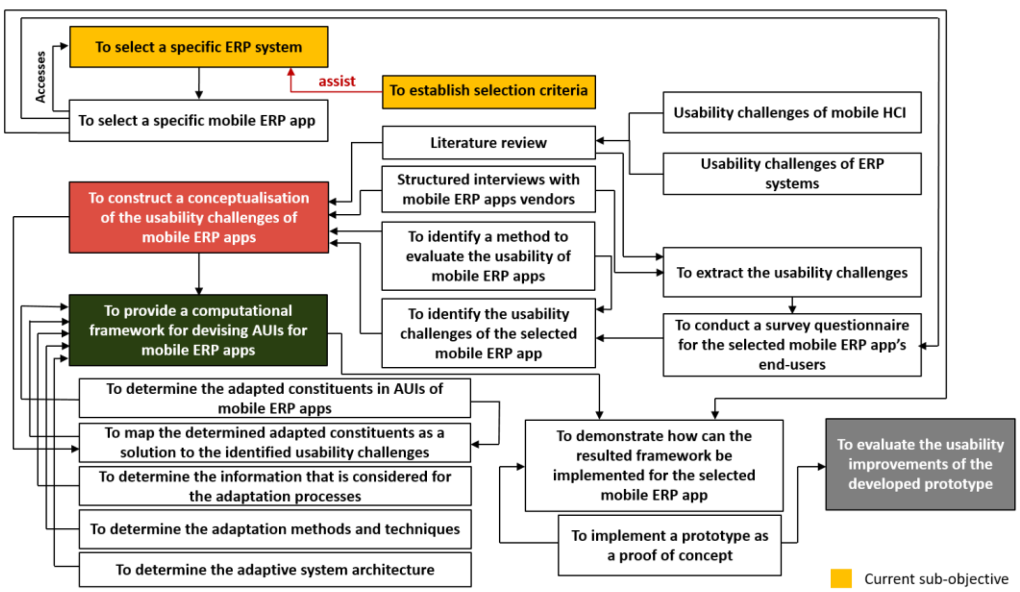

Fig. 2.1: Research objectives status; sub-objectives that will be achieved in Chapter 2

2.1 Enterprise Resource Planning (ERP) Systems

This section presents the definition of an enterprise and enterprise applications, along with a discussion of the approaches that are followed in deploying IS within enterprises. It is then followed by listing some of the observed definitions of ERP systems and their characteristics in the literature, then it is followed by a conceptual model for ERP systems in practices, the chronological evolution of ERP systems, and a discussion regarding the benefits of ERP systems and their drawbacks. This integrated overview of ERP systems supported the development of a set of selection criteria of an appropriate ERP system in order to be researched within the context of this research study.

2.1.1 Enterprise and Enterprise Applications

An enterprise can be defined as:

> "*the group of people with a common goal, which has certain resources at its disposal to achieve this goal"* (Leon, 2014, p. 1).

According to Leon[8], two approaches can be followed in deploying IS within the enterprise, namely the traditional approach, and the enterprise approach. In the traditional approach, the organisation is divided into different units based on the functions which they perform. These units are defined as departments which are compartmentalised and have their own goals and objectives. Therefore, each department has its own systems of data collection and analysis, and its functions that are in isolation from other departments, and thus, the created or generated information from a specific department is available only for top management and not to other departments (Leon, 2014). This approach is also known as silos, because each department has its stack or silo of information that is unrelated to the next silo (Monk & Wagner, 2012). Accordingly, the traditional approach only ends up in working in different directions, and not for the common goal of the enterprise. Furthermore, the departmental objectives can be conflicting and costly inefficiencies can result, and thus, the lack to gain the competitive advantages (Leon, 2014; Monk & Wagner, 2012).

While in the enterprise approach, the enterprise acts as a single system and all departments are considered its sub-systems. Therefore, all information about all the aspects of the organisation is available to all departments because it is stored centrally (Leon, 2014). However, integrating various systems within the enterprise to work in sync is considered a major challenge, and one solution for this challenge is to implement enterprise applications.

Laudon[9] and Laudon[10] define enterprise applications as:

> "*systems that span functional areas, focus on executing business processes across the business firm, and include all levels of management*" (Laudon & Laudon, 2014, p. 83).

Enterprise applications support businesses to become more flexible and productive, by coordinating and integrating their business processes[11], and thus, more emphasis is placed on efficient management of enterprise resources and customer services (Laudon & Laudon, 2014).

Enterprise applications can be classified into four major types, namely supply chain management systems, customer relationship management systems, knowledge management systems, and enterprise resource planning (ERP) systems (Laudon & Laudon, 2014). The latter are also known as enterprise systems (Laudon & Laudon, 2014; Rashid, Hossain, & Patrick, 2002).

In the literature, several definitions can be found for ERP systems, and the following sub-section highlights some of these definitions.

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[8] Alexis Leo is a software consultant and an author for more than fifty books and 30 articles on IT. Further information about Leon can be found online at: http://www.alexisleon.com/.

[9] Kenneth C. Laudon is a professor of Information Systems at the Stern School of Business at New York University. He has authored twelve books. Further information about Kenneth C. Laudon can be found online at: http://pages.stern.nyu.edu/~klaudon/.

[10] Jane Price Laudon is a management consultant in the information systems area and the author of seven books (Laudon & Laudon, 2014).

[11] Business process is a collection of activities that takes one or more kinds of input and creates an output, such as a report or forecast, while business function is an activity specific to a functional area of operation (Monk & Wagner, 2012).

2.1.2 ERP System Definitions

The in-depth research in ERP systems leads to note that several definitions can be observed for these types of systems. Therefore, some of these definitions were quoted in order to deepen the fundamental understanding of the concept of ERP systems, and these definitions are:

> "*to integrate business processes in manufacturing and production, finance and accounting, sales and marketing, and human resources into a single software system. Information that was previously fragmented in many different systems is stored in a single comprehensive data repository where it can be used by many different parts of the business*" (Laudon & Laudon, 2014, p. 83).

> "*Enterprise Resource Planning (ERP) systems are core software programs used by companies to integrate and coordinate information in every area of the business. ERP (pronounced "E-R-P") programs help organizations manage company-wide business processes, using a common database and shared management reporting tools*" (Monk & Wagner, 2012, p. 1).

> "*Enterprise resource planning (ERP) systems are the world's largest and most complex ES. ERP systems focus primarily on intra-company processes—that is, the operations that are performed within an organization—and they integrate functional and cross-functional business processes. Typical ERP systems support Operations (Production), Human Resources, Finance & Accounting, Sales & Distribution, and Procurement*" (Magal & Word, 2011, p. 25).

> "*ERP is an abbreviation for Enterprise Resource Planning, and means the techniques and concepts for integrated management of businesses as a whole from the viewpoint of the effective use of management resources to improve the efficiency of enterprise management. ERP packages are integrated (covering all business functions) software packages that support these ERP concepts*" (Leon, 2008a, p. 14).

> "*Enterprise Resource Planning software systems (ERP) encompass a wide range of software products supporting day-to-day business operations and decision-making. ERP serves many industries and numerous functional areas in an integrated fashion, attempting to automate operations from supply chain management, inventory control, manufacturing scheduling and production, sales support, customer relationship management, financial and cost accounting, human resources and almost any other data oriented management process*" (Singla, 2008, p. 119).

> "*A packaged business software system that lets an organisation automate and integrate the majority of its business processes, share common data and practices across the enterprise and produce and access information in a real-time environment. The ultimate goal of an ERP system is that information must only be entered once*" (Marnewick & Labuschagne, 2005, p. 145).

> "*Enterprise Resource Planning (ERP) applications are software suites that help organizations integrate their information flow and business processes. They typically support the different departments and functions in the organization by using a single database that collects and stores data in real time*" (Abdinnour-Helm, Lengnick-Hall, & Lengnick-Hall, 2003, p. 258).

> "*Enterprise resource planning systems or enterprise systems are software systems for business management, encompassing modules supporting functional areas such as planning, manufacturing, sales, marketing, distribution, accounting, financial, human resource*

management, project management, inventory management, service and maintenance, transportation and e-business” (Rashid et al., 2002, p. 2).

Based on the abovementioned definitions, ERP systems aim to realise the enterprise approach in IS, and this is achieved through integrating all the information flowing through the enterprise into a single software system and in a single comprehensive data repository, and thus, it can be used by many different units of the enterprise.

However, ERP systems are considered the largest, more complex, and demanding systems (Grabski, Leech, & Schmidt, 2011), and these attributes stem from the characteristics that are attributed to such systems. Therefore, these characteristics will be discussed in the next sub-section.

2.1.3 Characteristics of ERP Systems

Several characteristics can be found in the literature that are associated with ERP systems which make these types of systems differ from the other traditional IS. (Uwizeyemungu & Raymond, 2005) regrouped these characteristics in regards to their nature under three dimensions, namely technical, organisational, and informational dimensions as depicted in Figure 2.2.

The technical dimension regroups characteristics that indicate the capabilities or features for applications development provided by ERP systems in comparison to traditional systems. This group includes two main characteristics, namely adaptability (flexibility) and openness (evolutionary).

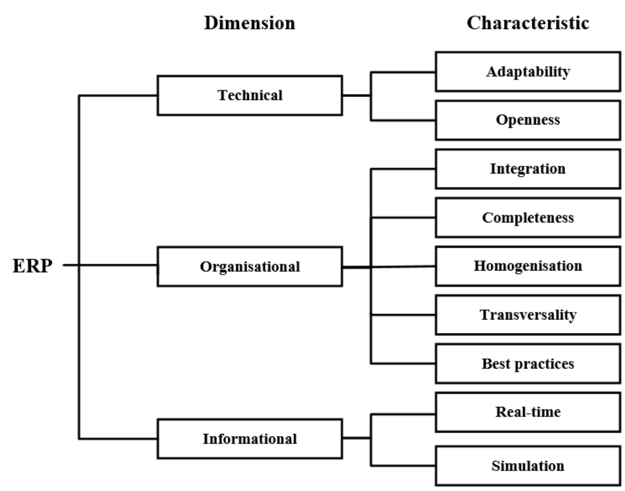


Fig. 2.2: Dimensions of ERP systems characteristics adapted from (Uwizeyemungu & Raymond, 2005, p. 72)

- **Adaptability** which means the capability of ERP system to be flexible and follow the organisation’s new rules and changes.
- **Openness** which means the modularity and portability characteristics that enable an ERP system to evolve with the organisation.

While the organisational dimension regroups the following characteristics:

- **Integration** which is considered the most important characteristic that is associated with ERP systems; therefore, it distinguishes them from traditional IS. This characteristic aims to enable the interconnections between functions and hierarchical levels, as well as the interaction between the various processes.

- **Completeness** refers to support a wide range of functions, the applicability to be deployed for various types of firms, and the connectivity with the outside.
- **Homogenisation** refers to the existence of a unique data referential, the uniformity of human-machine interfaces, and to the unity of the system's administration.
- **Transversality** refers to the process-oriented view of an ERP system in order to achieve its objectives, and a number of ERP projects had failed due to the lack of transversality characteristic in the installed system.
- **Best practices** characteristic refers to the capability to embed best practices in the field.

However, it can be noted from the abovementioned characteristics that they refer to the system's deployment in the firm, and these are the characteristics that reflect the impact of an ERP system on the organisation, on its structures, and likewise on its practices (Uwizeyemungu & Raymond, 2005).

Finally, the informational dimension regroups characteristics that refer to the quality and usefulness of the information provided by the system, namely real-time and simulation. Both of these characteristics are consequences of the successful integration that is provided by an ERP system; because an ERP system enables the same information to be visible in real-time to all parts of the organisation, and allows simulating the effect of an input on all activities of the organisation (Uwizeyemungu & Raymond, 2005).

2.1.4 Conceptual Model for ERP

In addition to the characteristics that have been described in the previous sub-section, (Marnewick & Labuschagne, 2005) proposed a conceptual model for ERP systems. This model aims to assist in understanding what ERP is and how to implement it. Therefore, this model should be understood by general and project managers in order to facilitate the successful implementation of ERP systems, and thus, achieving organisational success. Figure 2.3 depicts the proposed model that consists of four components, and these components are implemented and integrated through a methodology that refers to a systematic approach to implement an ERP system. This methodology aims to ensure the proper integration among the four components of this model (Marnewick & Labuschagne, 2005).

The first component of the proposed model is the software component which is the most visible part to the users, and thus, it is seen as the ERP product. This component typically consists of several generic functional modules, such as finance, human resources (HR), supply chain management (SCM), supplier relationship management (SRM), customer relation management (CRM), and business intelligence (BI) (Marnewick & Labuschagne, 2005).

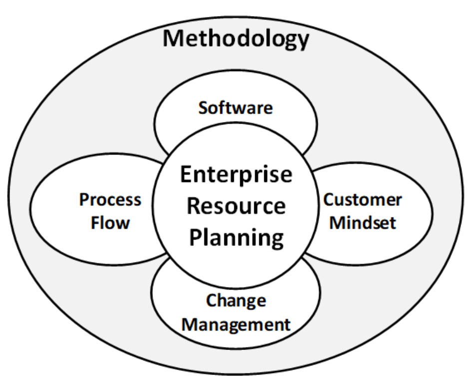


Fig. 2.3: Conceptual components of ERP (Marnewick & Labuschagne, 2005, p. 145)

The second component is the process flow within an ERP system; this component illustrates the way in which the information flows among the different modules within an ERP system. Therefore, the business processes must be modelled or in some cases reengineered before an ERP system can be implemented in order to enable a smooth integration (Marnewick & Labuschagne, 2005).

The third proposed component is the customer mindset. ERP systems change the prior way of working which users understand and are comfortable with, and thus, this change may lead to users' resistance. Therefore, the users' mindset change must be achieved through three levels, namely user influence, team influence, and organisational influence (Marnewick & Labuschagne, 2005).

The final component is the change management, which plays a key role in the successful implementation of an ERP system. Thus, change needs to be managed at several levels, namely user attitude and resistance to change, project changes, business process changes, and system changes (Marnewick & Labuschagne, 2005).

Furthermore, the concept of ERP systems can be illustrated in Figure 2.4, which depicts the anatomy of an enterprise system[12] which was proposed by (Davenport, 1998). As can be seen from Figure 2.4, the heart of an enterprise system is a central database that receives data and feeds data to various series of functional modules and business applications.

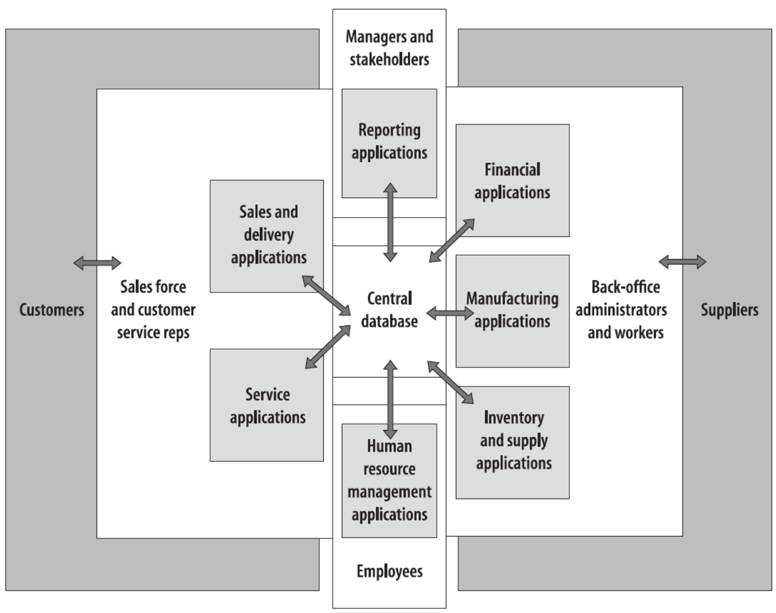


Fig. 2.4: Anatomy of an enterprise system (Davenport, 1998, p. 4)

2.1.5 Evolution of ERP Systems

This sub-section highlights the chronological order of the evolution of ERP systems, and this evolution resulted from three factors, namely (Monk & Wagner, 2012):

1. The improvement of the hardware and software technology that are needed to support these systems, such as computing power, memory, and communications.
2. The advancement of a vision of integrated information systems.

[12] Enterprise systems also commonly referred to as enterprise resource planning, or ERP systems (Laudon & Laudon, 2014; Davenport, 1998).

3. The increased interest and shift to a business-process focus rather than a functional focus.

Based on the abovementioned factors, ERP systems evolved through six milestones that will be presented in the following sub-sections.

2.1.5.1 Material Requirements Planning (MRP) Systems

The evolution of ERP systems began with the concept of inventory control in the 1960s and based on the traditional inventory control concepts, and thus, the customised software packages were designed to suit the requirements of manufacturing companies (Gupta & Kohli, 2006). In the 1960s, MRP systems began their life and became prominent in the 1970s (Leon, 2014). These types of systems were evolved from the bill of material (BOM) processing and simple inventory-tracking systems to planning and controlling manufacturing (Gupta & Kohli, 2006; Leon, 2014).

MRP systems aim to automate the manual procedures for planning and controlling production schedules (Abdinnour-Helm et al., 2003). Furthermore, MRP systems play a significant role in translating the master production schedule built for the end items into time-phased net requirements for the sub-assemblies, components, raw materials planning, and procurement (Gupta & Kohli, 2006). Therefore, these types of systems attempt to answer the listed questions in Table 2.1 through the corresponding process for each question (Leon, 2014). However, companies experienced difficulty in implementing these types of systems, with frequent failure on the expected benefits from these systems (Abdinnour-Helm et al., 2003).

Question	Process
What products are we going to make?	By using the master production schedule (MPS) to answer this question.
What are the materials needed to make the products?	By getting the details of the materials required to make the products from the bill of materials (BOM).
What are the materials that are in stock?	By searching the inventory records to find out what items are available in the stock.
What are the items that need to be purchased?	By calculating the items that need to be purchased for producing the goods.

Tab. 2.1: MRP systems processes (Leon, 2014)

2.1.5.2 Closed-loop MRP Systems

The second milestone in the evolution of ERP systems is Closed-loop MRP systems. These types of systems were evolved by merging the output of MRP and routing information to determine the capacity required, and thus, this combination aimed to provide a control loop to ensure that the MRP plans generated are realistic/valid by the capacity available (Gupta & Kohli, 2006). Consequently, several techniques and tools were developed to address both priority and capacity, and support both planning and execution (Leon, 2014). Various plant, production and supplier scheduling techniques for automating the processes inside and outside the organisation are examples of the developed techniques. While the developed tools to assist the planning of sales and production levels, development of productions schedules, forecasting, sales planning, capacity planning and order-processing are examples of the tools that were developed.

2.1.5.3 MRP II Systems

In the 1980s, closed-loop MRP systems were further evolved and extended into manufacturing resource planning (MRP II) systems that served the shop floor and distribution management

(Gupta & Kohli, 2006). These types of systems aim to integrate all departments and functional areas across a company into a single computer system (Gupta & Kohli, 2006). Therefore, MRP II systems plan all the resources of a manufacturing company by integrating and including other functional areas, such as business planning, sales and operations planning, demand management, production planning, master scheduling, material requirements planning, capacity requirements planning, and the execution support systems for capacity and material. Finally, the result from these systems is integrated with financial reports, such as the business plan, purchase commitment report, shipping budget, inventory projections and so forth (Leon, 2014).

2.1.5.4 ERP Systems

ERP systems first emerged in the late 1980s and the beginning of the 1990s (Rashid et al., 2002). The term "ERP" was first coined in the early 1990s (Klaus, Rosemann, & Gable, 2000; Uwizeyemungu & Raymond, 2005), and some scholarly publications state that this term was coined by the Gartner Group, such as (Chen, 2001), (Dahlén & Elfsson, 1999), and (Lea, Gupta, & Yu, 2005).

The emergence of ERP systems was established on the technological foundations of MRP and MRP II (Rashid et al., 2002), and these types of systems have a broader scope than MRP and MRP II systems; by having the capability of dealing with more business functions, having a better and tighter integration with the finance and accounting functions, and their capability of integrating with other tools and enterprise applications, such as CRM and SCM (Leon, 2014). Besides, these types of systems differ in the areas of relational database management, graphical user interface (GUI), the fourth generation languages, client-server architecture and open system capabilities (Dahlén & Elfsson, 1999; Gupta & Kohli, 2006; Keller & Teufel, 1998; Koch, Slater, & Baatz, 1999). Furthermore, ERP systems are not only limited to manufacturing companies, but are useful for any company that needs to integrate the flow of information across its functional areas (Abdinnour-Helm et al., 2003). In addition, ERP systems have the capability to enable organisations to reorient their departmental functions into enterprise business processes, such as customer management, supplier management, product management, and others.(Gupta & Kohli, 2006).

ERP systems follow the depicted anatomical structure of the enterprise system in Figure 2.4. According to (Dahlén & Elfsson, 1999), the software system must integrate three of the following core modules in order to belong traditionally to the ERP group, namely manufacturing, distribution, finance, and human resources. However, the following are some of the traditional core modules that can be found in the successful ERP systems (Rashid et al., 2002):

- Accounting management.
- Financial management.
- Manufacturing management.
- Production management.
- Transportation management.
- Sales & distribution management.
- Human resources management.
- Supply chain management.
- Customer relationship management.

- E-Business.

In software market, SAP, Oracle, Sage, Microsoft, and Odoo vendors have large shares based on a report entitled "*Market Share Analysis: ERP Software, Worldwide, 2013"* that was analysed by (Pang, Dharmasthira, Eschinger, F. Brant, & Motoyoshi, 2014) and published by Gartner. Figure 2.5 presents worldwide ERP software market shares for 2013.

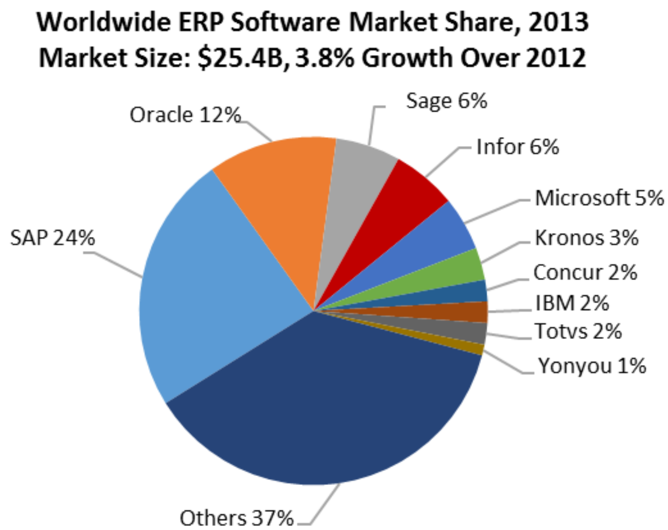


Fig. 2.5: Worldwide ERP software market share for 2013 adapted from (Louis Columbus, 2014; Pang et al., 2014)

While Odoo company belongs to the others category in this report, and it has been considered in the aforementioned list due to the promised future of its ERP system (Odoo ERP system), and this is what will be justified in Section 2.3.

The aforementioned modules of ERP systems can either work as stand-alone units or can be combined together to form an integrated system. Besides, most ERP systems employ client/server architecture rather than mainframe-based computing. Therefore, ERP systems functions are performed through the client/server architecture by following three layers (Rashid et al., 2002):

- **Presentation Layer** which includes UI components that enable users to access the ERP system functions and data. It might be in the form of GUI, or browser for data entry, or accessing system functionality.
- **Application Layer** which includes the business rules, functions, logic, and programs. In addition, this layer is responsible for processing and controlling the data transfer from or to the database servers.
- **Database Layer** which is responsible for managing and storing the organisation's operational or transactional data including metadata. Currently, most ERP systems employ the relational database management systems (RDBMS) with the structured query language (SQL) to achieve the responsibilities and objectives of this layer.

In the late 1990s, the Y2K problem emerged and motivated many enterprises to migrate into adopting ERP systems. Besides, new paradigms emerged that assisted in deploying, accessing and implementing these types of systems. These paradigms will be discussed in the next sub-section.

2.1.5.5 ERP II

In the 2000s, ERP systems have been accessed successfully anytime and anywhere, due to the exploitation of the advances in the information and internet technology, and electronic commerce. Therefore, these systems evolved into extended ERP systems (Gupta & Kohli, 2006). In addition, accessing ERP systems via internet has helped ERP vendors to extend their legacy ERP systems by integrating these systems with external business modules, such as SCM, CRM, sales force automation (SFA), advance planning and scheduling (APS), BI, and e-business capabilities (Rashid et al., 2002).

In 2004, adopting the service oriented architecture (SOA) became the goal that ERP vendors needed to adopt in their ERP products, because this software architecture enables different systems to communicate between one another (Căilean & Sharifi, 2013). Later, several technologies were combined into ERP systems in order to keep up with the competition, such as Software as a Service (SaaS) and BI (Căilean & Sharifi, 2013).

2.1.5.6 Alternative ERP Solutions

Two types of ERP deployments models have been used, namely on-premise and hosted. In the on-premise model, an ERP solution is usually acquired via a license model, and the software is installed on the enterprise server. In addition, the enterprise controls the related operations to the infrastructure, platforms, and their maintenance issues. While in the hosted model, the ERP system is defined as a service which is offered by a provider that hosts the whole system and its infrastructure (Duan, Faker, Fesak, & Stuart, 2013).

In 2009, cloud computing emerged as a new computing infrastructure and software model that changed the architecture of the manufacturing software, due to its exploitation of the web-based architecture to manage and integrate of manufacturing software across powerful data centres (Căilean & Sharifi, 2013). Cloud computing has many benefits such as (Saini, Saini, Yousif, & Khandage, 2011):

- Less initial capital investment.
- Less amount of time will be required to start new services.
- Maintenance and operation costs could go down.
- Effective utilisation through virtualisation.
- Simpler disaster recovery.

The rapid technological advances in mobile computing and ERP systems architecture, the huge leaps in mobile HCI, and the proliferation of mobile devices, led up to the fulfilment of the increasing demands to access ERP systems via mobile devices (Omar & Marx Gómez, 2016b). Thus, the latest era in the chronological evolution of ERP systems is mobile ERP. Figure 2.6 summarises the chronological evolution of ERP systems.

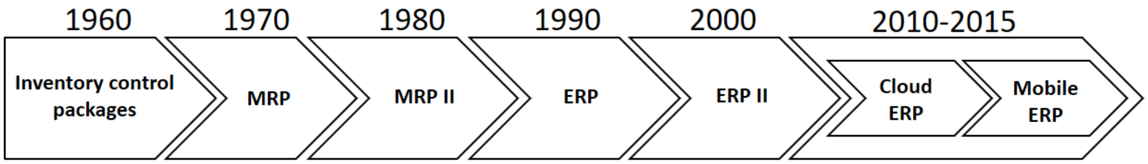


Fig. 2.6: Chronological evolution of ERP systems adapted from (Căilean & Sharifi, 2013)

During the abovementioned chronological evolution, organisations gradually realised the tangible and intangible benefits of adopting ERP systems, and these benefits will be discussed in the following sub-section.

2.1.6 ERP Systems Benefits

The main benefits of ERP systems are their real-time capabilities and visibility within an organisation (Leon, 2014), and their capabilities to automate the majority of organisations' business processes (Marnewick & Labuschagne, 2005). However, several researchers have identified further theoretical and industrial benefits which can be gained when ERP systems are fully realised in business organisations, and these benefits could be classified into direct and indirect benefits. The direct benefits, such as improved efficiency, information integration for better decision-making, and faster response time to customer queries. While the indirect benefits are a better corporate image, improved customer goodwill, and customer satisfaction (Leon, 2014). In addition, further benefits have been quoted from (Leon, 2014) which are:

- Streamlining processes and workflows within a single integrated system.
- Reduction of redundant data entry and processes.
- Information integration and the sharing of information across the various departments.
- Introduction of uniform processes that are based on recognised best business practices.
- Improved workflow and efficiency.
- Improved customer satisfaction based on improved on-time delivery, increased quality, and shortened delivery times.
- Reduced inventory costs resulting from better planning, tracking, and forecasting of requirements.
- Turn collections faster based on better visibility into accounts and fewer billing and/or delivery of errors.
- Reduction in vendor pricing by taking better advantage of quantity breaks and tracking vendor performance.
- Ability to track actual costs of activities and perform activity-based costing.
- Capability to provide a consolidated picture of sales, inventory, and receivables.
- Increased security of organisation's data.
- Better communication across the various departments.

According to Deloitte Consulting survey, ERP benefits can be classified into tangible (quantifiable) and intangible (non-quantifiable) benefits. Figure 2.7 depicts the major tangible benefits that can be realised from an ERP system. In turn, Figure 2.8 depicts the intangible benefits that can be realised from an ERP system (Deloitte Consulting, 1998). As can be seen from Figure 2.7, inventory reduction was the main tangible benefit, followed by personnel reduction and productivity improvements. In turn, information visibility was the main intangible benefit followed by improved processes and improved customer responsiveness as can be seen from Figure 2.8.

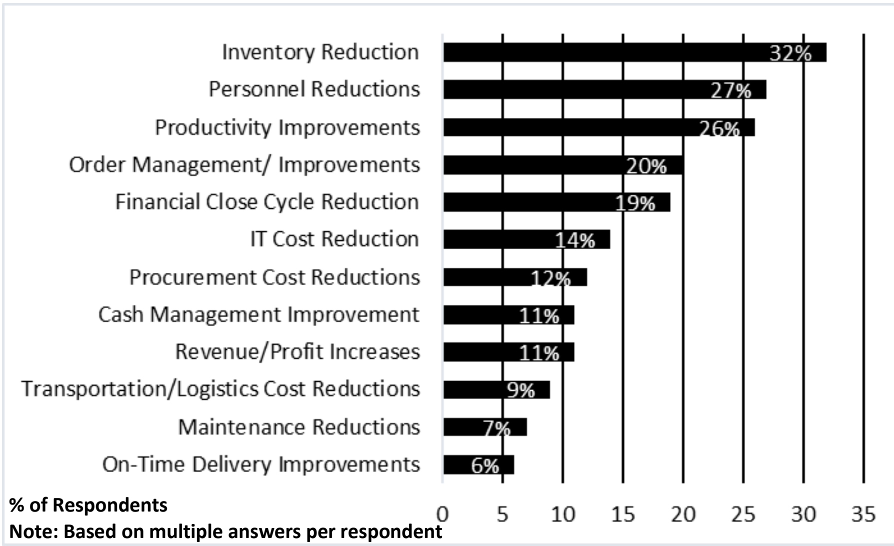


Fig. 2.7: Tangible benefits of ERP systems adapted from (Deloitte Consulting, 1998)

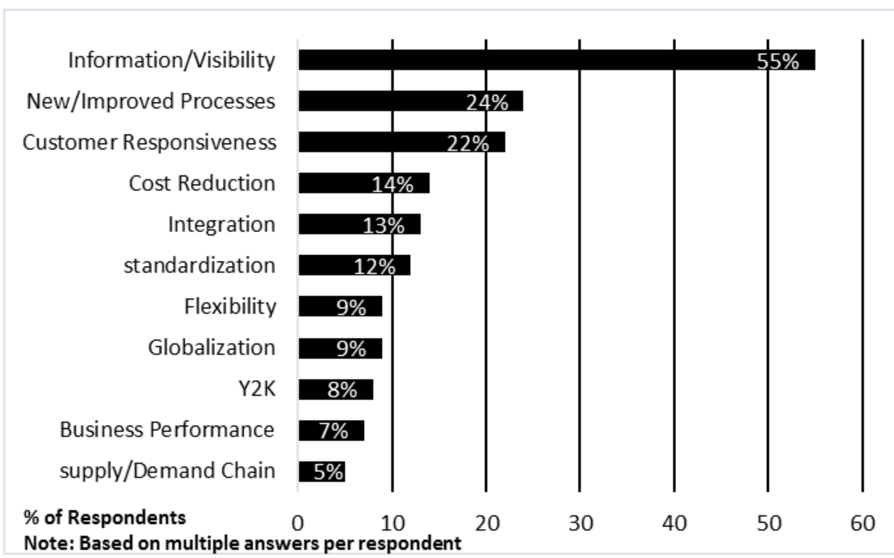


Fig. 2.8: Intangible benefits of ERP systems adapted from (Deloitte Consulting, 1998)

However, several enterprises have failed to attain the abovementioned benefits, due to the shortcomings and drawbacks of ERP systems that will be discussed in the following sub-section.

2.1.7 Shortcomings and Drawbacks of ERP Systems

ERP systems have a set of shortcomings and drawbacks that have led to a high failure rate of their implementation (Chen, Law, & Yang, 2009). Hershey, FoxMeyer, and Nike are examples of such failed projects in well-known companies (Amid, Moalagh, & Ravasan, 2012). According to the Panorama Consulting Solutions[13], twenty-one percent of ERP projects were considered failed projects in the year of 2014, and this information was based on a total of five hundred sixty-two respondents who completed the Panorama Consulting surveys (Panorama Consulting Solutions, 2015).

Several researchers have pointed out several shortcomings and drawbacks of ERP systems, and the following are some of them that have been summarised from (Akiki et al., 2015), (Parks, 2012), (Rajesh K, 2011), (Scholtz et al., 2010), (Singh & Wesson, 2009), (Chou & Chang, 2008), (Ragowsky & Gefen, 2008), (Yeh, 2006), (Topi et al., 2005), (Boudreau, 2003), and (T O'Connor & Dodd, 2000).

- ERP systems have poor usability due to their complex, rigid, and bloated UIs.
- The high costs of ERP systems regarding planning, hardware, implementation, configuration, customisation, testing, training, support, and others.
- Lengthy implementation processes and projects may take one to three years or more.
- The customisation processes are costly and time-consuming. Furthermore, too little customisation may not integrate into the ERP systems with the business process, while too much customisation may slow down the project timeline and make it difficult to upgrade.
- The delay of the cost saving and payback after the ERP implementation.
- ERP systems are difficult to learn, while the participation of users is very important for the successful implementation of ERP projects.
- The difficulties of data migration from legacy systems to the ERP system, and incompatibility issues.
- ERP implementations are complex.
- The problem of single vendor lock-in in case of further upgrades after the implementation of an ERP system.
- Inadequate fit between business and system requirements.
- Inadequate training and organisational resistance.
- High failure rate of implementing ERP system projects.

Consequently, it is required from organisations to identify the methods, strategies, and factors in order to overcome the abovementioned disadvantages and drawbacks. It might be in the selection phase for an appropriate ERP system, or in the implementation, or post-implementation phase.

After this integrated overview of ERP systems that has been presented in this sub-section, the next section will focus on selecting an appropriate ERP system that can be used for experimental purposes in the context of this research study.

[13] Panorama Consulting Solutions specialises in enterprise consulting, enterprise resource planning (ERP) and IT market for mid- to large-sized, private and public-sector organisations across the globe. Further information about Panorama Consulting Solutions can be found online at: http://panorama-consulting.com.

2.2 Selection Model of an ERP System in Mobile ERP Design Science Research

The mobile ERP research domain is considered one of the latest trends in the ERP systems research domain, and thus, this trend needs to be polished by further IS innovations through employing the design science research paradigm as a problem-solving paradigm. One of the challenges and problems that might hinder the mobile ERP model is usability (Omar & Marx Gómez, 2015), and thus, the design science research paradigm can be employed to address this problem.

Presently, several products of ERP systems can be found in the ERP software market, around 120 or more, which makes the selection process of one of these products in order to be researched, extremely difficult.

Furthermore, there is an absence of a specific scientific approach or a model that aims to assist researchers in the selection of an appropriate ERP system in order to be researched by following the design science research paradigm. Whereas the literature has been enriched with different models and frameworks for ERP system selection to perform business processes and functions, rather than for research purposes such as the proposed models from (Verville & Halingten, 2003), (Wei, Chien, & Wang, 2005), and (Lien & Chan, 2007).

Furthermore, several challenges were encountered during this research study in the selection process of this component which is considered a core component of the mobile ERP model.

Consequently, the abovementioned issues were extracted from the mobile ERP research's realm, and formulated as criteria to be fulfilled by the researcher or the organisation in order to select an appropriate ERP system to conduct a mobile ERP research on it by following the design science research paradigm. This model is one of the artefacts of this research study and its criteria are (Omar & Marx Gómez, 2016b):

(C1). Maintaining the Concept of the ERP Model

The selected ERP system must have the ability to support the integration of the most core functional modules and activities that can be found in the conventional ERP systems (see Figure 2.4). Therefore, this criterion aims to maintain the concept of an ERP system, and after applying this criterion the resulted artefact from the conducted mobile ERP research would be applicable as a model to most ERP systems in the software market.

(C2). Accessibility and Flexibility in the Source Code

The selected ERP system must enable access its source code. This means following the open source model that enables further development and customisation for the selected ERP's functionalities and modules after their deployment, and thus, this will support the researcher in case of the need to develop a prototype that will act as proof of concept.

(C3). Enables to be Accessed via Mobile Devices

The selected ERP system must enable mobile access to most of its core modules (see Figure 2.4), through one mobile app. Thus, after applying this criterion, the resulted artefact from the conducted mobile ERP research would be applicable as a model to other mobile ERP apps in the software market.

(C4). Able to Accommodate Different Enterprise Sizes

The selected ERP system must be able to accommodate the different sizes of enterprises, and thus, the resulted artefact from the conducted mobile ERP research can be utilised to develop mobile ERP apps that are able to serve different enterprise sizes.

(C5). Deployed in a Variety of Industry Sectors

The selected ERP system must be deployed in a variety of industry sectors, and thus, the resulted artefact from the conducted mobile ERP research can be exploited to develop apps that aim to serve a wide range of industries.

(C6). Supported by Developers' Community

The selected ERP system must be supported by the developers' communities to assist the researcher in addressing the emergence of any potential issues, or in case of the need to perform any customisation at the programming level.

(C7). Bearable in Cost Terms

The selected ERP system must be bearable in cost terms, such as the infrastructure cost and any hidden costs, whether for the researcher or the organisation that intends to conduct a mobile ERP research.

(C8). Compatible with the Practice Skills and Programming Skills of the Researcher

The selected ERP system must be appropriate for the context of the intended research, and this means that the researcher must have sufficient experience in the selected ERP system. Besides, the selected ERP system must be compatible with the programming skills of the researcher in a case of the need to perform any customisation at the programming level.

Consequently, the abovementioned criteria were employed in a comparison analysis to select an appropriate ERP system to be researched in this research study. The included ERP systems in this comparison analysis were selected based on the determined prominent ERP vendors of the worldwide ERP software market in the year 2013 (see Figure 2.5). These vendors have been declared in a report entitled "*Market Share Analysis: ERP Software, Worldwide, 2013*" that was analysed by (Pang et al., 2014) and published by Gartner. As can be seen from Figure 2.5, the "others" category of vendors has a large share of thirty-seven percent, and thus, this share has been considered within the selection process. Odoo Company is considered from the "others" category of the ERP vendors, and the motivation behind considering its ERP system in this selection process stems from the increasing number of the adoption rates of it within enterprises. Table 2.2 presents the results of the conducted comparisons analysis based on the identified eight selection criteria.

For instance, SAP ERP system does not fulfil the criterion C7 and criterion C8 regarding the researcher in this research study. In turn, Odoo ERP system has fulfilled all of the identified selection criteria, and thus, these fulfilled criteria will be discussed in terms of their applicability regarding Odoo ERP system in the upcoming sections.

Consequently, the Odoo ERP system was selected as an answer to the first research question which is:

RQ.1) What is the appropriate ERP system that can be used for experimental purposes in the context of this research study?

The following section presents an integrated overview of the Odoo ERP system, which includes a series of facts that raised the motivations behind selecting this ERP system.

ERP System	C1	C2	C3	C4	C5	C6	C7	C8
SAP Business One	✓	✓	x	x	✓	✓	x	x
SAP ERP	✓	✓	✓	✓	✓	✓	x	x
Oracle E-Business Suite	✓	✓	x	✓	✓	✓	x	x
PeopleSoft Applications	✓	✓	x	✓	✓	✓	x	x
JD Edwards EnterpriseOne	✓	✓	x	x	✓	✓	x	x
JD Edwards World	✓	✓	x	✓	✓	✓	x	x
Oracle Fusion Applications	✓	✓	x	✓	✓	✓	x	x
Sage 100c	✓	✓	x	x	x	✓	x	x
Sage 300c	✓	✓	x	x	✓	✓	x	x
Sage X3	✓	✓	✓	✓	x	✓	x	x
Microsoft Dynamics AX	✓	✓	x	✓	x	✓	x	x
Microsoft Dynamics GP	✓	✓	x	x	✓	✓	x	x
Microsoft Dynamics NAV	✓	✓	✓	x	✓	✓	x	x
Microsoft Dynamics SL	✓	✓	x	x	x	x	x	x
Odoo ERP system	✓	✓	✓	✓	✓	✓	✓	✓

Tab. 2.2: Updated results of the comparisons analysis among some of the prominent ERP systems adapted from (Omar & Marx Gómez, 2016b)

2.3 Odoo ERP System

This section presents an integrated overview of Odoo ERP system that has been selected for the experimental purposes in this research study, beginning with the historical background of the Odoo Company and its released versions of Odoo ERP system. The remainder of this section comprises the following sub-sections: Odoo core modules, and Odoo ERP system architecture.

2.3.1 Historical Background

Fabian Pinckaers is the founder of the Odoo ERP system, and his dream was to lead the enterprise management market with a fully open source software. Based on this motivation, the enterprise software giant SAP was selected as a competitor to fuel Fabian in his motivation. This was his strategy from the beginning (Pinckaers, 2016).

In 2005, TinyERP ERP system was developed under GNU General Public License (GPL)[14] for micro, small and medium size enterprises in the trade, distribution, and services sectors (Herzog, 2006). This ERP system provided the conventional modules that can be found in any ERP system, such as accounting, CRM, sales, purchases (delivery, purchase, sales management, point of sale), human resources, marketing, MRP, MRP II, inventory control, and project management. In addition, some specific modules and an interface were provided to eZ Publish[15] eCommerce application (Herzog, 2006). TinyERP system supported the operating system's (OS) independence and follows the client-server architecture; where the client's OS could be Linux, Windows, or MAC OS X, and while the server could be Linux or Windows (Herzog, 2006). In addition, TinyERP was programmed by using Python programming language and its data was stored in PostgreSQL (Herzog, 2006). The released versions of TinyERP were 1.0,2.0,3.0, and 4.0 (Odoo, 2016a).

[14] GNU is a software license agreement that intends to guarantee the end-user freedom to share and change free software, Further information about GNU license agreement can be found online at: http://www.gnu.org/licenses/gpl-3.0.en.html.
[15] Further information about eZ products can be found online at https://ez.no/.

In 2008, TinyERP was renamed to OpenERP for marketing reasons with a significant increase in numbers of its adoption rates in business; and the total number of its downloads reached more than one thousand downloads per day (van Vossel & Pinckaers, 2011). During that time, OpenERP supported eighteen languages and had a world network of partners and contributors (Pinckaers & Gardiner, 2009).

OpenERP was available under the AGPL[16] license version three. The released versions of OpenERP are 5.0,6.0, 6.1 and 7.0 (Odoo, 2016a). Furthermore, the conventional modules of ERP systems were provided in OpenERP, such as sales, CRM, project management, warehouse management, manufacturing, financial management, and human resources. Besides, more than one thousand modules were available from the OpenERP Apps marketplace (van Vossel & Pinckaers, 2011).

OpenERP continued in evolving with a constant increase in its community, and achieved the following accomplishments (Pinckaers, 2016):

- More than one thousand installations per day, and thus, it became the most installed management software in the world.
- OpenERP was analysed by researchers who have years of experience in the ERP world, and it was evaluated with SAP. The analysis results were published in a book entitled "*Openerp Evaluation with SAP as Reference*" authored by (Delsart & van Nieuwenhuysen, 2011).
- OpenERP is now being taught to students at universities.
- An average of sixty new modules were released every month.
- In 2013, OpenERP had two million users worldwide.

OpenERP moved beyond the conventional concept of an ERP model through extending it. The belief behind this movement was the integration of business activities is not restricted to the conventional ERP modules, such as sales, accounting, inventory, and procurements (Pinckaers, 2016). Therefore, OpenERP v8.0 was released in June 2014 under AGPL license version 3 with a content management system (CMS), e-Commerce, a Point of Sales, an integrated BI engine, and more than three thousand modules (Pinckaers, 2016).

In May of 2014, OpenERP had raised ten million dollars in funding to support its research and development (R&D) efforts and commercial growth. This funding was jointly provided by leading venture capital firms XAnge (France), SRIW (Belgium), Sofinnova Partners (France), and the management team. Accordingly, and as part of OpenERP company growth strategy, the company and its ERP system were renamed to Odoo to support its vision, and better reflect its expanded areas that exceeded beyond the core ERP functions (Pinckaers, 2016). The latest released version of Odoo is 10.0.

Presently, Odoo penetrates rapidly in the ERP software market, and this can be seen in Figures 2.9 and 2.10 that depict a set of comparative graphs that were generated by using Google Trends exploration tool. The coloured curved lines present the number of Google searches for the associated keywords (i.e. between Odoo and other ERP systems) during the years of 2013 until 2016. This metric shows the relative searcher interest for each ERP system.

[16] AGPL is a modified version of the ordinary GNU GPL version 3. "It has one added requirement: if you run a modified program on a server and let other users communicate with it there, your server must also allow them to download the source code corresponding to the modified version running there", Further information about AGPL license agreement can be found online at: http://www.gnu.org/licenses/agpl-3.0.en.html.

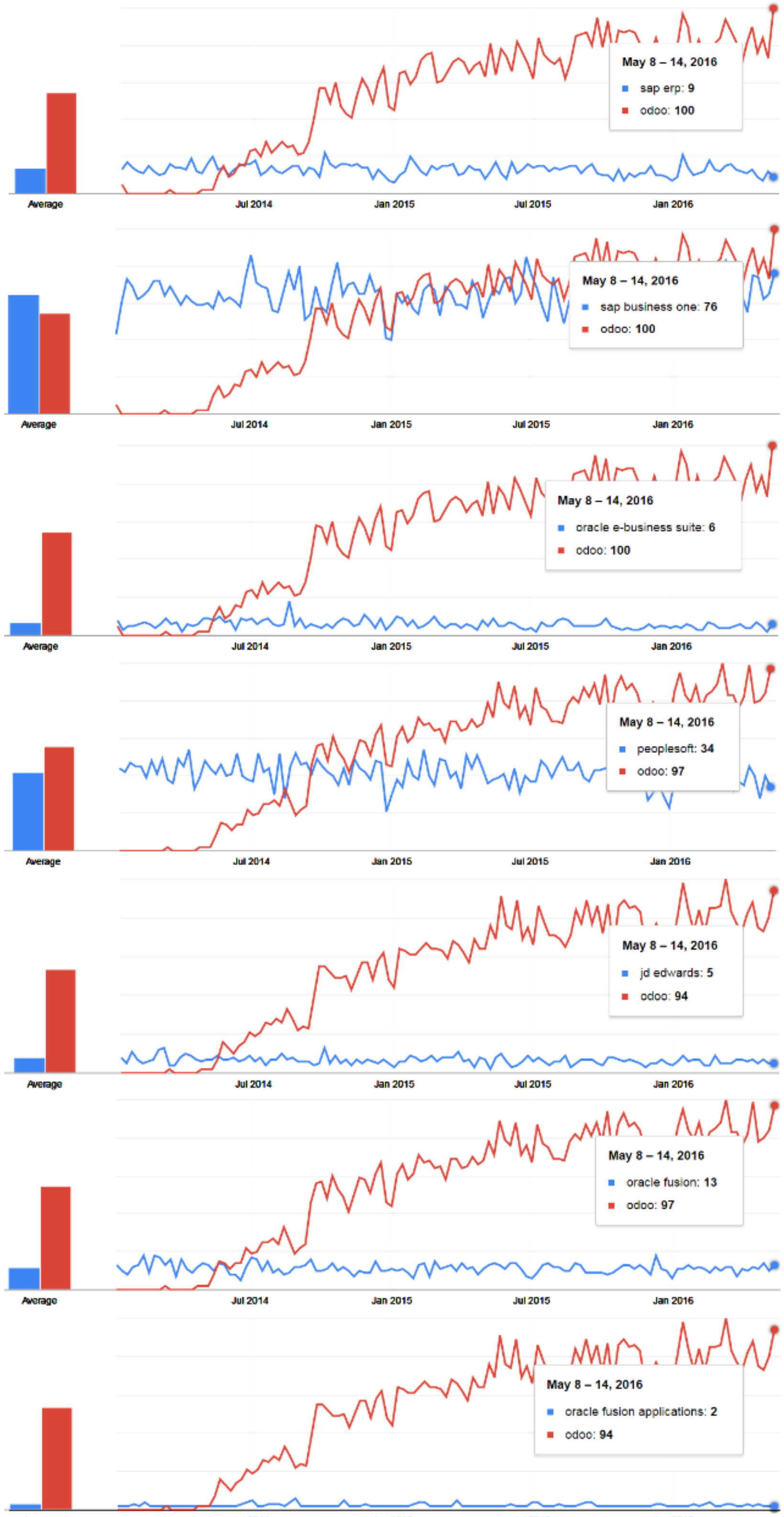


Fig. 2.9: Relative number of Google searches for Odoo ERP system and other ERP systems

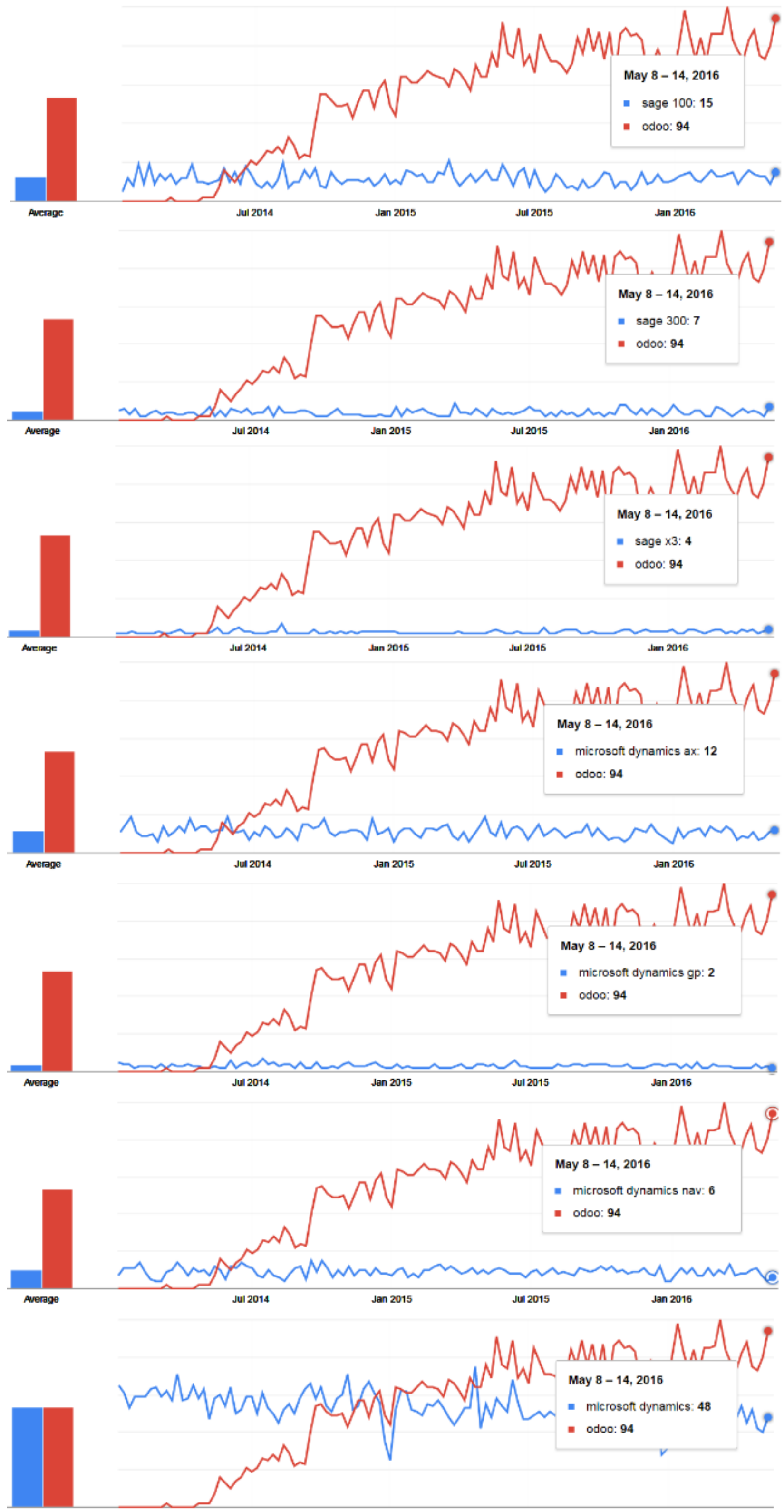


Fig. 2.10: Relative number of Google searches for Odoo ERP system and other ERP systems

2.3.2 Odoo Core Modules

Odoo ERP system consists of a set of core functional modules, and these modules are (Ioppolo & Associates, 2016; Odoo, 2016b):

- **CRM**

  The CRM module manages enterprise's sales funnel without effort, attracts leads, follow-ups on phone calls, and coordinates meetings. In addition, this module provides the ability to analyse the quality of enterprise's leads to make informed decisions and save time by integrating emails from all contacts directly into the application. Besides, it enables the tracking of sales teams and progress towards goals with the gamification feature.

- **Project Management**

  The project management module helps an enterprise organise its jobs and projects. In addition, this module provides the ability to work on tasks and issues using the Kanban view, to schedule tasks in the Gantt chart, and to control deadlines in the calendar view. Furthermore, it provides the ability to create specific stages for each project, and thus, all enterprise teams can optimise their work in a simple and professional fashion.

- **Accounting and Finance**

  The accounting and finance module offers a better manner for an accounting team to work with their customers and suppliers. In addition, it provides the standard accounting and finance features that include integrated analytic, budgets, assets management, and multiple companies' consolidation accounting and finance management.

- **Point of Sale (POS)**

  The point of sales module is fully integrated with the inventory management module and accounting module. This means any transaction through POS will automatically be input into the inventory management and accounting modules. In addition, it has the ability to be used online or offline via different devices, models and platforms that can display websites, such as tablet computers, laptops, or industrial POS machines. Besides, it includes extra features, such as customer service and the creation of invoices.

- **Warehouse Management**

  The warehouse management module enables an enterprise to decrease stock processing times, automate its transactions, reduce the stock levels, and get complete traceability on all operations. Furthermore, this module provides an advanced real-time reporting and custom dashboards to get a picture of the enterprise warehouse efficiency at a glance.

- **Website Builder and e-Commerce**

  Odoo's website builder and e-Commerce modules provide the ability to create websites and web stores without required knowledge in web development and design. These modules provide numerous functionalities to facilitate the creation of a website such as "edit inline" approach and integration with the enterprise features, such as e-commerce, call-to-actions, job announcements, events, customer references, blogs, and many other functionalities.

- **Manufacturing and Resource Planning**

  The manufacturing module enables an enterprise to manage all the assembly and/or manufacturing operations, to schedule manufacturing orders and work orders automatically, to review the proposed planning with the smart Kanban and Gantt views, and to use the advanced analytics features to detect bottlenecks in the resource capacities and inventory locations.

- **Human Resources**

  The human resources module enables an enterprise to manage the human resources operations, such as knowledge sharing, recruitment, appraisals, timesheets, contracts, attendance, and payroll.

- **Purchasing Management**

  The purchasing management enables an enterprise to automate procurement propositions, launch request for quotations, track purchase orders, manage suppliers' information, and control products reception and check suppliers' invoices.

In addition to the abovementioned modules, the open source model (i.e. the AGPL licence version 3) of the Odoo ERP system has allowed it to leverage from thousands of developers and business experts who built hundreds of apps in just a few years (Odoo, 2016b).

2.3.3 Odoo ERP System Architecture

This section illustrates the system architecture of the Odoo ERP system along with the applied technology for each component of this architecture.

The system architecture of the Odoo ERP system is a multitenant[17] and it is composed of three-tiers, which are: the database tier for data storage, the application tier for processing and functionalities, and the presentation tier that provides UIs. Figure 2.11 depicts the typical deployment of the Odoo ERP system, where this deployment is called web embedded deployment (Odoo, 2012). As can be seen from Figure 2.11, the Odoo system architecture consists of the following three main tiers (Odoo, 2012):

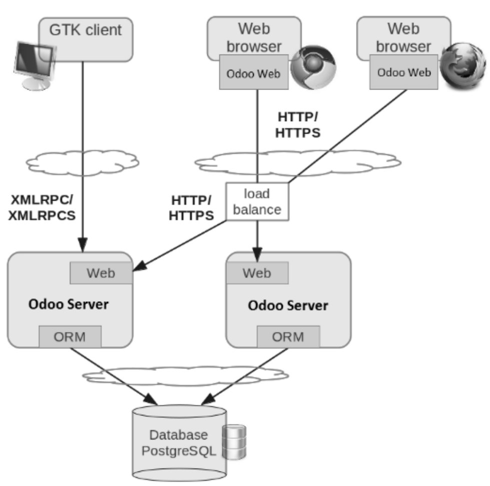


Fig. 2.11: Odoo system architecture for embedded web deployment adapted from (Odoo, 2012)

[17] Multi-tenancy is "an approach to share an application instance between multiple tenants by providing every tenant a dedicated 'share' of the instance, which is isolated from other shares with regard to performance and data privacy" (Krebs, Momm, & Kounev, 2012, p. 2).

1. **PostgreSQL Database Server**

   The database tier in the Odoo system architecture contains all databases which include all application data and most of the system configuration elements. This tier is managed by a PostgreSQL, the open-source Object-Relational DBMS. In addition, this DBMS can possibly be deployed using clustered databases.

2. **Odoo Server**

   The Odoo server includes all enterprise logic and ensures that Odoo ERP system runs effectively. This server provides two layers. The first layer is the Object Relational Mapping (ORM) engine layer which is responsible for communicating and interfacing with the PostgreSQL database server. The second layer is the Web layer that enables communications between the server and a web browser. In addition to the previous layer, Odoo server hosts different modules to implement any business requirement.

   - **ORM Layer**

     This layer provides additional and essential functionalities on top of PostgreSQL server. In the Odoo ERP system, the data models are described using Python programming language, and Odoo creates the underlying database tables by using the ORM. In addition, all benefits of RDBMS are used and completed by Python flexibility, such as unique constraints, relational integrity, or efficient querying.

   - **Web Layer**

     This layer provides an interface to communicate with standard browsers, and it is a WSGI-compatible[18] application based on werkzeug[19]. It handles the regular HTTP queries to server static file or dynamic content, XML-RPC, and JSON-RPC queries for the RPC made from the browser.

   - **Modules**

     The role of the modules is to implement any business requirement, and the server is the only necessary component to add these modules and manage them.

3. **Clients**

   Odoo application logics are included in the server-side, while the end-user sends a request to the server and receives a response. The retrieved results are displayed in different ways, such as forms, lists, or calendars. Furthermore, the end-user can modify data by sending queries to the server.

   In complex computer applications that offer a huge amount of data, it is preferably decoupling data (model) from the UI (view), and thus, any changes to the UI will not impact data management, likewise, data can be reorganised without changing the UI (Odoo, 2012). The model-view-controller (MVC) solves this problem by decoupling data access and business logic from data presentation and user interaction. This decoupling is achieved by introducing an intermediate component which is the controller (Odoo, 2012). Therefore, Odoo follows the MVC architectural pattern and semantic with:

[18] WSGI the Web Server Gateway Interface is a simple and universal interface between web servers and web applications or frameworks for the Python programming language. Further information about WSGI can be found online at: https://www.python.org/dev/peps/pep-0333.

[19] Werkzeug is a flexible WSGI implementation and toolkit. Further information about Werkzeug can be found online at: http://werkzeug.pocoo.org.

- **Model:** the PostgreSQL tables which define the structure of the data.
- **View:** views are defined in the XML files in Odoo.
- **Controller:** the objects of Odoo that support the business logic of the application.

2.4 Summary

This chapter provided an integrated overview of ERP systems that includes a set of essential ERP concepts which makes such systems differ from the other traditional IS, namely definition, characteristics, benefits, drawbacks, and the conceptual model that is being followed. In addition, the chronological evolution of ERP systems was recounted from the beginning up to the present in this chapter.

This research study aims to improve the usability of mobile ERP apps by identifying their usability challenges and tackling these challenges through following the design science research paradigm. However, several products of ERP systems can be found in the ERP software market, which only makes the selection process of one of these products tedious in order to be researched in the mobile ERP research domain. Therefore, a selection model was proposed that consists of a set of criteria that needs to be fulfilled by the researcher or the organisation in order to select an appropriate ERP system to conduct a mobile ERP research on it by following the design science research paradigm.

Odoo ERP system has been selected based on the proposed selection model, and an integrated overview of this ERP system has been presented in this chapter.

3 Usability of Mobile ERP Apps

One of the main sub-objectives of this research study is to construct a conceptualisation of the usability challenges of mobile ERP apps. Therefore, five research studies were conducted in order to achieve this sub-objective, and their results will be discussed and presented in this chapter. Consequently, this chapter consists of five main sections. The first section provides an overview of mobile computing. Then it is followed by an integrated overview of mobile ERP apps with highlighting the selected mobile ERP app for experimental purposes. Thereafter, an overview of the usability of mobile apps will be provided in section three. The five conducted research studies and their results will be presented and discussed in section four, and the final section is a summary.

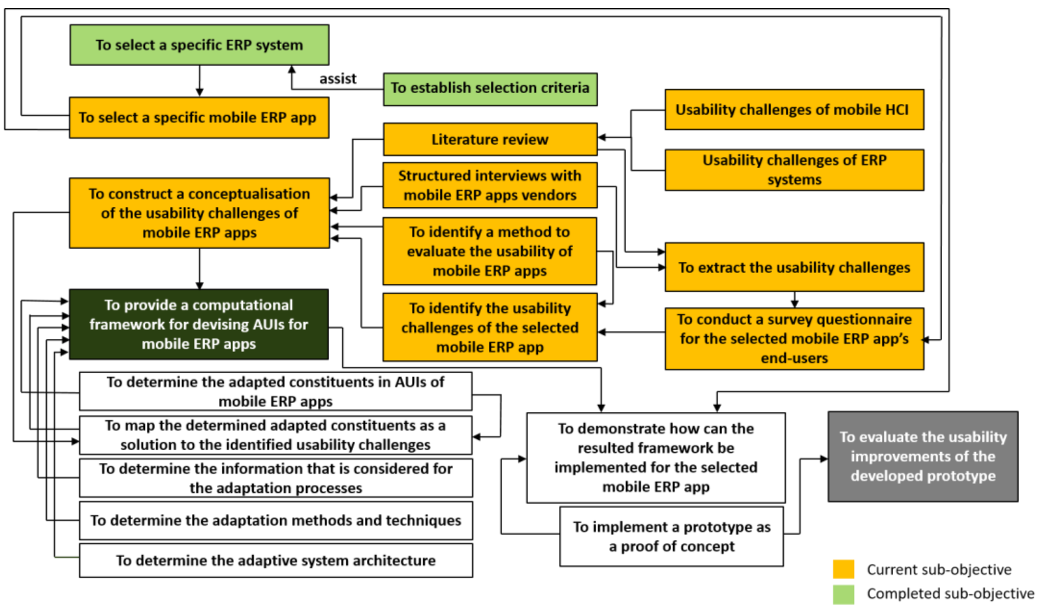


Fig. 3.1: Research objectives status; sub-objectives that will be achieved in Chapter 3

3.1 Mobile Computing and Related Concepts

In the early 1990s, several visions were sketched of new kinds of computing after the era of the personal computer (PC), and one of these first visions was sketched by Mark Weiser, the pioneer of mobile computing (Reichenbacher, 2004; Weiser, 1991).

In the literature, several concepts that are related to mobile computing can be found, such as nomadic computing, ubiquitous computing, pervasive computing, embedded computing, everyday computing, and invisible computing (Reichenbacher, 2004). However, Reichenbacher clarified the differences among these categories as follows; mobile and nomadic computing refer to the capability of using computing during mobility in contrary to traditional stationary desktop based computing. While the other categories go a step further in their computing concept by enabling computing almost everywhere and embedding it in every kind of everyday object, and thus, the accessing process to such computing will not be limited to a particular device or to a certain place. The systems of the final category are known as context-aware systems which are aware of the vision of invisible computing. These types of systems are strongly connected to the field of mobile computing.

Consequently, this research study belongs to the mobile computing research domain, and it exploits the concepts of context-aware computing to solve the main research problem. This exploitation is achieved through devising AUIs which adapt their components automatically based on the context of use. Therefore, the concepts of mobile computing which are related to this research study will be illustrated briefly in the remainder of this section. While the concepts of context-aware computing which are related to this research study will be illustrated in Chapter 4.

Mobile computing systems are defined as:

> "*Mobile computing systems are computing systems that may be easily moved physically and whose computing capabilities may be used while they are being moved. Examples are laptops, personal digital assistants (PDAs), and mobile phones*" (B'far, 2005, p. 3).

Such systems differ from the other types of computing systems in their tasks' nature which they are designed to perform, their design model, and the way that they are operated (B'far, 2005). (Krogstie et al., 2004) described these systems as follows:

> "*Mobile computing systems entail end-user terminals that are easily movable in space, are operable independent of location and typically have wireless access to information resources and services. As in conventional information systems, users share data and are able to perform collaborative work, either synchronously or asynchronously, with other users*" (Krogstie et al., 2004, p. 4).

Mobile computing systems involve three combined components in order to successfully accomplish their mobile computing processes, namely hardware, software, and mobile communication (Zimmerman, 1999).

The mobile hardware consists of the physical components and devices that are needed for mobility. These physical components and devices are characterised by size and form factor, weight, microprocessor, primary storage, secondary storage, screen size and type, means of input and output, battery life, communications capabilities, expandability, and durability of the device (Zimmerman, 1999). Since the 1990s, several types of mobile devices have emerged, such as personal digital assistant (PDA)/ enterprise digital assistant, smart phones, tablet computers, ultra-mobile PCs, and wearable computers (Nosrati, Karimi, & Hasanvand, 2012).

Regarding the mobile software, it is a computer software that can be classified into system and application software.

Mobile OS is a system software that controls and executes mobile apps, and manages the hardware components of mobile devices and their resources. At present, the most prominent mobile OSes are Android, iOS, Windows Mobile, and Blackberry OS (IDC Research, 2015; Jobe, 2013). However, each one of these mobile OSes has some form of the integrated development environment (IDE) to support its mobile apps development (Zimmerman, 1999).

The mobile app software is typically known as mobile apps, and most of these apps can be categorised into games, utilities, news, entertainment, social networking, and life style. These types of apps can be obtained by one of the following resources:

- Pre-installed apps by the manufacturers of the mobile device, or mobile network carrier, or OS, such as email client, web browser, weather, calculator, and global positioning system (GPS) app.
- From the app store of the mobile devices OS, such as Google Play for Android, Apple's App store (iTunes) for iOS, and Windows Phone Apps for Windows phones.
- Developed and installed by mobile apps developers.

In the realm of mobile computing, three development paradigms can be followed for developing mobile apps, namely web apps, native apps, and hybrid apps. Each one of these paradigms has its own advantages and disadvantages. The divergence among them stems from the differences of the underlying development technology of each paradigm.

Regarding the mobile web apps, these types of apps are web applications that have been customised and formatted for smart phones and tablet computers in order to be accessed through the web browser of a mobile device (Lionbridge, 2012). Furthermore, such apps are developed by using web programming languages, such as Hypertext Markup Language (HTML), HTML5, Cascading Style Sheets (CSS), and JavaScript. Since mobile web apps are browser-based, these types of apps are platform and device independent, and thus, it has the ability to overcome the variations of mobile OSes (Lionbridge, 2012; Raluca, 2013). In addition, mobile web apps are typically modelled as a three-tiered client/server architecture which consists of the thin client layer, which represents the mobile devices, the application server layer, which is the web server, and the data layer, which stores the databases and data for the application (Huy & van Thanh, 2012; Lim, Azlianor, Suhaizan, & Massila, 2008).

Regarding the mobile native apps, these types of apps are specifically designed and developed for a particular device platform, and it can be installed manually from the online apps store of that platform. Mobile native apps are typically developed by Java programming language for Android OS, C or Objective-C programming language for iOS, or the .NET framework for Windows Phone OS (Huy & van Thanh, 2012; Jobe, 2013; Raluca, 2013; Tarkoma & Kangasharju, 2009). This development paradigm has the following advantages (Lionbridge, 2012; Raluca, 2013):

- The ability to leverage device-specific hardware, such as camera, GPS, accelerometer, gestures, and notifications.
- The ability to leverage device-specific software, such as email, calendar, and contacts.
- The ability to incorporate with the gestures, either the standard OS gestures, or the new app-defined gestures.
- The ability to work offline and re-synchronise its data with the back-end server when the connection is restored.

Despite the abovementioned advantages, the development of such apps is complex and requires further efforts (Huy & van Thanh, 2012). In addition, mobile native apps are platform dependent, and thus, they cannot accommodate the variation of the available platforms. Therefore, mobile developers of these types of apps need to develop different versions of their apps in order for them to be operated across multiple platforms, and thus, this will increase the cost of development (Charland & Leroux, 2011; Lionbridge, 2012).

(Jobe, 2013) identified the general aspects and key characteristics regarding the web and native paradigms for the mobile apps development. Table 3.1 tabulates these aspects and characteristics.

	Native apps	**Mobile web apps**
Create vs. consume content	Native apps are more suitable for content creation due to performance and hardware access	Mobile web apps are less suited for content creation, but equally suited for content consumption
User experience	Seamless integration with native operating system	Limited integration, requires external frameworks
Update frequency	Updates are formal through app stores	Updates are more informal and equivalent to website updates

Performance	Maximum performance and access to device hardware	Performance is dependent on JavaScript rendering and mobile web browsers, limited access to device hardware
Functionality	All functionality in the mobile operating system is available	Most of the functionality of the mobile operating system is available
Development	Requires specific development for each mobile operating system	Open web languages and browsers make "Write once, run anywhere" development possible
Profitability	Framework for monetizing apps is available via app stores	No clear, unified strategy for monetization

Tab. 3.1: Explanation of how native and mobile web apps presumably address key characteristics of app usage and development (Jobe, 2013, p. 28)

Regarding the mobile hybrid apps, these types of apps are neither truly mobile web apps nor native apps, which means such apps are developed by using web techniques of HTML5, JavaScript application program interfaces (APIs), and CSS and run inside a 3rd party native app container, and thus, they typically have access to the native device APIs and hardware (Jobe, 2013). PhoneGap, Appcelerator, and Appspresso are some examples of well-known hybrid mobile frameworks that allow developers to design and code across platforms of mobile hybrid apps (Jobe, 2013; Raluca, 2013). Similar to the mobile native apps, mobile hybrid apps can be found in app stores. Therefore, companies develop hybrid apps as wrappers for their existing web pages in order to be found in different mobile app stores, without spending significant efforts in developing native apps (Raluca, 2013).

The final component of the mobile computing system is the mobile communication. This component relies on the type of wireless communications which has its roots in radio communications, and the first radio transmission was discovered by Marconi in 1895 (Pattnaik & Mall, 2015). Presently, there are various types of mobile communications technologies that are widely used, such as Global System for Mobile Communications (GSM); Wireless local area networks (WLANs) which are typically known as Wi-Fi; Mobile Satellite Services (MSS); Bluetooth, ZigBee; and Microwave communication technology.

Recently, the term mobile enterprise has been steadily gaining momentum to describe the organisation that supports its enterprise systems via wireless mobile devices, such as smart phones, mobile full-screen phones, and tablet computers (Stieglitz & Brockmann, 2012). Mobile ERP app is an instance of mobile enterprise apps, and thus, the following section presents an integrated overview of mobile ERP apps for further understanding of this application model. In addition, an overview of the selected mobile ERP app for experimental purposes in this research study will be presented in the following section.

3.2 Mobile ERP Apps

3.2.1 Overview

In 2002, the term "mobile ERP" was noticed in a paper entitled "*Extending the value of ERP*" for (Willis & Willis-Brown, 2002), where the authors emphasised that the mobile ERP would be the future of ERP systems and an extension of them. Thereby, mobile ERP is considered an instance of a larger concept which is the ERP (Căilean & Sharifi, 2013).

Obviously, the mobile ERP topic is still in its early developmental stage, and thus, it is considered a budding topic in practice and research. In addition, there is a lack of reviews related to this topic (Căilean & Sharifi, 2013; Dospinescu, Fotache, Munteanu, & Hurbean, 2008; Hailu & Rahman, 2012).

Three key factors assisted in the realisation and implementation of the mobile ERP notion; the proliferation of mobile devices that penetrate every aspect of our life, the constant advances in mobile computing, and the huge leaps in mobile HCI. Consequently, enterprises' demands have increased to access ERP systems via mobile devices, such as smart phones, tablet computers, and mobile handheld computers (Omar & Marx Gómez, 2016b).

According to (Dabkowski & Jankowska, 2003), mobile ERP is mobile access to the information and functionality which are needed by an enterprise employee and are stored in the enterprise's ERP system, and this access aims to perform flexible actions and reactions. However, several definitions can be found in the literature for mobile ERP, and each one of these definitions attempts to clarify the mobile ERP notion.

> "*mobile ERP is about having access to a software that allows a mobile device (portable computer, phone, Tablet PC, PDA) to be connected to the ERP system of an organization through a mobile net of communications and transmission of data GPRS/UMTS*" (Dospinescu et al., 2008, p. 92).

> "*One good example is mobile ERP, which refers to the use of mobile device (e.g. a smartphone or tablet) to perform different business functions such as sales, customer relationship management and supply chain management through a single integrated system. In other words, it is a tool used to carry out business functions on-the-go*" (Albashrawi & Motiwalla, 2016, p. 1).

Based on the abovementioned definitions, mobile ERP apps are able to perform and manage several business functions and processes of ERP systems. Sales order, request for quotation (RFQ), tender, purchase order, shipment, warehousing, inventory control, delivery order, invoicing, customer service order, production monitoring and control, work order are all examples of business processes and functions that can be performed and managed by mobile ERP apps. In addition to managing the basic utilities, such as an enterprise calendar, address book, bulletin board, notes and internal messaging (Al Bar, Mohamed, Akhtar, & Abuhashish, 2011).

Mobile ERP strategy can be used in several cases in the business environment. For instance, a sales representative would be pleased if real-time information could be accessed regarding order-tracking when a question in regard to the delivery status of an order by a very prominent customer. In addition, a sales representative could use a mobile device to verify the current stock quantity of the requested items by a customer or to verify the status of the ordered deliveries for a given warehouse (Dabkowski & Jankowska, 2003).

Several benefits can be reaped from adopting a mobile ERP model, and the next sub-section highlights these benefits.

3.2.2 Benefits of Mobile ERP

Mobile ERP has become a core requirement for enterprises that have ERP systems, due to the benefits that can be reaped from such a model, and these benefits are (Albashrawi & Motiwalla, 2016; Castellina, 2014; Charlton, 2014; Gelogo & Kim, 2014; Pavin & Klein, 2015):

- Increasing enterprise productivity.
- Achieving higher operational efficiencies and effectiveness within the enterprise.
- Reducing some costs of the enterprise.
- Increased surveillance and control.

- Providing real-time visibility and traceability of all business processes and functions.
- Providing a better and an accelerating time-to-decision by top management.
- Deepening customer engagements.
- Streamlining workflow processes.

Consequently, the role of mobility is considered a crucial requirement for enterprises, which are involved in the evaluation and selection process of an ERP system.

3.2.3 Mobile ERP System Architecture

Mobile apps are typically constructed with three-tier or multi-tier architectures, in order to address some limitations of the two-tier architectures by separating presentation, business logic, and data into separated tiers (Kurbel, Dabkowski, & Jankowska, 2003).

(Kurbel et al., 2003) proposed a multi-tier architecture for a mobile ERP system, which is browser-based and designed for the thin client applications. Their system architecture enables ERP system functionality to be accessed via mobile devices. As can be seen from Figure 3.2, this architecture consists of four tiers:

1. The data tier which represents the ERP system's database.
2. The content access engine tier which includes the application logic of the mobilisation task, such as requesting data, returning data, formatting data, and the data retrieved which is transformed into XML format.
3. The content extraction engine, which is responsible for device-context aware content delivery to the end-user by determining the type of the browser and the most important device characteristics. Therefore, it adapts the retrieved content based on the stored presentation logics in it to the device specifications.
4. Finally, the UI tier that consists of different mobile devices with their respective browsers and GUIs.

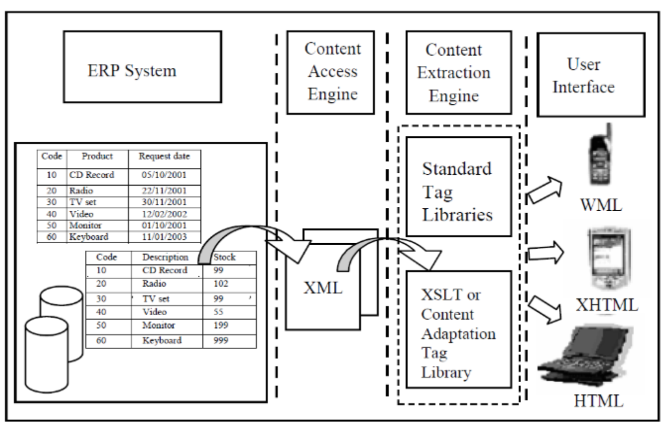


Fig. 3.2: Architecture for mobile ERP (Kurbel et al., 2003, p. 81)

Based on the emergence of Web Services, ERP vendors have started to adopt the SOAs built on Web Services (Jankowska & Kurbel, 2005; Kezmah & Rozman, 2002). This adoption stems from the benefits that can be gained from implementing SOAs, such as achieving business agility, faster time-to-market, and reduced costs and risks (Jankowska & Kurbel, 2005). Figure 3.3 depicts an architecture for a mobile ERP system based on SOA concept that was proposed by (Jankowska & Kurbel, 2005).

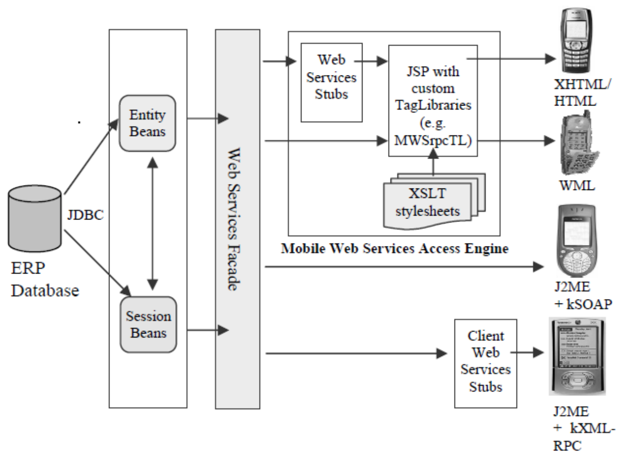


Fig. 3.3: System architecture for mobile ERP system based on SOA concept (Jankowska & Kurbel, 2005, p. 383)

3.2.4 Selection of a Mobile ERP App for Experimental Purposes

One of the sub-objectives of this chapter is to answer the following research question:

> *RQ.2) What is the appropriate mobile ERP app that can be used for experimental purposes in the context of this research study and can connect with the selected ERP system (Odoo ERP system)?*

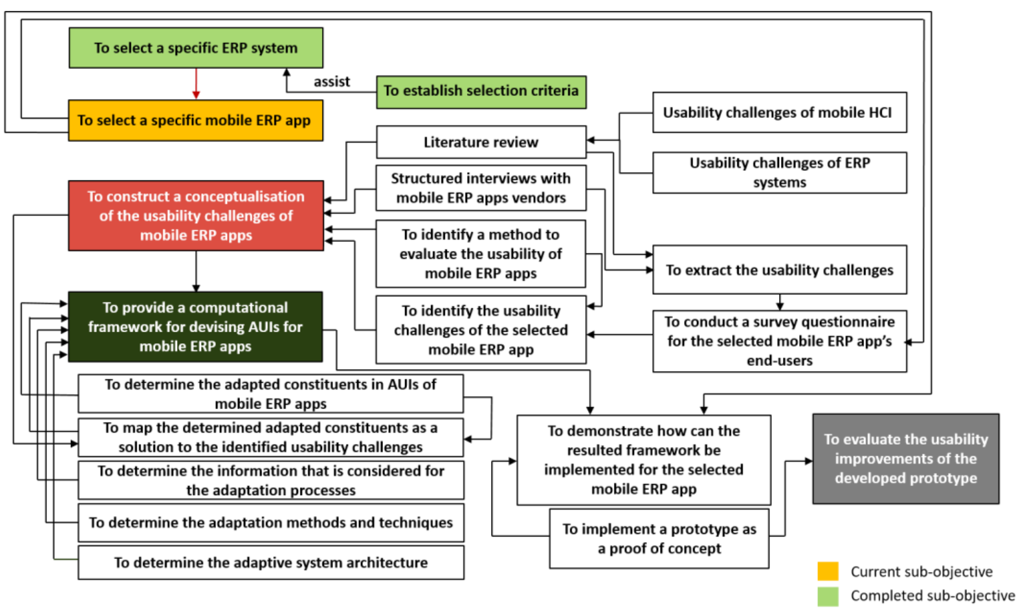


Fig. 3.4: Research objectives status; selection of a mobile ERP app for experimental purposes

Therefore, a market study was conducted to analyse current mobile ERP apps in prominent mobile app stores, such as the Apple store app (iTunes), Google play store, and Microsoft store, and this analysis was based on the search for a mobile ERP app that fulfils the following criteria:

1. Enables access to the core modules of Odoo ERP system.
2. Capability to be operated on different mobile form factors.

3. Compatible with the programming skills of the researcher of this research study.

After analysing the available mobile ERP apps in the aforementioned mobile app stores, mERP app has fulfilled the abovementioned criteria, and thus, it was selected for experimental purposes in this research study. Figure 3.5 depicts several screen-shots of mERP app in different mobile form factors.

The mERP app is a native mobile app that was developed by the Xpansa Group, and it is the first application that gives its end-user a full mobile experience with the Odoo ERP system.

Fig. 3.5: mERP app installed and operated on different form factors

The main objective of this research study is to improve the usability of mobile ERP apps. Therefore, the usability of mobile apps will be discussed in the following section.

3.3 Usability of Mobile Apps

Presently, it is notable that enterprises have a massive orientation to adopt mobile enterprise applications (Stieglitz & Brockmann, 2012). However, this orientation faces some challenges that drive business owners and CIOs to deeply think about obstacles which might hinder this working model. For instance, enterprises confront the challenge to rapidly develop, deploy and maintain mobile apps in order to meet the increasing demands of their customers and employees, and it is extremely difficult and costly to employ mobile apps developers (Moore, 2015). Moreover, the usability of mobile apps is considered one of these challenges that this research study aims to address in regards to ERP systems (Omar, 2015; Omar & Marx Gómez, 2015).

The usability term was first coined in the early 1980s in order to replace the “user friendly” term which was undesirably vague and possessed different subjective connotations (Bevan, Kirakowski, & Maissel, 1992). Usability is considered a crucial indication of software quality (Holzinger, Searle, & Wernbacher, 2011), and one of the critical success factors of software systems (Butler, 1996). In the field of software engineering, usability is associated to UI design, and this means usability has a direct impact on the UI and not on the core of the system (Folmer & Bosch, 2004; Juristo, Moreno, & Sanchez-Segura, 2007a).

Consequently, the following sub-sections discuss the prominent usability models of software applications and their definitions and attributes of usability. Besides, the benefits of usability and its popular measures and evaluation methods will be discussed in the following sub-sections.

3.3.1 Usability Models

In the literature, several usability models can be found that aim to assess the quality of software applications, and these models were proposed either by researchers such as Jakob Nielsen or by standardisations such as the International Organisation for Standardisation (ISO) in its proposed standards, such as 9241, 13407, 9126, 14598. However, in the usability research community, Nielsen's usability model and ISO 9241-11 model are considered the prominent models of usability (Harrison, Flood, & Duce, 2013).

Nielsen defined usability as:

> "*Usability is a quality attribute that assesses how easy user interfaces are to use. The word "usability" also refers to methods for improving ease-of-use during the design process*" (Nielsen, 2003, p. 1).

Nielsen considers usability a sub-category of the system usefulness that in turn has a direct impact on practical acceptability, which leads to the acceptability of the software system (Nielsen, 1993). In addition, Nielsen identified five attributes of usability that are depicted in Figure 3.6 under the usability category, which are:

- **Efficiency** which means that the resources are expended in relation to the accuracy and completeness with which end-users achieve goals.
- **Satisfaction** which means the lack of discomfort, and a positive attitude towards the use of the product.
- **Learnability** which means the system should be easy to learn so that the end-user can immediately start getting work done with the system.
- **Memorability** which means the system should be easy to remember so that the casual - end-user is able to return to the system after some period of not having used it without having to learn everything all over again.
- **Errors** which means the system should have a low error rate, so that end-users make few errors during the use of the system and that if they do make errors, they can easily recover from them. Furthermore, catastrophic errors must not occur.

In addition, Nielsen identified Utility as the ability of a system to do what is needed from its end-users, and this attribute is separated from the usability category in his model because when a product is missing the utility attribute then it does not provide the required features and functions.

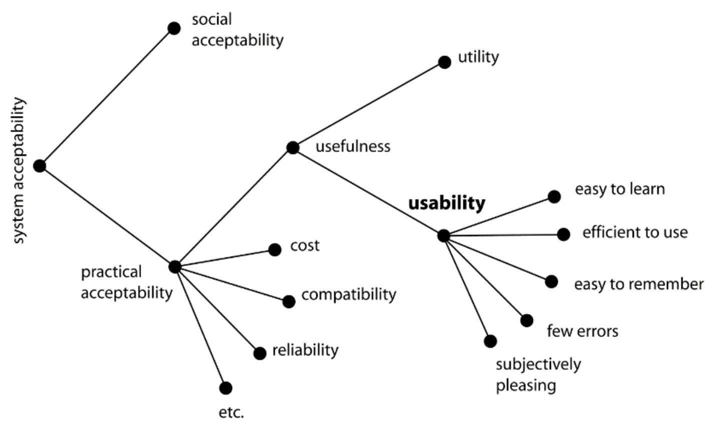


Fig. 3.6: Proposed model of the attributes of system acceptability by (Nielsen, 1993, p. 25)

Likewise, in ISO 9241-11 standard the usability is defined as:

> "*Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*" (ISO, 1998, p. 6).

The abovementioned definition determines three attributes of usability, namely effectiveness, efficiency, and satisfaction, and the following are their definitions that are quoted from (ISO, 1998):

- **Effectiveness**: Accuracy and completeness with which users achieve specified goals.
- **Efficiency**: Resources are expended in relation to the accuracy and completeness with which users achieve goals.
- **Satisfaction**: Freedom from discomfort, and a positive attitude towards the use of the product.

In addition, three factors are determined in ISO 9241-11standard that should be considered in the usability evaluation, namely the user, goal, and context of use.

1. User: person who interacts with the product.
2. Goal: intended outcome.
3. Context of use: users, tasks, equipment (hardware, software, and materials), and the physical and social environments in which a product is used.

It can be noted from the definition of usability in the ISO 9241-11 standard that it doesn't consider the attributes learnability, memorability, and errors that were considered by Nielsen. According to (Harrison et al., 2013), this disregard could be justified by the implicit inclusion of these attributes within the definitions of effectiveness, efficiency, and satisfaction. For instance, error rates can be argued to have a direct impact on efficiency.

However, the abovementioned models were mainly derived from traditional desktop applications. Besides, the emergence of mobile devices has presented new usability challenges that are difficult to be modelled by employing the traditional models of usability, and many of these models do not consider the consequences of mobility, such as additional cognitive load (Harrison et al., 2013). Therefore, (Harrison et al., 2013) proposed the PACMAD (People At the Centre of Mobile Application Development) usability model which aims to address some of the drawbacks of the existing usability models when applied to mobile devices.

The PACMAD model incorporates and extends the attributes of both Nielsen's model and the ISO 9241-11 standard model to the context of mobile apps. For instance, the cognitive load attribute is introduced in this model which is considered an important attribute to mobile apps. Besides, the PACMAD usability model identifies three factors that should be considered when designing mobile apps, namely the user, task, and context of use. Each one of these factors will affect the design of the UIs for the mobile apps (Harrison et al., 2013).

The PACMAD model combines the key attributes from different usability models to create a more comprehensive model. Therefore, seven attributes of usability are identified in this model, namely effectiveness, efficiency, satisfaction, learnability, memorability, errors, and cognitive load. However, these attributes are not new, but the existing prominent usability models neglect one or more of them, and thus, this could lead to an incomplete usability evaluation. Figure 3.7 depicts the PACMAD usability model besides the Nielsen's and the ISO 9241 standard's definition of usability.

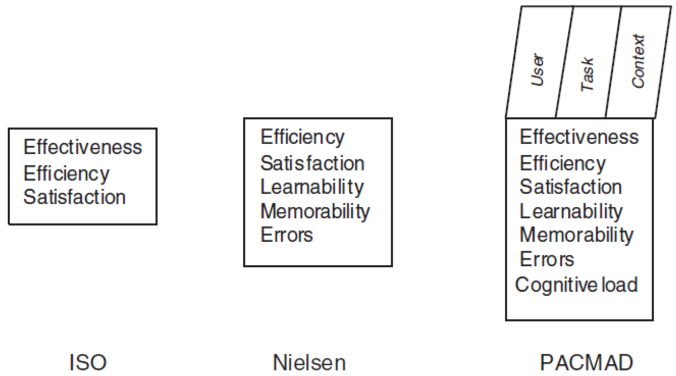


Fig. 3.7: Comparison among the ISO, Nielsen and PACMAD usability models (Harrison et al., 2013, p. 3)

The seven attributes of the PACMAD model are defined as:

1. **Effectiveness**

   Effectiveness is the ability of the user to achieve a task in a specified context, and it is normally measured by evaluating whether participants can complete a set of specified tasks or not.

2. **Efficiency**

   Efficiency is the ability of the user to complete their task in a manner of speed and accuracy (productivity), and this attribute can be measured in several ways, such as the time spent to complete a given task, or the number of keystrokes required to complete a given task.

3. **Satisfaction**

   Satisfaction is the user's perceived level of comfort and pleasantness while using a particular software system, and it is reflected in the attitude of the user towards the software usage. Satisfaction level differs between individual users and it is measured subjectively by questionnaires and other qualitative techniques.

4. **Learnability**

   Learnability is the level of ease with which a user can gain proficiency with an application, and indicates how long it takes a user to become effectively familiar with an application. This attribute was drawn from Nielsen's usability model, and measuring it requires assessing how long a user takes to reach a pre-specified level of proficiency.

5. **Memorability**

   Memorability is the user's ability to maintain use of an application, without needing to relearn how to use it after a period of inactivity or sporadically of usage. This attribute was drawn from Nielsen's usability model, and it can be measured by asking the users to perform a series of tasks after having proficiency with the use of the application, and then asking them to perform the same task after a long period of inactivity. Thereafter, a comparison analysis can be made between the two sets of the obtained results to identify how memorable the application was.

6. **Errors**

   This attribute indicates how well the user can complete the desired tasks without errors. Based on this indication, developers can identify the most troublesome areas for users, and thus, improve these areas in subsequent iterations of development. Therefore, its evaluation should consider the frequency with which errors occur and the registry of the nature of the errors. The error rate of users may indicate the simplicity of a system, while by analysing the nature of errors, the developers can prevent these errors from occurring in future versions of the application. This attribute was drawn from Nielsen's usability model, and it expanded to include an evaluation of the errors that are made by the user while using mobile apps.

7. **Cognitive load**

   Cognitive load refers to the amount of cognitive processing required by the user to use the application. In traditional usability studies, the prevailing assumption is that the users are performing a single task, and thus, they could completely focus their attention and cognitive processing on that task. While in a mobile context, the users are simultaneously performing other tasks during the usage of the application such as driving a car. The cognitive load attribute can be measured through the NASA Task Load Index (TLX), and thus, this attribute will not be measured in this research study, due to the unavailability of NASA TLX in the context of this research study.

3.3.2 Benefits of Usability

Several benefits can be gained from a high usable software system, and in the list below are some of these benefits (Britsios, 2013; Donahue, 2001; Juristo, Moreno, & Sanchez-Segura, 2007b; Lauesen, 2005; Singh, 2011):

- Improves user acceptance.
- Improves user satisfaction.
- Achieve users' objectives efficiently and effectively.
- Improves productivity and raises team morale.
- Reduces training and documentation costs.
- Commits fewer errors.
- Achieves rapid learning of software system.
- Reduces development cost and time.
- Reduces cost of support and time.
- Improves image and reputation of a software system.

3.3.3 Usability Measures and Evaluations

Measuring usability can be achieved by making its abstract attributes more concrete through describing them in terms of the actual product (Dix, Finlay, D. Abowd, & Beale, 2004). Based on this, usability attributes can be classified into two types of criteria. On the one hand, the objective operational criteria that aim to indicate user performance, such as efficiency, effectiveness, learnability, memorability, errors, and cognitive load. On the other hand, the subjective operational criteria that measure users' subjective perceptions of the product, such as satisfaction

(Folmer & Bosch, 2004). Consequently, usability measures are classified into objectives and subjective measures (ISO, 1998). Table 3.2 depicts some of the usability measures that were proposed by ISO 9241-11 standard. Regarding the memorability and cognitive load attributes, Section 3.3.1 highlights how these attributes can be measured.

Usability objective	Effectiveness measures	Efficiency measures	Satisfaction measures
Overall usability	Percentage of goals achieved; Percentage of users successfully completing task; Average accuracy of completed tasks	Time to complete a task; Tasks completed per unit time; Monetary costs of performing the test	Rating scale for satisfaction; Frequency of discretionary use; Frequency of complaints
Learnability	Number of functions learned; Percentage of users who manage to learn criterion	Time to learn criterion; Time to re-learn criterion; Relative efficiency while learning	Rating scale for ease of learning
Error Tolerance	Percentage of errors corrected or reported by the system; Number of user errors tolerated	Time spent correcting errors	Rating scale for error handling

Tab. 3.2: Examples of usability measures adapted from (ISO, 1998)

Usability evaluation can be conducted during both the development and implementation phases of the systems development life cycle (SDLC). In addition, it can be achieved on a chain from formative[20] to summative[21] evaluation, and this chain applies to both the development and implementation phases of SDLC (Crowther, Keller, & Waddoups, 2004).

However, there are two main approaches for usability evaluation that can be found in the literature, namely expert analysis and end-user testing (Crowther et al., 2004). In the expert analysis approach, the usability experts perform analysis to identify problems with the software application based on their past experience with similar products in addition to a predefined set of usability guidelines which are known as heuristics. While in the end-user testing approach, the end-users' representatives are involved in using the application at the stage of development and give their feedback, and thus, the usability experts collect end-users' feedback, analyse them, and report the obtained results to the design team. These approaches include several methods and techniques which can be classified into usability inspection methods, user testing methods, exploratory methods, and analytic methods (Tselios, Avouris, & Komis, 2008). Figure 3.8 depicts this taxonomy.

Regarding the usability inspection methods, these types of methods have a formative characteristic that can be utilised by usability experts, and the popular methods of this group are: heuristic evaluation, cognitive walkthrough, features inspection, inspection of standards, and the use of guideline checklists that are provided to experts with a reference for assessing application UIs (Tselios et al., 2008).

Regarding the user testing methods, the selected participants in these methods are asked to perform typical tasks in a usability evaluation laboratory, afterwards, the evaluators collect the results and analyse them to determine how the UI assisted the end-users and their expectations during the performance of the tasks. Think aloud protocol is a typical technique of this category,

[20] Formative is a type of evaluation that is performed during developing stages of design to verify that the design meets its stated objectives and goals (Bowman, Gabbard, & Hix, 2002)
[21] Summative or comparative evaluation is an assessment and statistical comparison of two or more configurations of UI designs, UI components, and/or interaction techniques (ITs), and it is typically performed after completing the UI designs (or components) (Bowman et al., 2002, p. 418).

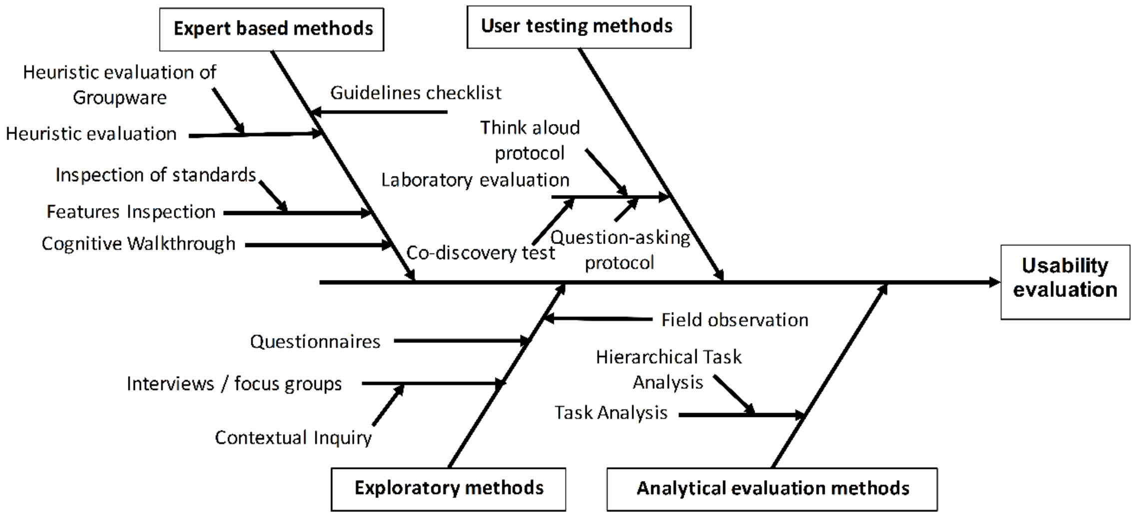


Fig. 3.8: Taxonomy of software usability evaluation methods (Tselios et al., 2008, p. 5)

where in this technique the participants are asked about their thoughts, feelings, and opinions during the interaction with the software application. In addition, the co-discovery test and the question-asking protocol are variants of the think aloud protocol technique, and these variants enable the participants to ask the evaluators questions regarding the software application (Tselios et al., 2008).

Regarding the exploratory methods, these types of methods aim to observe the end-user in real settings and context of use, and this observation attempts to record the way the end-users act, the tools they use, their interactions with each other, and how the context of use affects the way they interact with the system. Questionnaires are used in this category to reveal the misinterpretation and for obtaining their subjective satisfaction. In addition, interviews, contextual inquiry[22] , and focus groups are used to collect end-users' opinions regarding their usage experiences with the software application (Tselios et al., 2008).

Finally, the analytical evaluation methods aim to describe goals and sequences of end-user's activities that are performed during the interaction with the software application which can be represented by task models. The models used in those methods are characterised by predictive models which are achieved by the designer (designer's models) and descriptive models based on the observation of real-time system usage (users' models). Furthermore, the analytical methods could be incorporated with user testing methods to acquire the required data to build the representative user models (Tselios et al., 2008).

One of the main sub-objectives of this research study is to identify the potential usability challenges of mobile ERP apps. Therefore, five research studies were conducted. In these research studies, the discussed usability concepts, measures, and evaluation approaches in this section were utilised, and thus, the following section discusses these research studies in its sub-sections.

3.4 Usability Challenges of Mobile ERP Apps

One of the main sub-objectives of this research study is to construct a conceptualisation of the usability challenges of mobile ERP apps. Therefore, the following research question was identified:

[22] Contextual inquiry is a method of the structured interview that is controlled by certain principles that distinguish it from the classic interview (Tselios et al., 2008, p. 5).

RQ.3) What are the potential usability challenges of mobile ERP apps?

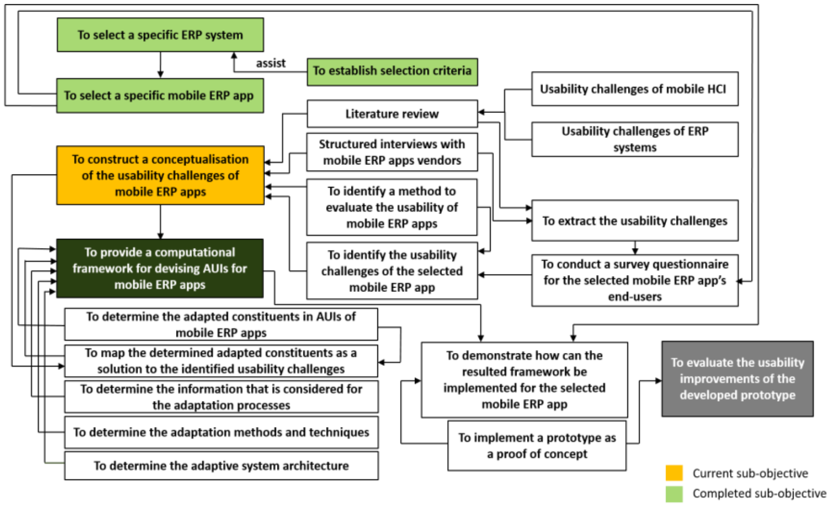


Fig. 3.9: Research objectives status; construction of a conceptualisation of the usability challenges of mobile ERP

This construct is a necessity for mobile ERP developers, due to its role to increase their awareness regarding the potential usability challenges that might hinder the sustainability of their developed apps. The adopted strategy to develop this construct was based on four resources, namely literature review, the perceptions of mobile ERP vendors, the assessment of usability experts, and the perceptions of the end-users of the selected mobile ERP app (mERP app). Therefore, five research studies were conducted in order to construct this conceptualisation, and these research studies will be discussed in the following sub-sections with their results.

3.4.1 Literature Review to Identify the Usability Challenges of Mobile HCI

The first research study aimed to answer the following research question:

RQ.3.1) What are the usability challenges of mobile HCI?

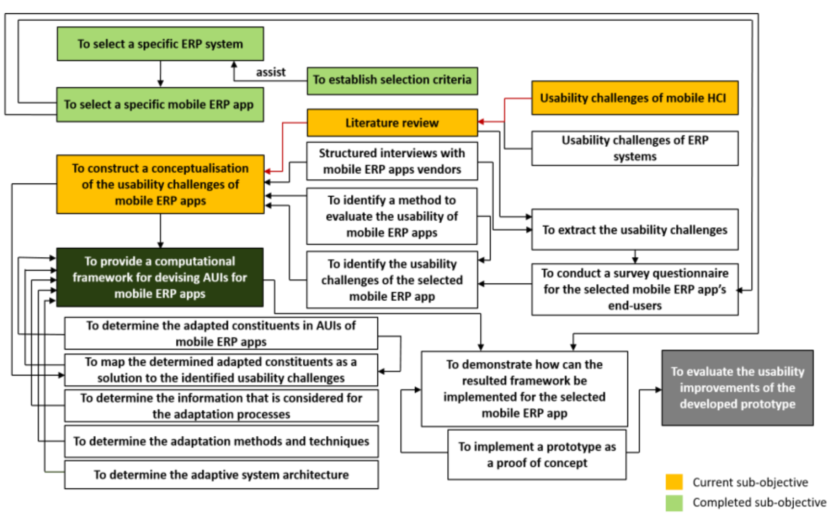


Fig. 3.10: Research objectives status; literature review to identify the usability challenges of mobile HCI

In order to answer the abovementioned research question, a literature review was conducted to identify the usability challenges of mobile HCI.

In the conducted literature review, the methodological framework for conducting a literature review which was proposed by (Schryen, 2015) was followed, and this framework consists of six phases, namely a framing process that impacts all phases, search and assessment, synthesis, interpretation, guidance, and conclusion. In addition, an ontology of literature reviews was defined by him, and this ontology is depicted in Figure 3.11.

Focus	Outcome	Framing	Phase
Topic	Synthesis	Ad hoc	Search and assessment
Domain	Interpretation	Incremental	Synthesis
Discipline	Guidance	Conceptual	Interpretation
			Guidance
			Conclusion

Fig. 3.11: Ontology of literature reviews (Schryen, 2015, p. 289)

Based on Schryen's ontology of literature reviews, the conducted literature review focused on the topic "the usability challenges of mobile HCI", and this topic belongs to the HCI discipline in the mobile computing domain. While the type of outcomes from the conducted literature review belongs to the synthesis type that synthesised the reported usability challenges of mobile HCI in the literature, and thus, this synthesis provides guidance for future research in the mobile computing domain. Regarding the framing, the ad hoc type was followed by performing a simple search on a topic and provides the author-centric presentation of results.

As can be seen from Figure 3.12, a cyclic process of the literature search was performed in several literature pools, such as scholars' literature reviews, literature databases, table of contents (TOCs) of academic journals, textbooks, and TOCs of conference proceedings. In addition, a review of the literature from different literature databases was performed, such as AIS Electronic Library (AISeL), EBSCO host, Web Of Science, ScienceDirect, Scopus, ABI/INFORM, Google Scholar, IEEE Xplore Digital Library, and ACM Digital Library.

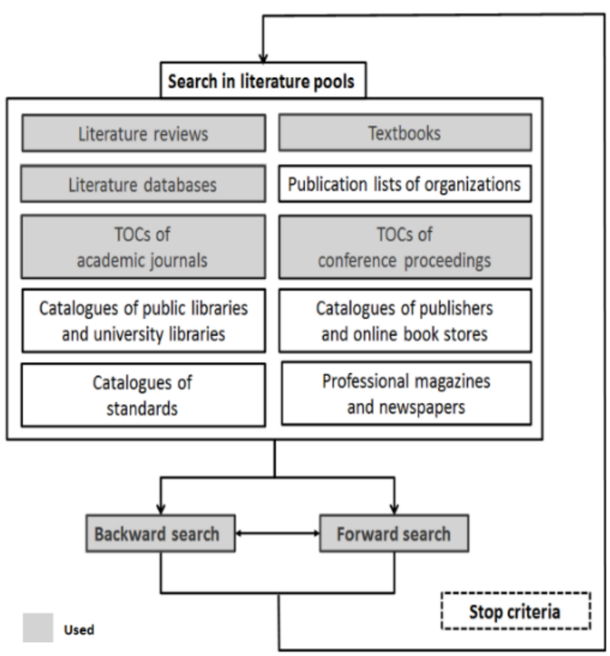


Fig. 3.12: Cyclic literature search process adapted from (Schryen, 2015)

Furthermore, a number of specialised journals and proceedings in HCI and mobile HCI disciplines were reviewed, such as:

- The Mobile HCI conference (MobileHCI).
- The International Journal of Mobile Human Computer Interaction (IJMHCI).
- The ACM Transactions on Computer-Human Interaction (TOCHI).
- The International Journal of Human Computer Studies (IJHCS).
- The Personal and Ubiquitous Computing Journal (PUC).
- The International Journal of Human-Computer Interaction (IJHCI).

In the conducted literature review, the search strings that were used during the search process in the abovementioned resources were “Usability of mobile applications”, “Mobile usability challenges”, “Mobile usability problems”, and “Mobile usability issues”.

The conducted literature review revealed that there are three factors that affect the usability of mobile apps, namely technology, environment, and the heterogeneity of the end-users. Furthermore, thirteen usability challenges were identified that belong to these factors. Table 3.3 highlights the identified usability factors and challenges of mobile HCI from the conducted literature review.

Factor	**Usability Challenge**	**(Satyanarayanan, 1996)**	**(Uther, 2002)**	**(Dunlop & Brewster, 2002)**	**(Lee & Benbasat, 2003)**	**(Adipat & Zhang, 2005)**	**(Looije, Te Brake, & Neerincx, 2007)**	**(Zhang, 2007)**	**(Holzinger & Errath, 2007)**	**(Budiu & Nielsen, 2008)**	**(Svanæs, Alsos, & Dahl, 2010)**	**(Tsiaousis & Giaglis, 2010)**	**(Baharuddin, Singh, & Razali, 2013)**
Technology	Limited screen size	x	x	x	x	x	x	x	x	x	x	x	x
	Different display resolutions			x		x							
	Multitude of form factors										x		
	Limited processing and power capabilities	x			x	x	x	x	x				
	Data entry methods and output		x	x	x	x			x	x	x	x	
	Mobile data connectivity	x	x		x	x	x	x		x			x
	Security and privacy	x					x				x		
Environment	Activity (tasks, motion)			x		x	x	x			x	x	x
	Ambient light					x	x					x	
	Ambient sound		x		x	x	x					x	x
Heterogeneity of the end-users	Physiological characteristics			x		x	x						x
	Knowledge			x		x							x
	Preferences					x	x						
x: It has been mentioned by the author													

Tab. 3.3: Identified usability factors and challenges of mobile HCI

Based on the definitions of the usability attributes, which are defined in the PACMAD usability model, these attributes are negatively impacted by the identified usability challenges in the conducted literature review study, and this impact will be justified as follows:

Regarding the technology factor, the conducted literature review revealed that there are seven usability challenges of mobile HCI which belong to this factor, and they are:

1. **Limited screen size**

   Mobile devices have a limited screen size compared to the desktop computers. Therefore, there is a limitation on the information volume that can be displayed (Budiu, 2015). Accordingly, there is a huge possibility for loss of meaning, and thus, the increase of errors (Zhang & Adipat, 2005).

   (Bickmore & Schilit, 1997) stated that the direct display of most World Wide Web (WWW) pages on small mobile devices can be aesthetically unpleasant, un-navigable, and in the worst case, completely illegible. This issue was affirmed by (Adipat & Zhang, 2005) for mobile apps in general who stated that such an issue requires intensive cognitive effort from the end-users.

   Furthermore, presenting content which is above the fold on a 30-inch monitor demands five full screens on a small 4-inch screen, and thus, the end-users must bear a higher interaction cost in order to access the same amount of information, and depend on their short-term memory to access information that is not presented on the screen (Budiu, 2015). Consequently, the limited screen size of mobile devices negatively impacts all the selected usability attributes of the PACMAD model.

2. **Limited capability of battery power**

   Presently, mobile devices are being used widely to access rich internet applications, such as video streaming, video conferencing, and mobile TV, due to the notable advances in the physical specifications of mobile devices, such as high-resolution screens, faster processors, and graphic cards (Ismail, Ibrahim, & Md Fudzee, Mohd Farhan, 2013). However, these types of applications consume a substantial amount of battery power (Ismail et al., 2013; Thiagarajan, Aggarwal, Nicoara, Boneh, & Singh, 2012). Therefore, the end-user may feel frustrated if the battery is drained while browsing, and would also lose certain in-progress data (Ismail et al., 2013). Consequently, the limited capability of battery power negatively impacts the following usability attributes of the PACMAD model: satisfaction, efficiency, and effectiveness.

3. **Data entry methods**

   Today, most of the mobile devices utilise touch-based interactions (virtual keyboard) as the main input modal. Recently, (Kim, Aulck, Bartha, Harper, & Johnson, 2014) found that this type of input modal had lower finger flexor/extensor muscle activity, and thus, decreases the typing productivity and self-reported comfort in the upper extremities. Besides, they found that typing accuracy was significantly lower on virtual keyboards compared to notebook and desktop keyboards. Consequently, virtual keyboards negatively impact the following usability attributes of the PACMAD model: errors, satisfaction, efficiency, and effectiveness.

4. **Mobile data connectivity**

   This challenge impacts data downloading time and quality of streaming media, due to the differences in the strength of data connectivity signals at different times and locations. Besides, the unreliability of wireless network connectivity unlike the stable connection for desktop computers (Zhang & Adipat, 2005). Thus, the end-user may feel frustrated in case of slow or loss of internet connection, and would also lose certain in-progress data. Consequently, slow and unreliable mobile data connectivity negatively impact the following usability attributes of the PACMAD model: errors, satisfaction, efficiency, and effectiveness.

5. **Security**

   Some of the security solutions and techniques might hinder the usability of mobile apps, such as the request of permission dialogs to different local services and data repositories in the app installation process. Typically, the accept action is performed without reading the terms and conditions in these types of dialogs, due to their length, which makes the end-users feel frustrated. In addition, the mobile device's screen is visible to surrounding people, and thus, personal information is leaked. Consequently, some security solutions negatively impact the following usability attributes of the PACMAD model: satisfaction and efficiency.

Presently, the challenges of limited processing capabilities and different display resolutions no longer exist, due to the remarkable advances in mobile device technology. Therefore, these challenges were excluded from this research study, but should be mentioned on account of being mentioned in the earlier literature. Regarding the challenge of a multitude of form factors, the focus of this research study is on smart phones, mobile full-screen phones, and tablet computers, which are typically used to operate mobile ERP apps. Therefore, the proposed solution for improving the usability of mobile ERP apps will be limited to these types of mobile devices.

Regarding the environmental factor, the conducted literature review revealed that there are three usability challenges of mobile HCI, which belong to this factor, they are:

1. **Activity (tasks, motion)**

   In a mobile context of use, the end-user normally performs multiple tasks during the usage of mobile apps (Adipat & Zhang, 2005). For instance, finding the desired component of UI for interaction by the end-user while driving. Therefore, reducing the cognitive load of mobile users is crucial in order to reduce error rates, and perform the desired tasks efficiently and effectively with a pleasant level of comfort.

2. **Ambient luminance, and ambient sound**

   Mobile end-users are more vulnerable to be distracted by environmental factors, such as ambient light and noise. Therefore, the UIs of mobile apps should support the end-users to access the desired information without or almost without the need of high visual attention and memory on the interfaces themselves, such as memorising the positions of buttons (Adipat & Zhang, 2005).

Consequently, both of the abovementioned challenges negatively impact the following usability attributes of the PACMAD model: errors, satisfaction, efficiency, and effectiveness.

Regarding the heterogeneity of the end-users factor, the conducted literature review revealed that there are three usability challenges of mobile HCI which belong to this factor, they are:

1. **Physiological characteristics**

   Mobile end-users vary in their physiological characteristics, such as thumb circumferences, visual acuity, and hand type, which in turn impact the usability of mobile apps. For instance, some end-users have large thumb circumferences and combined with the existence of the limited screen size constraint; there would be a greater error rate in completing the desired task. Besides the unpleasant feeling that originates from the collision between the physiological characteristics of the end-user and the presentation style of the UI's components. Thus, the physiological characteristics of the end-users play a significant role in the efficiency of task completion and completing it effectively. Consequently, the physiological characteristics of some end-users negatively impact the following usability attributes of the PACMAD model: errors, satisfaction, efficiency, and effectiveness.

2. **Knowledge**

   Knowledge of end-users varies on how to use the application effectively and efficiently. For instance, novice end-users would need step by step demonstration of how to use an application. In turn, professional end-users would prefer to employ shortcuts to complete their tasks efficiently (Adipat & Zhang, 2005). In complex mobile apps such as mobile ERP apps, the UIs for these types of apps are bloated with components, and thus, such UIs require advance knowledge to interact with them. Therefore, presenting such UIs to novice end-users might increase the possibility of mistakes. Besides, the difficulties that might be encountered in memorising these bloated UIs and their components, and learning them for the future use. Consequently, the variety of end-users' knowledge impact all of the selected attributes of the PACMAD model.

3. **Preferences**

   Mobile end-users have different preferences on how information should be presented on mobile devices, and displaying the information that matches their interests in a preferred format (Adipat & Zhang, 2005). Therefore, presenting undesired information impacts the efficiency of task completion, which in turn increases the time in finding the desired information. Besides, the uncomfortable feeling that originates from the collision between the end-user's preferences and what is displayed. Consequently, end-users' preferences impact the following usability attributes of the PACMAD model: efficiency and satisfaction.

Factor	**Usability Challenge**	**Errors**	**Memorability**	**Learnability**	**Satisfaction**	**Efficiency**	**Effectiveness**
Technology	Limited screen size	x	x	x	x	x	x
	Limited capability of battery power				x	x	x
	Data entry methods (Virtual Keyboards)	x			x	x	x
	Mobile data connectivity	x			x	x	x
	Security				x	x	
Environment	Activity (motion)	x			x	x	x
	Ambient luminance	x			x	x	x
	Ambient noise	x			x	x	x
Heterogeneity of the end-users	Physiological characteristics	x			x	x	x
	Knowledge	x	x	x	x	x	x
	Preferences				x	x	
x: the identified usability challenge negatively impacts the usability attribute							

Tab. 3.4: Impact of the identified usability challenges of mobile HCI on the selected attributes of the PACMAD usability model

3.4.2 Literature Review to Identify the Usability Challenges of ERP Systems

Moving to the second research study that aimed to answer the following research question:

RQ.3.2) What are the usability challenges of ERP systems?

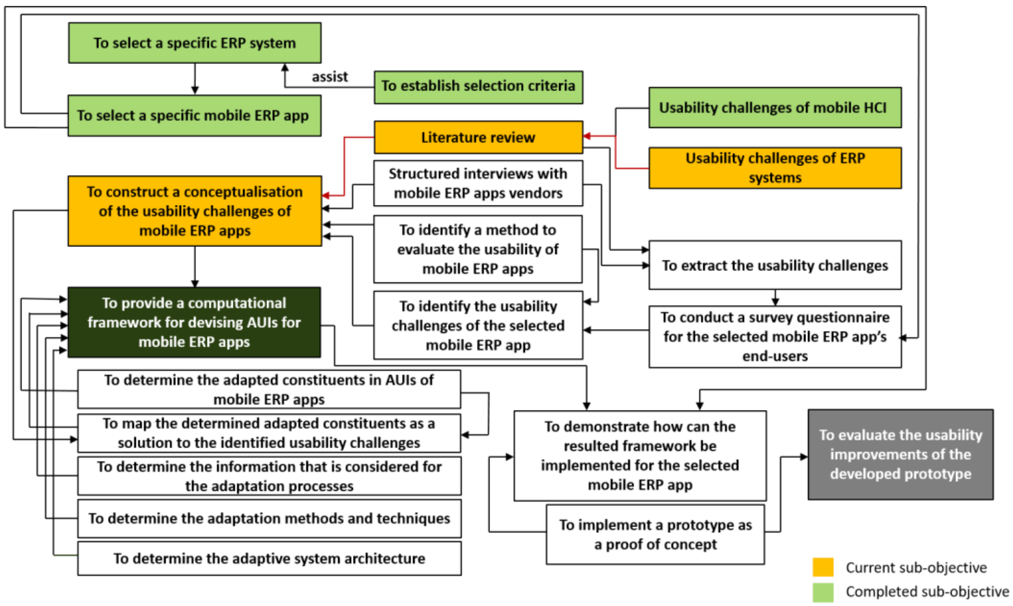


Fig. 3.13: Research objectives status; literature review to identify the usability challenges of ERP systems

The answer to the abovementioned research question was based on conducting a literature review in the domain of the usability of ERP systems. Thus, the proposed framework for conducting a literature review and the ontology of literature reviews by (Schryen, 2015) were employed in this research study. Therefore, the conducted literature review focused on the topic "the usability challenges of ERP systems", and this topic belongs to the HCI discipline. While the type of outcomes from the conducted literature review belongs to the synthesis type that synthesised the reported usability challenges of ERP systems in the literature, and thus, this synthesis provides guidance for future research in the ERP systems domain. Regarding the framing, the ad hoc type was followed by performing a simple search on a topic and provides the author-centric presentation of results. In addition, the used search strings during the searches were "Usability of ERP systems", "ERP systems usability challenges", "ERP systems usability Problems", and "ERP systems usability issues". Consequently, the conducted literature review revealed that there are five prominent studies that focused on UI aspects in ERP usability. Table 3.5 highlights these studies and the usability challenges that were identified in each of these studies.

Author(s)	**System**	**Usability challenges**
(Lambeck, Muller, Fohrholz, & Leyh, 2014)	Various systems and branches	• Higher level of complexity in comparison to the supplementary applications such as spreadsheet applications. • Higher amount and detailed information in comparison to the supplementary applications such as spreadsheet applications. • Difficulty in locating the required functionality in the ERP system which issues the uncertainty of the system usage and loss. • The existence of identified usability challenges of ERP systems in prior researches was confirmed, but these challenges are not considered critical as described in those researches.
(Parks, 2012)	PeopleSoft	• UIs are complex due to their bloated UIs with components which required many interaction steps, and this lead to more time required to complete the tasks.
(Singh & Wesson, 2011)	SAP business one	• Too many steps required to complete a task. • SBO does not enable efficient completion of tasks. • SBO does not improve user productivity. • SBO does not automate routine tasks. • Finding information and functionality is difficult. • SBO cannot guide the user through the correct sequence of tasks. • Evidence of the next sequence of steps to complete a task is not provided. • There are too many unused fields on the screen. • Layout of the UI does not contribute to the efficient completion of tasks. • Steps need to be manually recorded the first time in order to be remembered for future use. • Personalisation of UIs is not possible.
(Scholtz et al., 2010)	SAP R/3	Navigation and presentation have been considered the most common problem areas with the UI in this research work. • Navigation: - Finding functions in the menus. - Struggling to search for customer details. - Confusion between lookup and search buttons. • Presentation: - Complexity and abundance of tabs. - Information overload.
(Topi et al., 2005)	Confidential	• Identification of and access to the correct functionality. • Transaction execution support. • System output limitations. • Support in error situations. • Terminology problems. • Overall system complexity.

Tab. 3.5: Prominent studies that focused on UI aspects in ERP usability

The identified usability challenges of ERP systems in Table 3.5 were analysed thematically by using thematic analysis, and thus, these challenges can be categorised as follow:

- Bloated UIs.
- A multitude of interaction steps.
- Memorability unsupportiveness.
- Findability of the desired information and functionalities.
- Task completion unsupportiveness.

- Automation of routine tasks.
- Guidance.
- Personalisation.
- Contextual help.

Based on the definitions of the selected attributes of the PACMAD usability model (see section 3.3.1), these attributes can be used to measure the usability of different types of software applications, and based on the discussed literature review study in this section, the dereliction of addressing the aforementioned categories negatively impacts the selected attributes of the PACMAD usability model. Table 3.6 maps the identified categories of the usability challenges of ERP systems with the selected attributes from the PACMAD usability model.

Usability Challenge	**Errors**	**Memorability**	**Learnability**	**Satisfaction**	**Efficiency**	**Effectiveness**
Bloated UIs	x	x		x	x	x
Multitude of interaction steps	x	x	x	x	x	x
Memorability unsupportiveness	x	x		x	x	x
Findability of the desired information and functionalities	x			x	x	x
Task completion unsupportiveness	x			x	x	x
Automation of routine tasks				x	x	x
Guidance	x		x	x	x	x
Personalisation		x		x	x	x
Contextual help	x		x	x	x	x
x: negatively impact						

Tab. 3.6: Identified categories of the usability challenges of ERP systems mapped with the selected attributes of the PACMAD usability model

This sub-section discussed the conducted literature review study that identified the usability challenges of ERP systems from the five prominent studies in the usability of ERP systems domain. These identified challenges will be investigated whether they have been inherited to mobile ERP apps or not in the remaining three conducted research studies that will be discussed in upcoming sub-sections.

The conducted third research study aimed to provide a better understanding of the proliferation of mobile ERP apps in business and to search for any potential usability challenges of mobile ERP apps. Therefore, this research study will be discussed in the next sub-section that highlights the remarkably obtained results from this research study.

3.4.3 Structured Interviews with Mobile ERP Vendors

As stated earlier in this dissertation, mobile ERP is still a young topic in both academic and industry where few academic papers and research could be found regarding the mobile ERP topic (Căilean & Sharifi, 2013; Pavin & Klein, 2015). Therefore, there is an essential need to provide further understanding of the status of mobile ERP apps, their usability, and their proliferation in businesses. Therefore, this research study aimed to examine the following issues:

- The degree of adoption of the mobile ERP model in different business sectors and enterprise sizes.
- The reasons behind the adoption of the mobile ERP model, and arrange them based on their importance from the enterprises' perspective.
- The ERP modules that are frequently being accessed via mobile devices.
- The level of difficulty, acceptability, and learnability for each typical ERP module that is being accessed via mobile devices.
- The predominant mobile OSes and devices that are used to operate mobile ERP apps.
- Usability challenges of mobile ERP apps.

Consequently, a survey study was conducted in the form of structured interviews with different mobile ERP vendors to examine the abovementioned issues, and to find any related aspects that would support the understanding of the mobile ERP model.

The results of this survey study have been presented at the 2017 8th International Conference on Information and Communication Systems (ICICS) and published in its proceedings (Omar & Marx Gómez, 2017b).

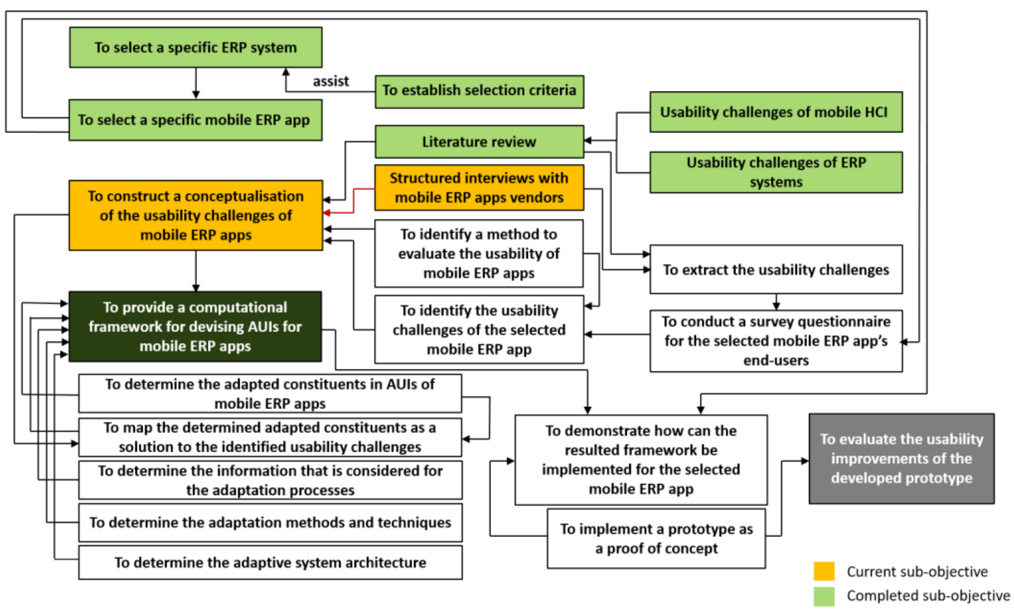


Fig. 3.14: Research objectives status; structured interviews with mobile ERP vendors

3.4.3.1 Methodology

Twenty-two structured interviews were conducted with mobile ERP's salespersons, customer service representatives, and developers from numerous enterprises. Most of these interviews were carried out at CeBIT 2016, the world's premier trade fair and conference for the IT industry at Hannover in Germany, whereas the other interviews were carried out via the internet. These structured interviews consisted of a pre-set of fixed questions which were compiled in a questionnaire that contains six sections to collect data from the interviewees, and the goals of these sections will be discussed in the next sub-section.

3.4.3.2 Instruments

A questionnaire of ten questions (Appendix C) was developed to collect data from the interviewees, and these questions consisted of a pre-set of nine Likert-type scale questions (closed questions), while the tenth question is an open-ended question. The Likert-type scale questions aimed to measure the respondents' opinions and their attitudes towards the aforementioned issues that this study aimed to address. While the tenth question aimed at capturing any information regarding the proliferation, usability challenges, and status of mobile ERP apps in business.

The ten questions were classified into the following six sections:

- Section I: Demographic Data about the Respondents.
- Section II: Adopting Mobile ERP in Business Sectors and Enterprise Sizes (Questions 1 and 2).
- Section III: Motivations and Reasons behind Adopting a Mobile ERP (Question 3).
- Section IV: Mobile ERP Modules (Questions 4 to 7).
- Section V: Mobile OSes and Devices (Questions 8 and 9).
- Section VI: General (Question 10).

Each one of the abovementioned sections aims to explore a particular area of the mobile ERP status in businesses. Thereby, the objectives of these sections are summarised as below:

- Section I aims at gathering the demographic data about the respondents.
- Section II aims at identifying the business sectors and enterprise sizes that frequently desire to adopt the mobile ERP model for their business.
- Section III aims at identifying the most important motivations and reasons behind the adoption of mobile ERP in business.
- Section IV aims at assessing each one of the conventional ERP modules when it is accessed via mobile devices by determining the level of:
    - Enterprises' interest to access it via mobile devices.
    - Difficulty of use when it is accessed via mobile device.
    - Acceptability of use when it is accessed via mobile device.
    - Learnability when it is accessed via mobile device.
- Section V aims at determining the most frequently used mobile OSes and device types that are used to operate and install mobile ERP apps.

- Section VI aims at identifying any further information that may assist in achieving further understanding of the proliferation, usability challenges, and status of mobile ERP apps in business.

3.4.3.3 Procedure

For each interview, a consent form (Appendix A) and information sheet (Appendix B) were handed out and explained to each interviewee before starting the interview. Afterwards, the interviewee was given the developed questionnaire sheet to start answering it based on the questions asked and the provided explanation by the interviewer. Finally, the interviewee was asked to return the completed questionnaire sheet. In addition, a few of the conducted interviews were carried out via the internet.

3.4.3.4 Data Analysis

This sub-section presents the significant findings from the statistical analysis of the collected data for each identified section of the questionnaire, and the complete results are provided in Appendix D.

Section I: Demographic Data

In this section, the interviewees were asked to state their demographic data. Some of this data is considered confidential, such as interviewee’s name, company name, and email. While other data is not considered confidential, such as interviewee’s age, gender, country, and work position. The collected data were analysed, and the following results were obtained:

- 77.3% of the interviewees were male, and 22.7% were female.
- The majority of the interviewees (45.5%) were from age group 3 aged between 31 and 40 years, 22.7% were from age group 2 aged between 21 and 30 years, 22.7% were from age group 4 aged between 41 and 50 years, and 9.1% from age group 5 aged between 51 and 60 years. In contrast, there are no interviewees from age group 1 aged between 20 years or less, and similarly age group 6 aged between 61 and more.
- Regarding the countries of the interviewees, the majority of them (72.7%) were from Germany, 9.1% from Belarus, 9.1% from India, 4.5% from the Kingdom of Saudi Arabia (KSA), and the same percent from Serbia.
- The majority of the interviewees (45.5%) hold a sales job position. However, it was noted that some of the participants have other job positions, but they perform sales persons’ roles.

Section II: Adopting Mobile ERP in Business Sectors and Enterprise Sizes

Section two consists of two questions that aim to identify the business sectors and enterprise sizes that frequently desire to adopt the mobile ERP model for conducting their business. In question number one, the interviewees were asked to determine the degree of adopting a mobile ERP for each of the given business sectors that belong to a specific business category. These sectors are served by the majority of ERP systems in the software market. While question number 2 aims to determine the degree of interest in adopting a mobile ERP for each of the given enterprise sizes.

Q1- ***For each sector of the below business categories, please determine the degree of mobile ERP adoption for this sector?***

The Likert scale for this question is described as follows:

Not at all = 1; Slightly = 2; Somewhat = 3; Moderately = 4; and Extremely = 5.

Starting with the financial and public services category, the analysis of the interviewees' responses for this category revealed that the business sector has remarkably adopted the mobile ERP among the other sectors with a mean of (3.7727), a median of (4.0), a mode of (5.0), and a standard deviation of (1.26986). In turn, the defence and security sector has scored the lowest degree of the mobile ERP adoption with a mean of (2.2273), a median of (2.5), a mode of (3.0) and a standard deviation of (0.86914). Furthermore, the depicted bar charts in Appendix D for this category support these conclusions by demonstrating the distribution of responses (in percentages) for each sector that belongs to the financial and public services category.

Regarding the government category, the analysis of the interviewees' responses for this category revealed that that there is a slight adoption degree of mobile ERP in this category, where this conclusion is based on a mean of (2.2273), a median of (2.0), a mode of (1.0), and a standard deviation of (1.10978). Furthermore, the depicted bar chart in Appendix D for this category supports this conclusion by demonstrating the distribution of responses (in percentages) for this category.

Regarding the manufacturing category, the analysis of the interviewees' responses for this category revealed that the high technology sector has remarkably adopted mobile ERP among the other manufacturing sectors with a mean of (4.136364), a median of (4.0), a mode of (4.0), and a standard deviation of (0.774317). In turn, the oil, gas and water sector has scored the lowest degree of mobile ERP adoption with a mean of (2.636364), a median of (3.0), a mode of (3.0), and a standard deviation of (1.135801). Furthermore, the depicted bar charts in Appendix D for this category support these conclusions by demonstrating the distribution of responses (in percentages) for each sector that belongs to this category.

Regarding the non-profit organisations category, the analysis of the interviewees' responses for this category revealed that there is a slight adoption degree of mobile ERP in this category. This conclusion is based on a mean of (2.4545), a median of (2.50), a mode of (1.0), and a standard deviation of (1.14340). Furthermore, the depicted bar chart in Appendix D for this category supports this conclusion by demonstrating the distribution of responses (in percentages) for this category.

Regarding the services category, the analysis of the interviewees' responses for this category revealed that the trade sector (retail, wholesale distribution) has remarkably adopted mobile ERP among the other services sectors with a mean of (4.0909), a median of (4.0), a mode of (5.0), and a standard deviation of (1.10880). In turn, the community sector has scored the lowest degree of mobile ERP adoption with a mean of (2.5909), a median of (2.0), a mode of (2.0), and a standard deviation of (1.25960). Furthermore, the depicted bar charts in Appendix D for this category support these conclusions by demonstrating the distribution of responses (in percentages) for each sector that belongs to this category.

For each business category, the mean was calculated for the means of its business sectors, and by comparing these means, the services category has the highest degree in adopting mobile ERP with a mean of (3.24), followed by the manufacturing category with a mean of (3.19), then the financial and public service category which has a mean of (2.90), followed by the non-profit organisations category with a mean of (2.45), while the government category has the lowest degree of mobile ERP adoption with a mean of (2.23). Table 3.7 demonstrates the calculated mean for each business category that was assessed in question number one.

Category	Mean
Services	3.24
Manufacturing	3.19
Financial and public service	2.90
Non-profit organisations	2.45
Government	2.23

Tab. 3.7: Results of the central tendency (mean) for each business category that was assessed in question number one (n=22)

Q2- ***For each of the following enterprise sizes, please determine the degree of interest in the adoption of mobile ERP?***

The Likert scale for this question is described as follows:

Not at all = 1; Slightly= 2; Somewhat= 3; Moderately =4; and Extremely= 5.

The analysis of the interviewees' responses for this question revealed that small size enterprises (10-49 employees) have remarkably adopted mobile ERP with a mean of (4.1818), a median of (4.0), a mode of (4.0), and a standard deviation of (0.79501). In turn, large size enterprises (250 employees or more) have the lowest degree of mobile ERP adoption with a mean of (3.3636), a median of (3.0), a mode of (3.0), and a standard deviation of (1.00216). Furthermore, the depicted bar charts in appendix D for the distribution of responses (in percentages) for each of the given enterprise size support these conclusions.

Section III: Motivations and Reasons behind Adopting Mobile ERP

Section III consists of one question that aims to determine the level of agreement between the participants with the given list of reasons that motivate enterprises to start adopting mobile ERP.

Q3- ***The following are the reasons that motivate enterprises to start adopting mobile ERP. Can you determine the level of your agreement with each reason?***

Some of the given reasons motivate enterprises to adopt mobile ERP (Albashrawi & Motiwalla, 2016; Castellina, 2014; Charlton, 2014; Gelogo & Kim, 2014; Pavin & Klein, 2015). While the others motivate enterprises to adopt a mobile enterprise (Stieglitz & Brockmann, 2012). The reason behind the inclusion of the motivational reasons of adopting mobile enterprise in the given list is that mobile ERP apps are considered instances of mobile enterprise apps.

The Likert scale for this question is described as follows:

Strongly disagree = 1; Disagree= 2; Neutral= 3; Agree =4; and Strongly agree= 5.

The analysis of the interviewee's responses for this question revealed that "expanded real-time visibility into all business activities" is the most effective reason that motivates enterprises to start adopting mobile ERP with a mean of (4.5909), a median of (5.0), a mode of (5.0), and a standard deviation of (0.59033). Whereas "cost reduction" is the least effective reason with a mean of (3.6364), a median of (4.0), a mode of (4.0), and a standard deviation of (0.72673). Furthermore, the depicted bar charts in Appendix D support these conclusions by demonstrating the distribution of responses (in percentages) for each of the given enterprise size.

Section IV: Mobile ERP Modules

Section four consists of four questions that aim to determine the level of concern, difficulty, acceptability, and learnability for each of the given ERP modules when it is accessed via mobile devices.

Q4- ***For each of the following ERP's modules, please determine the level of concern of enterprises to access it via mobile device?***

In this question, the interviewees were asked to determine the level of concern of enterprises to access each of the given ERP modules via mobile devices.

The Likert scale for this question is described as follows:

Not at all = 1; Slightly= 2; Somewhat= 3; Moderately =4; and Extremely= 5.

The analysis of the interviewees' responses for this question revealed that the level of concern to access the CRM module is the highest among the other ERP modules, and this conclusion is based on a mean of (4.7727), a median of (5.0), a mode of (5.0), and a standard deviation of (0.42893). In turn, the banking module received the lowest level of concern based on a mean of (2.8636), a median of (3.0), a mode of (3.0), and a standard deviation of (1.16682). Furthermore, the depicted bar charts in Appendix D for the distribution of responses (in percentages) for each module support these conclusions.

Q5- ***For each of the following ERP's modules, please determine the level of difficulty of use when it has been accessed via mobile devices based on your customers' feedback?***

In this question, the interviewees were asked to determine the level of difficulty of use from their clients' perspective for each of the given ERP modules when it is accessed via mobile devices.

The Likert scale for this question is described as follows:

Very easy = 1; Easy= 2; Neutral= 3; Difficult =4; and Very difficult= 5.

The analysis of the interviewees' responses for this question revealed that the financial and accounting module is the most difficult module when it is accessed via mobile devices, and this conclusion is based on a mean of (3.2727), a median of (3.0), a mode of (4.0), and a standard, deviation of (0.88273). In turn, the CRM module is the easiest module based on a mean of (2.1364), a median of (2.0), a mode of (1.0), and a standard deviation of (0.99021). Furthermore, the depicted bar charts in Appendix D for the distribution of responses (in percentages) for each module support these conclusions.

Q6- ***For each of the following ERP's modules, please determine the level of acceptability of your clients when it has been accessed via mobile devices?***

In this question, the interviewees were asked to determine the level of acceptability from their clients' perspective for each of the given ERP modules when it is accessed via mobile devices.

The Likert scale for this question is described as follows:

Totally unacceptable = 1; Unacceptable= 2; Neutral= 3; Acceptable =4; and Perfectly acceptable= 5.

The analysis of the interviewees' responses for this question revealed that the services module has the highest level of acceptability in usage via mobile devices among other ERP modules, and this conclusion is based on a mean of (3.8636), a median of (4.0), a mode of (3.0), and a standard deviation of (0.94089). In turn, the inventory module has the least level of acceptability in usage via mobile devices among the other ERP modules based on a mean of (3.1818), a median of (3.0), a mode of (4.0), and a standard deviation of (0.90692). Furthermore, the depicted bar charts in Appendix D for the distribution of responses (in percentages) for each module support these conclusions.

Q7- ***For each of the following ERP's modules, please determine the required amount of time to learn how to use it when it has been accessed via mobile devices*?**

In this question, the interviewees were asked to determine the required amount of time by their clients to learn how to use each of the given ERP modules when it is accessed via mobile devices.

The Likert scale for this question is described as follow:

Too short = 1; Short= 2; Neutral= 3; Long =4; and Too long= 5.

The analysis of the interviewees' responses for this question revealed that the amount of time that is required to learn how to use the purchase module via mobile devices is the longest among the other given ERP modules, and this conclusion is based on a mean of (3.3182), a median of (3.0), a mode of (2.0), and a standard, deviation of (1.21052). In turn, the marketing module scored the shortest amount of time to learn based on a mean of (2.3182), a median of (2.0), a mode of (3.0), and a standard deviation of (0.94548). Furthermore, the depicted bar charts in Appendix D for the distribution of responses (in percentages) for each module support these conclusions.

Section V: Mobile OSes and Devices

Section five consists of two questions that aim to determine the most frequently used mobile OSes that are used in operating mobile ERP apps, and to determine the most frequently used types of mobile devices that are used in installing mobile ERP apps on them.

Q8- ***For the following mobile OSes, determine the frequency of use in operating mobile ERP apps?***

In this question, the interviewees were asked to determine the frequency of use for each of the given mobile OSes to operate mobile ERP apps.

The Likert scale for this question is described as follows:

Never = 1; Rarely= 2; Occasionally= 3; A moderate amount =4; and A great deal= 5.

The analysis of the interviewees' responses for this question revealed that Android OS has the highest frequency of use in operating mobile ERP apps among the others mobile OSes, and this conclusion is based on a mean of (4.5455), a median of (5.0), a mode of (5.0), and a standard deviation of (0.91168). In turn, the Symbian OS has the lowest frequency of use based on a mean of (1.9545), a median of (2.0), a mode of (1.0), and a standard deviation of (1.09010). Furthermore, the depicted bar charts in Appendix D for the distribution of responses (in percentages) for each module support these conclusions.

Q9- ***For each of the following types of the mobile devices, determine the frequency of use in installing the mobile ERP apps on it?***

In this question, the interviewees were asked to determine the frequency of use for each of the given types of mobile devices in installing mobile ERP apps.

The Likert scale for this question is described as follows:

Never = 1; Rarely= 2; Occasionally = 3; A moderate amount =4; and A great deal = 5.

The analysis of the interviewees' responses for this question revealed that tablet computers have the highest frequency of use among the other types of mobile devices in installing mobile ERP apps on them, and this conclusion is based on a mean of (4.5909), a median of (5.0), a mode of (5.0), and a standard deviation of (0.59033). In turn, the wearable devices have the lowest frequency of use based on a mean of (2.8182), a median of (3.0), a mode of (4.0), and a standard deviation of (1.33225). Furthermore, the depicted bar charts in Appendix D for the distribution of responses (in percentages) for each of the given types of mobile devices support these conclusions.

Section VI: General

Section six consists of one open question that aims to determine any further information that may assist in achieving a further understanding of the proliferation, usability challenges, and status of mobile ERP apps in business.

Q10- ***Please, indicate any further comments that could assist in achieving a further understanding in terms of the proliferation, usability challenges, and status of mobile ERP apps in business?***

Qualitative data was obtained from the interviewees' answers and analysed thematically by using thematic analysis. The performed analysis aimed to pinpoint any patterns or themes within the collected data regarding the usability challenges of mobile ERP apps. Table 3.8 depicts the identified usability challenges which negatively impact the selected attributes of the PACMAD usability model based on the thematic analysis for interviewees' answers for this question.

Usability challenge	Errors	Memorability	Learnability	Satisfaction	Efficiency	Effectiveness
Large number of activities and interactions compared with the conventional approach (using ERP via PC and laptops)	x	x	x	x	x	x
Difficulty in remembering the designated steps of the conducted task	x	x		x	x	x
More time required compared with the conventional approach to complete a task				x	x	
End-users are more exposed to distractions in comparison to the usage of the conventional approaches (Distractions)	x			x	x	x
Difficulty in finding the desired information and functions	x			x	x	x
Stubborn to the context of use variability (needs to be adaptive)	x			x	x	x
Lack of intuitive learning	x		x	x		x
Lack of an appropriate helping technique that suits the context of use	x		x	x	x	x
Lack of a guidance techniques that suit the context of use	x		x	x	x	x
Lack of the correction and validation techniques that suit the context of use	x			x	x	x
x: negatively impact						

Tab. 3.8: Negative impact of the identified usability challenges from the structured interviews on the selected attributes of the PACMAD usability model

Some of the identified usability challenges of mobile ERP in Table 3.8 were revealed previously in the conducted literature review study in sub-section 3.4.2, and this affirms that mobile ERP apps are plagued from some of the identified usability challenges of ERP systems. Table 3.9 depicts the inherited usability challenges from ERP systems into mobile ERP apps.

Usability challenge of mobile ERP apps from Table 3.8	Usability challenge of ERP systems
Large number of activities and interactions compared with the conventional approach (using ERP via PC and laptops)	Bloated UIs and a multitude of interaction steps
Difficulty in remembering the designated steps of the conducted task	Memorability unsupportiveness
Difficulty in finding the desired information and functions	Findability of the desired information and functionalities
Lack of an appropriate helping technique that suits the context of use	Contextual help
Lack of guidance techniques that suit the context of use	Guidance

Tab. 3.9: Inherited usability challenges from ERP systems into mobile ERP apps

3.4.3.5 Discussion

The conducted structured interviews study with mobile ERP vendors has provided a further understanding of the proliferation of mobile ERP in businesses. According to the obtained results, the services category has the highest degree of mobile ERP adoption among other enterprise categories. Table 3.10 summarises the business sectors that are extensively adopting mobile ERP for each enterprise category.

Business category	Business sector
Services	Trade (Retail, Wholesale distribution)
Manufacturing	High Technology
Financial and public service	Business
Non-profit organisations	Non-Profit Organisations
Government	Government

Tab. 3.10: Summary of the business sectors that are extensively adopting mobile ERP for each enterprise category

Regarding the enterprise sizes, the conducted research study found that small and medium size enterprises have remarkably adopted mobile ERP among other given enterprise sizes.

In addition, this research study identified the most effective reasons that motivate enterprises to start adopting mobile ERP, and these reasons were sorted in Appendix D based on the interviewees' responses for question number three from the most effective reason such as "expanded real time visibility into all business activities" to the least effective reason such as "cost reduction".

Regarding accessing ERP modules via mobile devices, this research study found that the CRM module scored the highest degree in the level of concern to access it via mobile devices among the other ERP modules. In the same vein, the financial and accounting module scored the highest degree in the level of difficulty of use among other ERP modules when it is accessed via mobile devices. In addition, the inventory module scored the least acceptable module among the others ERP modules when it is accessed via mobile devices from the clients' perspective. Regarding the learnability, the purchases module scored the longest time in order to be learned among other ERP modules when it is accessed via mobile devices from the clients' perspective.

Regarding the frequency of use of mobile OSes and types of mobile devices in operating and installing mobile ERP apps, Android mobile OS and tablet computers have the highest frequency of use in operating and installing mobile ERP apps.

Finally, this research study identified a set of usability challenges that hinders the mobile ERP model (see Table 3.8), and these challenges were obtained from the thematic analysis of the interviewees' answers for question number ten. Moreover, this research study affirmed that some of the identified usability challenges of ERP systems in the conducted literature review study which was demonstrated in sub-section 3.4.2 were inherited to mobile ERP apps as can be seen from Table 3.9.

3.4.4 Preliminary Construct of the Conceptualisation of the Usability Challenges of Mobile ERP Apps

The results from the three conducted research studies that were presented in sub-sections 3.4.1, 3.4.2, and 3.4.3 were used to build the first version of the construct that depicts a set of the conceptualisation of the usability challenges of mobile ERP apps. Table 3.11 depicts this construct which can be used as a guide for mobile ERP apps developers to increase their awareness towards the usability challenges of such apps.

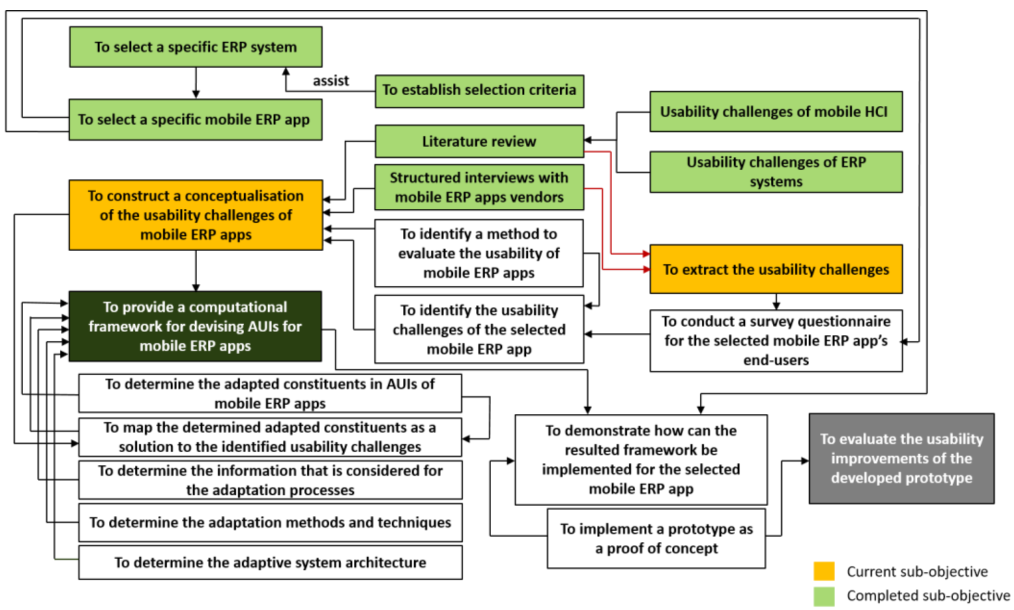


Fig. 3.15: Research objectives status; the first version of the construct of the conceptualisation for the usability challenges of mobile ERP apps

Based on the provided explanations for the usability challenges of mobile HCI in sub-section 3.4.1 and the interviewees' answers for question number ten in the conducted research study in sub-section 3.4.3, the identified usability challenges of mobile ERP apps from the conducted structured interviews research study are negatively impacted by the identified factors and their usability challenges of mobile HCI. Table 3.11 depicts these negative relations. For instance, based on the provided explanations of the usability challenges of mobile HCI in sub-section 3.4.1, those challenges increase the required time to complete the desired ERP task when it is performed via mobile ERP apps.

		Technology					**Environment**			**User**		
	Usability challenge of mobile ERP apps	Limited screen size	Limited capability of battery power	Data entry methods	Mobile data connectivity	Security	Activity (motion)	Ambient luminance	Ambient noise	Preferences	Physiological characteristics	Knowledge
Identified from the conducted structured interviews research study	More time required compared with the conventional approach to complete a task	x	x	x	x	x	x	x	x	x	x	x
	Stubborn to the context of use variability (needs to be adaptive)	x	x	x	x	x	x	x	x	x	x	x
	Lack of correction and validation techniques that suit the context of use			x			x		x	x		x
	Lack of intuitive learning									x	x	x
	Distraction	x		x			x	x	x	x		
Inherited from ERP systems based on Table 3.9	Bloated UIs	x			x	x	x	x	x	x	x	x
	Multitude of interaction steps	x	x	x	x	x	x	x	x	x	x	x
	Memorability	x					x		x	x		
	Findability of the desired information and functionalities	x		x	x		x	x	x	x	x	x
	Guidance	x					x	x	x	x		x
	Contextual help	x					x	x	x	x		x
x: negatively impact the usability of mobile ERP apps												

Tab. 3.11: First version of the construct of a conceptualisation for the usability challenges of mobile ERP apps

One of the main elements of the adopted strategy to construct the conceptualisation of the usability challenges of mobile ERP apps is the assessment of the usability experts. However, after an intensive reviewing of the literature, there is a lack of a dedicated usability assessment method for mobile ERP apps that can be used by usability experts. Therefore, the next sub-section discusses the development of a dedicated method for evaluating the usability of mobile ERP apps.

3.4.5 Usability Evaluation Method for Mobile ERP Apps

This sub-section attempts to answer the following research question:

> *RQ.3.3) What is the appropriate usability evaluation method that can be used to evaluate the usability of mobile ERP apps?*

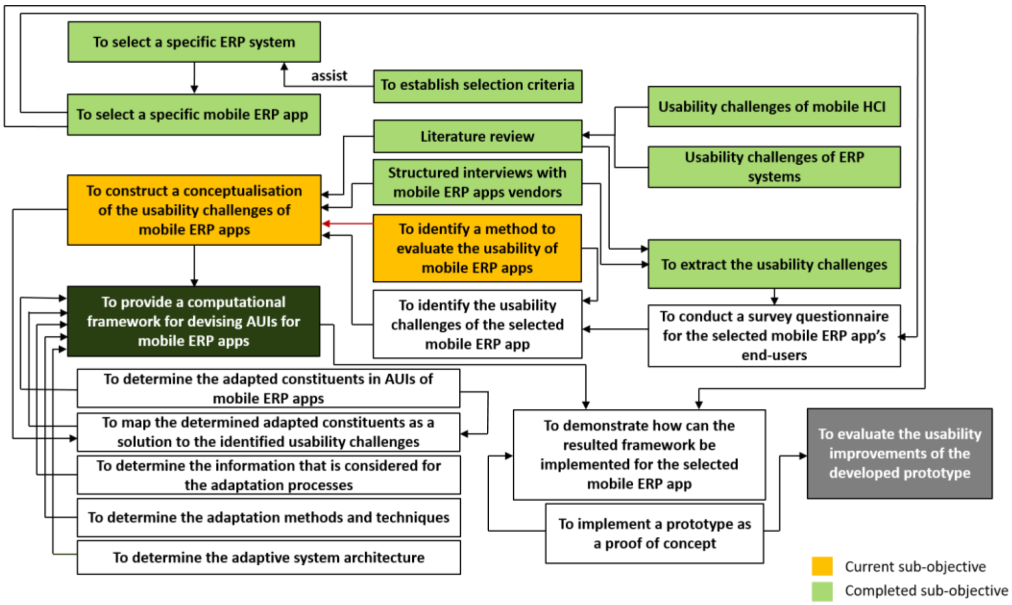


Fig. 3.16: Research objectives status; identifying a method to evaluate the usability of mobile ERP apps

In sub-section 3.3.3, four main classifications of usability evaluation methods and techniques were demonstrated, namely inspection methods, user testing methods, exploratory methods, and analytic methods. One of the popular inspection methods in the usability research community is heuristic evaluation (Hollingsed & Novick, 2007; Singh & Wesson, 2009), due to the following reasons (Nielsen & Molich, 1990):

- Low-cost to conduct it.
- It can be conducted early in the development process.
- It does not require advance planning.
- It is intuitive, fast, easily learned, and motivates people to use it.
- It is recommended to be conducted between three and five evaluators.
- It can be conducted by average computer professionals, but it is recommended to be conducted by usability experts.

Consequently, the heuristic evaluation was selected in this research study as a method to evaluate the usability of mobile ERP apps.

Heuristic evaluation is an informal method of usability analysis to evaluate the UI of any software application by pointing out the usability problems in the UI by experts as precisely as possible (Nielsen & Molich, 1990). This usability inspection method can be achieved through (Lauesen, 2005; Singh & Wesson, 2009):

- Heuristic rules: evaluators identify potential usability issues by evaluating a system against a set of guidelines as checklists.
- Subjective judgment: evaluators use their knowledge gained from previous usability evaluations to identify usability issues.
- Task-based evaluation: evaluators examine how tasks are executed on the system and observe any problems which they might encounter.

However, Nielsen's ten heuristics (Nielsen & Mack, 1994) and the eight golden rules of interface design that were proposed by (Shneiderman & Plaisant, 2004) are widely used to guide the UIs design process.

Nielson's ten heuristics are:

1. Visibility of system status.
2. Match between system and the real world.
3. User control and freedom.
4. Consistency and standards.
5. Error prevention.
6. Recognition rather than recall.
7. Flexibility and efficiency of use.
8. Aesthetic and minimalist design.
9. Help users recognise, diagnose and recover from errors.
10. Help and documentation.

The eight golden rules of interface design are:

1. Strive for consistency.
2. Cater to universal usability.
3. Offer informative feedback.
4. Design dialogs to yield closure.
5. Prevent errors.
6. Permit easy reversal of actions.
7. Support internal locus of control.
8. Reduce short-term memory load.

However, after an intensive reviewing of the literature, a knowledge gap was identified in finding a customised heuristic checklist for assessing the usability of mobile ERP apps' UIs. Besides, the current heuristic checklists in the literature are desktop-centred applications and vary according to the types of applications that they serve, such as (Pierotti, 1995), (Dringus & Cohen, 2005), and (U.S. Department of Health and Human Services, 2017). While some of these checklists have been adapted and enriched with further heuristics to evaluate mobile-centred apps such as the proposed checklists by (Ji, Park, Lee, & Yun, 2006), and (Yáñez Gómez, Cascado Caballero, & Sevillano, 2014). Therefore, a necessity to customise these checklists is crucial in order to assess the usability of mobile ERP apps' UIs, and this necessity stems from:

1. The usage nature of mobile ERP apps that are used in a variable context.
2. Accessing ERP systems which have complex, rigid, and bloated UIs.

Therefore, the next sub-section presents the followed methodology in order to compile a customised heuristic evaluation checklist for assessing the usability of mobile ERP apps' UIs.

3.4.5.1 Methodology

(Yáñez Gómez et al., 2014) proposed a compilation of a heuristic evaluation checklist by reusing the heuristics from the desktop-centred heuristics evaluation checklists in the literature, and the compiled checklist was readapted to mobile UIs by them. Figure 3.19 depicts the proposed classification of heuristics and sub-heuristics by (Yáñez Gómez et al., 2014), which contains 13 heuristics, 37 categories, and 230 sub-heuristics. In turn, their checklist was allocated to the mobile ERP apps' UIs by (Omar, Rapp, & Marx Gómez, 2016) through following the four stages that are described below, which were adapted from (Yáñez Gómez et al., 2014), and who in turn re-adapted them from (Rusu, Roncagliolo, Rusu, & Collazos, 2011):

1. Problem scope definition.
2. Analysing and enriching the current usability heuristics.
3. Enriching the proposed heuristic list with sub-heuristics.
4. Homogenisation of the redaction and format of sub-heuristics.

1. Problem scope definition

This stage aims to identify a clear definition of the problem scope in order to define and classify the special characteristics of mobile ERP apps' interaction and their usability challenges. In section 3.4.4, the first version of the construct of the conceptualisation for the usability challenges of mobile ERP apps was presented (see Table 3.11). Based on this construct, it is a necessity to provide a customised heuristics and sub-heuristics checklist to address the contained usability challenges in this construct. While the current checklists in the literature lack of presence of heuristics and sub-heuristics that are able to address most of the presented usability challenges in the resulted construct.

2. Analysing and enriching the current usability heuristics

This stage aims to analyse and enrich the existing and well-known heuristics, and compiling them into a new list which contains specific heuristics for mobile ERP apps. The well-known heuristics in the literature give an abstract meaning of the usability criteria, which means that they refer to a global usability issue which must be evaluated or taken into account when designing UIs.

As it mentioned earlier in the introduction to this sub-section, a heuristic evaluation checklist was compiled by (Yáñez Gómez et al., 2014) by reusing the general heuristics and sub-heuristics from the literature, and it was adapted to the mobile context. Figure 3.17 depicts the 13 heuristics that were proposed by (Yáñez Gómez et al., 2014) for designing usable mobile UIs.

In addition, (Singh & Wesson, 2009) proposed the following usability heuristics that are specific for ERP systems:

1. Navigation and access to information.
2. Presentation of screen and output.

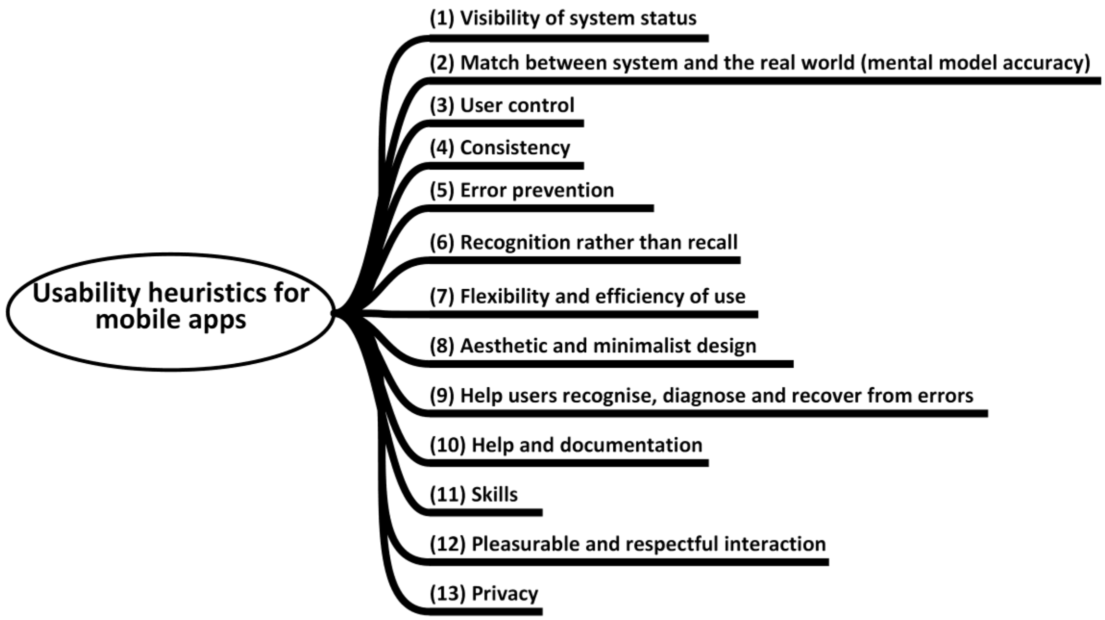


Fig. 3.17: Proposed heuristics list by (Yáñez Gómez et al., 2014) for designing a usable mobile UI

3. Appropriateness of task support.
4. Intuitive nature of system (Learnability).
5. Ability to customise.

Consequently, the abovementioned heuristics were combined with the proposed heuristics by (Yáñez Gómez et al., 2014) in order to form a new heuristic list which is specific for mobile ERP apps. Figure 3.18 depicts the allocated heuristics list for mobile ERP apps, and the newly added heuristics are highlighted in red colour.

Many research works exploited AUIs to address some of the usability challenges of software applications, due to their capabilities to accommodate the heterogeneity of end-users, and reacting automatically to the context variability in a continuous way (Akiki, 2014; Reichenbacher, 2004; Singh, 2011). Therefore, AUIs were crucially proposed by (Omar, 2015) to address the usability challenges of mobile ERP apps. Consequently, the ability to support AUIs was introduced as a new heuristic to improve the usability of mobile ERP apps.

Fig. 3.18: Proposed heuristics list for mobile ERP apps by (Omar et al., 2016)

3. Enriching the proposed heuristic list with sub-heuristics

This stage aims to enrich the compiled list from the previous stage with a set of sub-heuristics (guidelines) in order to clarify the abstract meaning of them, and in order to preserve the usability of application UIs, mobile application UIs, and mobile ERP's UIs.

(Yáñez Gómez et al., 2014) proposed a categorisation of sub-heuristics for their heuristic checklist, and Figure 3.19 depicts this categorisation. In turn, this categorisation was adapted and enriched with a new set of sub-heuristics that was gleaned from analysing and reviewing three main resources, namely mobile usability research, ERP systems usability research, and the best practices that were published in the literature. Figure 3.20 depicts the new categorisation list, and the newly added categories are highlighted in red colour.

In summary, (Yáñez Gómez et al., 2014) presented a checklist with the total of 13 heuristics, 37 categories of sub-heuristics that were enriched with 230 sub-heuristics to evaluate the usability of mobile UIs. In turn, the proposed list of mobile ERP apps in this research study was enriched with 6 new heuristics, and 13 new categories of sub-heuristics that were enriched with 230 new sub-heuristics. Thus, the new checklist has 19 heuristics, 50 categories of sub-heuristics which were enriched with 460 sub-heuristics. Table 3.12 depicts the added numbers of the heuristics, categories, and sub-heuristics to the (Yáñez Gómez et al., 2014) checklist by (Omar et al., 2016).

4. Homogenisation of the redaction and format of sub-heuristics

The final stage aims to homogenise the redaction and format of the newly compiled list from the previous stage in order to make it useful for non-experts, and it can be found online at: https://www.uni-oldenburg.de/fileadmin/user_upload/informatik/ag/vlba/download/Omar/checklist-v1-0.pdf.

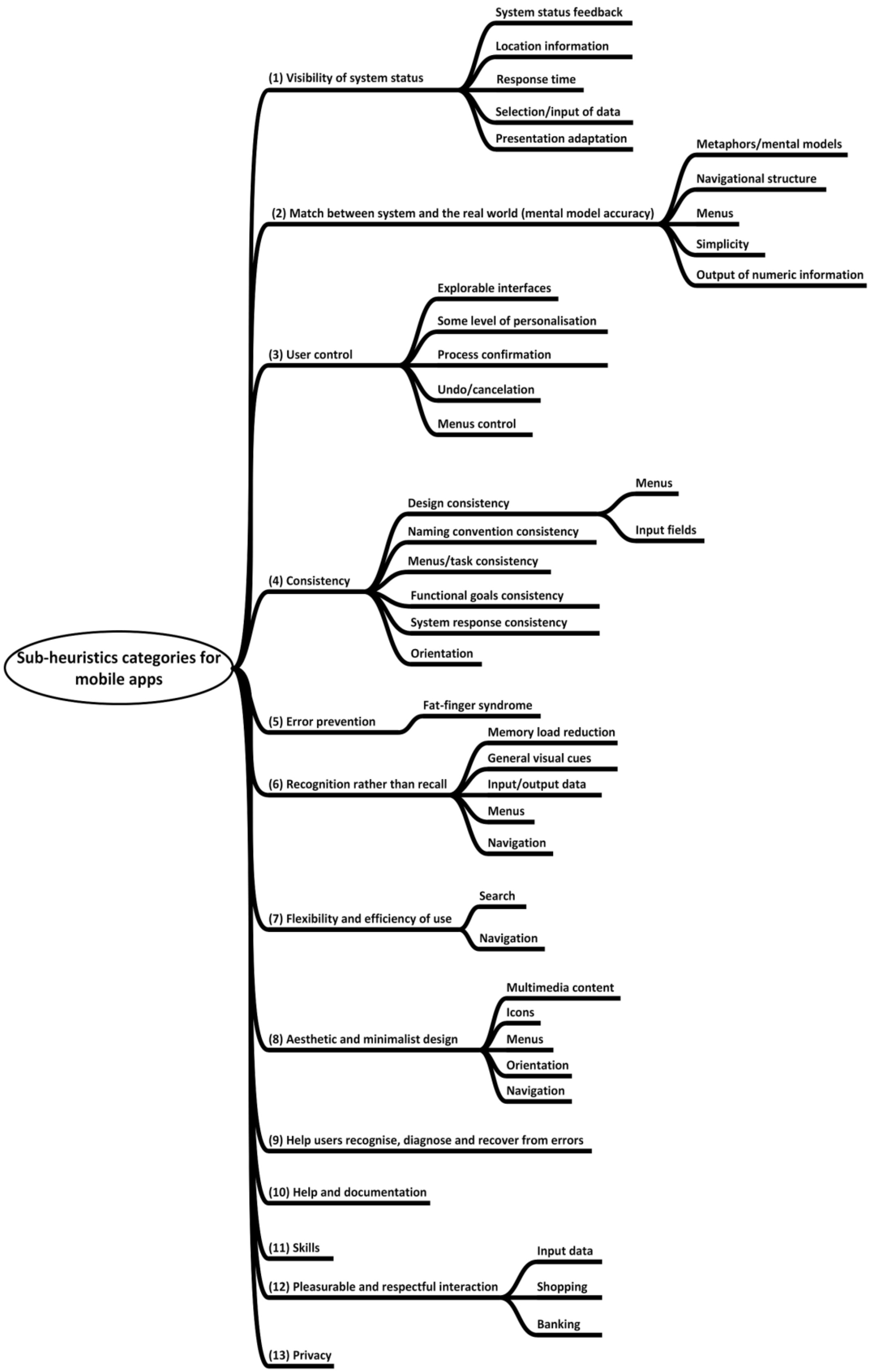


Fig. 3.19: Proposed categorisation of the detected heuristics and sub-heuristics by (Yáñez Gómez et al., 2014)

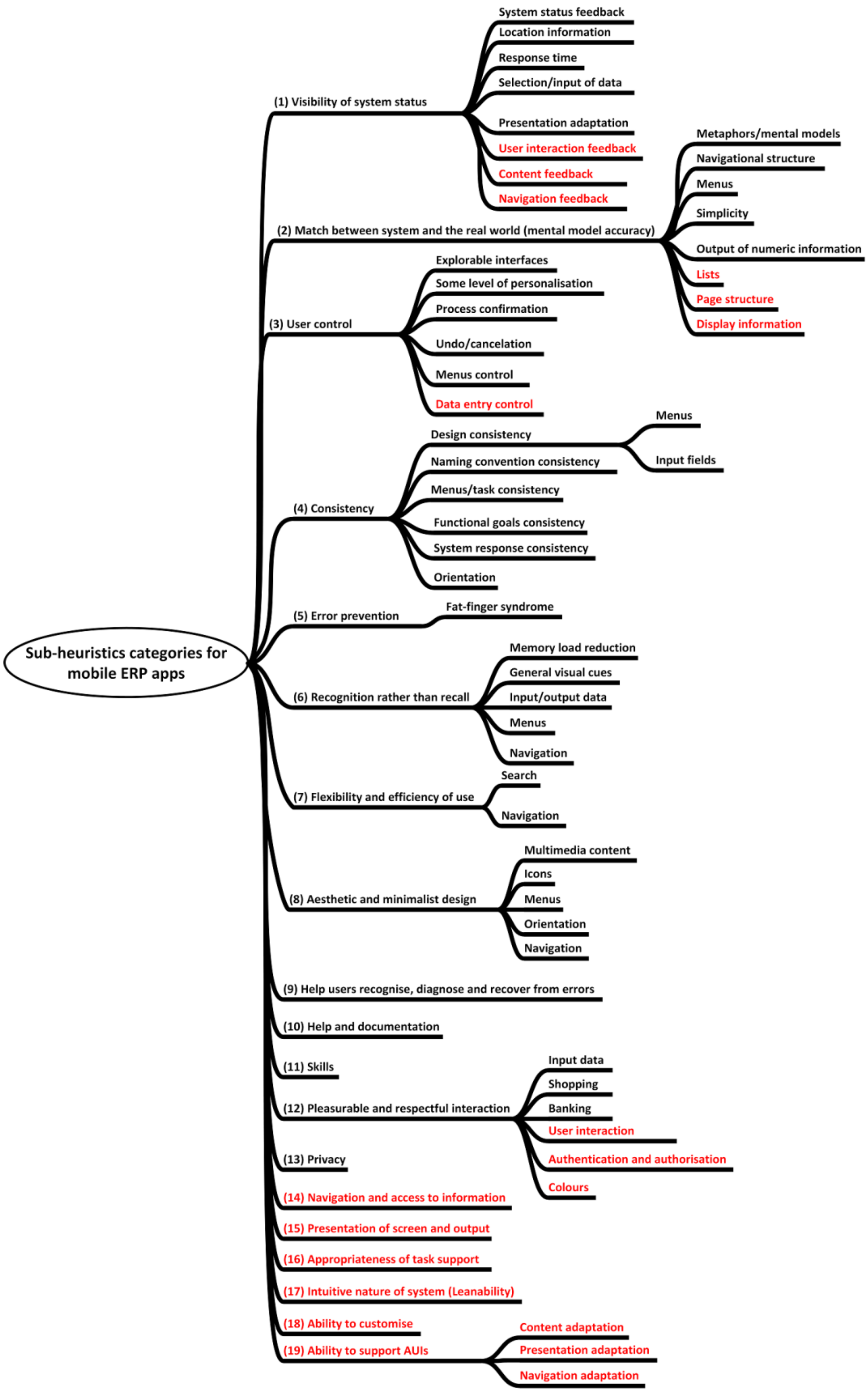


Fig. 3.20: Proposed categorisation of the detected heuristics and sub-heuristics for mobile ERP apps by (Omar et al., 2016)

	Proposed by (Yáñez Gómez et al., 2014)		Proposed by (Omar et al., 2016)	
Heuristic	**Categories**	**Sub-heuristics**	**New added categories**	**New sub-heuristics**
1	5	31	3	29
2	5	20	3	25
3	5	16	1	9
4	6	33	0	17
5	1	12	0	2
6	5	27	0	17
7	2	13	0	3
8	5	29	0	4
9	0	1	0	23
10	0	17	0	5
11	0	7	0	11
12	3	19	3	19
13	0	5	0	18
14	x	x	0	12
15	x	x	0	9
16	x	x	0	8
17	x	x	0	6
18	x	x	0	10
19	x	x	3	3
Total	**37**	**230**	**13**	**230**
x: not available				

Tab. 3.12: Summarisation of the added numbers of the heuristics, categories, and sub-heuristics to the (Yáñez Gómez et al., 2014) checklist by (Omar et al., 2016)

The compiled checklist of heuristics and sub-heuristics in this sub-section is one of the resulted artefacts from this research study that extended the methodologies of the IS knowledge base in a usability inspection method, which is dedicated to evaluate the usability of mobile ERP apps' UIs. This artefact was presented at the 7th International Conference on Information and Communication Systems 2016 (ICICS), and published in its proceedings (Omar et al., 2016).

3.4.5.2 Applying the Developed Checklist on mERP App

The selected mobile ERP app (mERP app) in section 3.2.4 was used to answer the following research questions:

RQ.3.4) How can the identified usability evaluation method in sub-section 3.4.5.1 be applied?

RQ.3.5) What are the usability challenges of mERP app?

Therefore, the developed heuristic checklist was provided to three usability experts to rate the usability of mERP app's UIs. Two of them are mobile usability experts and the other is a HCI usability expert. In addition, a five-point severity rating scale was added for each sub-heuristic in the provided heuristic checklist, and this scale was proposed by Nielsen to support the evaluators to assess the severity of the usability problems (Nielsen, 1995).

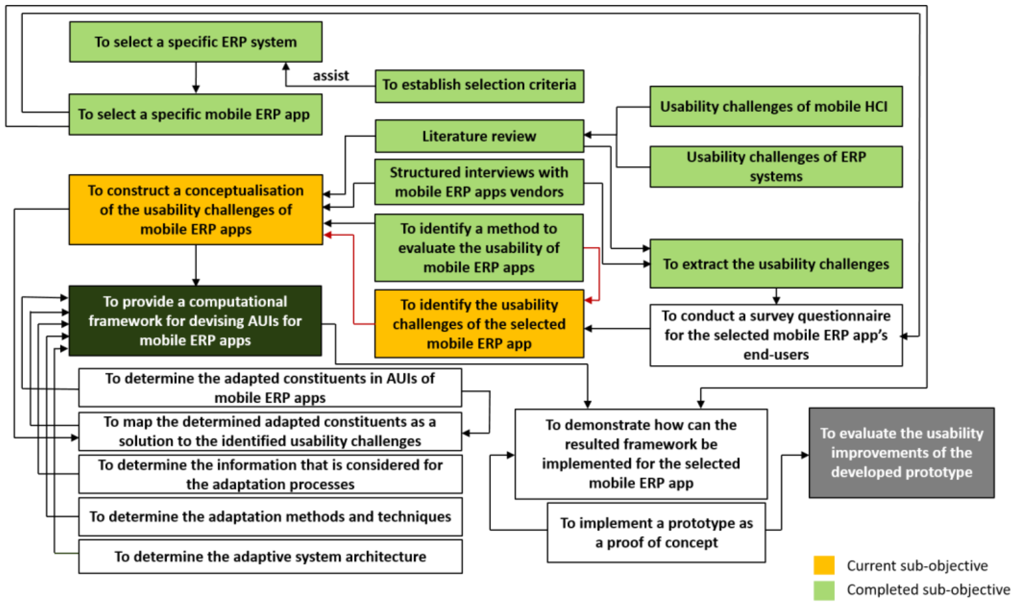


Fig. 3.21: Research objectives status; identifying the usability challenges of the selected mobile ERP app (mERP app)

The evaluators were asked to determine the severity rating for each usability problem that belongs to a specific sub-heuristic by using the following rating scale (Nielsen, 1995):

0 = I don't agree that this is a usability problem at all.
1 = Cosmetic problem only: need not be fixed unless extra time is available on project.
2 = Minor usability problem: fixing this should be given low priority.
3 = Major usability problem: important to fix, so should be given high priority.
4 = Usability catastrophe: imperative to fix this before product can be released.

3.4.5.3 Results

For each heuristic, the severity ratings for the identified usability problems (sub-heuristics) were collected from the three evaluators which are quantitative in nature. Afterwards, the collected data were statistically analysed by calculating the mode for the whole determined severity ratings of each expert. Finding the mode of the determined severity ratings for each heuristic aims to find the most frequently occurring item of the severity rating scale for each expert. Afterwards, the median of the resulted mode values was calculated to determine the best central value that could represent the severity of the usability problem. This approach was applied in the conducted heuristic evaluation by (Singh, 2011) to determine the usability problems of SBO ERP system. Figure 3.22 depicts the identified heuristics in sub-section 3.4.5.1 for mobile ERP apps and their median severity ratings for mERP app. For instance, the identified usability problems for the presentation of the screen and output heuristic were identified as minor usability problems (median=2). While the identified usability problems for the error prevention heuristic were identified as cosmetic problems (median=1).

Furthermore, the specific rating for the identified usability problems was determined by calculating the median value of the evaluators' responses for each sub-heuristic. Based on the proposed severity rating scale by (Nielsen, 1995), the sub-heuristics with median values that were equal to two were considered minor usability problems, while the sub-heuristics with median values that were equal to three were considered major usability problems, and finally, the sub-heuristics with median values that were equal to four were considered usability catastrophe problems. Figure 3.23 depicts the identified numbers of the usability problems for each heuristic with their severity classification. The complete results are provided in Appendix E.

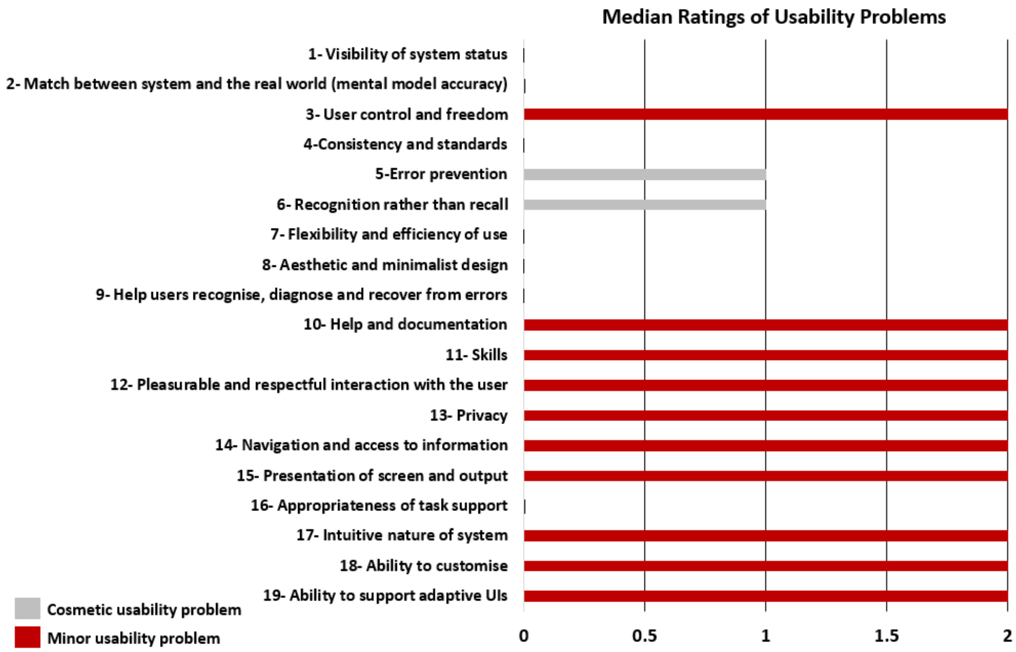


Fig. 3.22: Median ratings of the identified usability problems in mERP app for each heuristic (n=3)

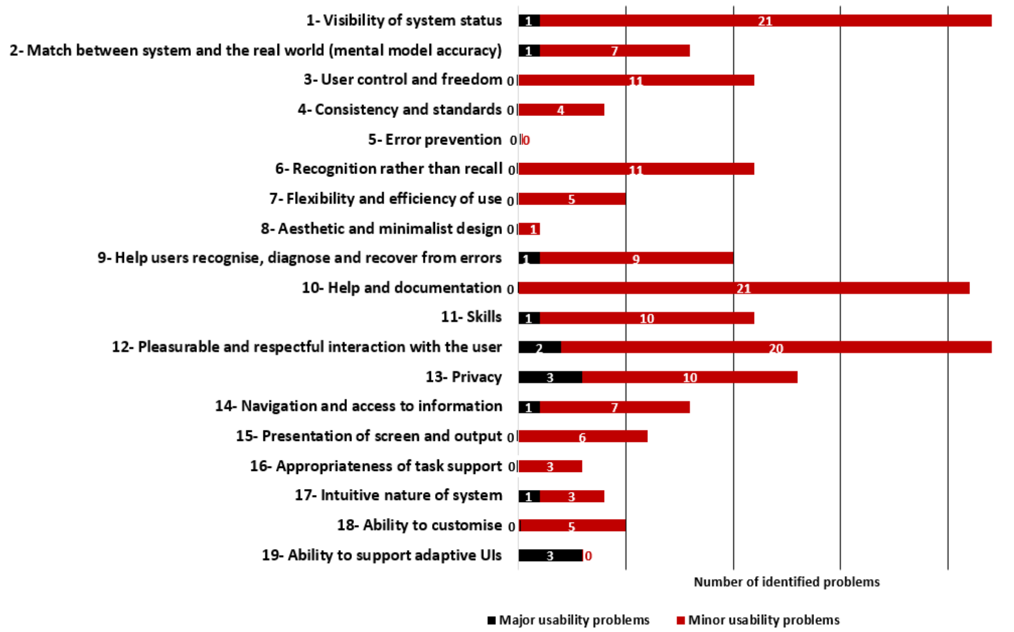


Fig. 3.23: Identified numbers of the usability problems for each heuristic with their severity classification

After analysing the identified major usability problems, the following results were obtained:

- Firstly, some of the identified major usability problems in this research study were pointed out in the resulted first version of the developed construct of a conceptualisation for the usability challenges of mobile ERP apps as can be seen from Table 3.13.

Identified usability problem in the resulted first version of the desired construct (see Table 3.11)	**Identified major usability problem from the conducted heuristic evaluation research study**
Stubborn to the context of use variability (needs to be adaptive)	App doesn't utilise the AUIs approach
Lack of correction and validation techniques that suit the context of use	Intolerance of input data typos and offering instant corrections
Lack of intuitive learning	Negligence of adopting an approach that supports the learnability of the app
Contextual help	Lack of providing sufficient help for finding the correct functionality, information, and screens

Tab. 3.13: Mapping between the identified usability challenges in the resulted first version of the developed construct and the identified major usability challenges from the conducted heuristic evaluation research study

- Secondly, it was revealed that the challenges of the task completion and personalisation in ERP systems are inherited to the mobile ERP apps in this research study as can be seen from Table 3.14.

Identified usability problem of ERP Systems based on the conducted literature review (see Table 3.6)	**Identified major usability problem from the conducted heuristic evaluation research study**
Task completion	Lack of saving partially completed tasks
	Lack of providing an autocomplete for the input data fields
Personalisation	Lack of being tailored to serve different user groups

Tab. 3.14: Mapping the identified usability problems of ERP systems from the conducted literature review to the identified major usability problems from the conducted heuristic evaluation research study

- Finally, a new challenge was identified in this research study, which is a lack of supporting and maintaining some critical security issues that impact the usability of mobile ERP apps' UIs, namely:
    1. The absence of providing an instant notification about any suspicious activity during the app usage.
    2. The absence of logging out automatically when the end-user does not interact with the app for a long-time (idle time).

3.4.5.4 Discussion

This research study employed the compiled heuristic checklist in section 3.4.5.1 to assess mERP app's UIs (the selected mobile ERP app) in order to search for further usability challenges from the usability experts' perspective, and thus, it was used by three usability experts.

Based on the descriptive statistical analysis of the experts' responses, some of the identified usability challenges in the resulted first version of the developed construct of a conceptualisation for the usability challenges of mobile ERP apps (see Table 3.13) were affirmed. In addition, it was acknowledged in this research study that some of the identified usability challenges of ERP systems from the conducted literature review in this research study are inherited to the mobile ERP apps (see Table 3.14). Finally, this research study revealed a new usability challenge regarding the supporting and maintaining of some critical security issues, and these issues negatively impact the satisfaction attribute of the PACMAD usability model. For instance, the end-user might feel uncomfortable when there is a suspicious activity during the app usage.

According to the obtained results from this research study, the resulted first version of the developed construct was revised as can be seen from table 3.15.

		Technology					**Environment**			**User**		
	Usability challenge of mobile ERP apps	Limited screen size	Limited capability of battery power	Data entry methods	Mobile data connectivity	Security	Activity (motion)	Ambient luminance	Ambient noise	Preferences	Physiological characteristics	Knowledge
Identified from the conducted structured interviews research study	More time required compared with the conventional approach to complete a task	x	x	x	x	x	x	x	x	x	x	x
	Stubborn to the context of use variability (needs to be adaptive)	x	x	x	x	x	x	x	x	x	x	x
	Lack of correction and validation techniques that suit the context of use			x			x		x	x		x
	Lack of intuitive learning									x	x	x
	Distraction	x		x			x	x	x	x		
Inherited from ERP systems based on Table 3.9	Bloated UIs	x			x	x	x	x	x	x	x	x
	Multitude of interaction steps	x	x	x	x	x	x	x	x	x	x	x
	Memorability	x					x		x	x		
	Findability of the desired information and functionalities	x		x	x		x	x	x	x	x	x
	Guidance	x					x	x	x	x		x
	Contextual help	x					x	x	x	x		x
Inherited from ERP systems based on the conducted heuristic evaluation research study	Task completion	x	x	x	x	x	x	x	x	x	x	x
	Personalisation			x						x	x	x
Identified from the conducted heuristic evaluation research study	Security issues			x		x				x		

Tab. 3.15: Second version of the construct of a conceptualisation for the usability challenges of mobile ERP apps

However, another research study was conducted in order to gather further usability challenges of mERP app from its end-users' perspective, and thus, the next sub-section presents the results of this research study, which complemented the obtained results from the conducted heuristic evaluation research study.

3.4.6 Survey Questionnaire for mERP App's End-users

The end-users of the selected mobile ERP app (mERP app) are considered the final element in the adopted strategy to construct a conceptualisation of the usability challenges of mobile ERP apps. Therefore, another research study was conducted that aimed to:

1. Identify further usability challenges that were experienced by the end-users of mERP app.
2. Investigate the existence of the identified usability challenges from the conducted literature review studies and structured interviews study.

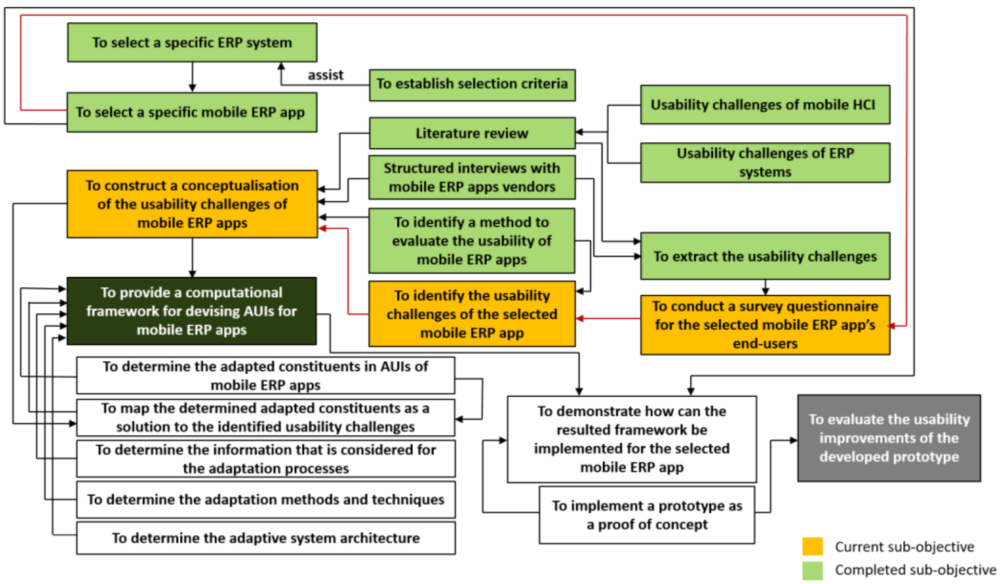


Fig. 3.24: Research objectives status; a survey questionnaire for mERP app's end-users

3.4.6.1 Methodology

A survey questionnaire of fourteen questions (Appendix F) was developed, and Table 3.16 presents the goals of these questions in order to achieve the main objectives of this research study. Google Forms was used to create an online version of this questionnaire, due to the geographical distribution of the mERP app's end-users who cannot be found in one place.

Question number	Goal
1	To determine the most frequently used mobile device in operating the mERP app
2	To determine the most frequently performed tasks of Odoo ERP system through mERP app
3	To determine the quality of efficiency of the mERP app in terms of finding the desired information timely (speed) in a specific context of use, such as distraction, walking, different environments, and mobile data disconnection

4	To determine the quality of efficiency of the mERP app in terms of accessing the desired functionality timely (speed) in a specific context of use, such as distraction, walking, different environments, and mobile data disconnection
5	To determine the quality of the effectiveness of the mERP app in terms of correctly finding the desired information in a specific context of use, such as distraction, walking, different environments, and mobile data disconnection
6	To determine the quality of the effectiveness of the mERP app in terms of accessing the desired functionality and completing it correctly (low rate of errors) in a specific context of use, such as distraction, walking, different environments, and mobile data disconnection
7	To determine whether the presentation of UIs of the mERP app and their layouts' components support tasks completion or not
8	To determine whether the UIs of the mERP app support the learnability and the intuitive use of it
9	To determine whether the UIs of the mERP app support the memorability in remembering how to use it in case it was not used for a long period of time
10	To determine whether the UIs of the mERP app provide an appropriate, sufficient, and intuitive help approach for their end-users
11	To identify the features that the end-users of the mERP app would like to find, and these features will motivate the usage of mERP proficiently
12	To identify the features that make the mERP app preferable among other apps
13	To identify the features and issues that create the aversion attitudes towards the mERP app
14	To identify the usability challenges that were experienced by the end-users of the mERP app while using it

Tab. 3.16: Goals behind the identified questions in the developed survey questionnaire for mERP app's end-users

The developed questionnaire was answered by 31 mERP app's end-users, and their answers were analysed quantitatively and qualitatively. Therefore, the following sub-section presents the obtained results from these analyses.

3.4.6.2 Data Analysis

The collected data from the questionnaires were analysed quantitatively and qualitatively in order to achieve the goals of this research study.

In the quantitative data analysis, the collected answers for questions 1 to 10 were statistically analysed by using descriptive statistics. Thus, the frequency distributions and percent distributions for these answers were calculated. Based on this analysis, the following results were obtained:

1. Tablet computers scored the highest percentage rate (48.4 %) in operating mERP apps among the other listed mobile devices.
2. The purchase order and RFQ tasks of the purchases module in Odoo ERP system scored the highest percentage rate (51.6 %) in accessing them via mERP app among the other listed modules of Odoo ERP system. In addition, this result influenced the prototyping phase of this research study.

3. 41.9 % of the respondents consider that the mERP app has poor efficiency in finding the desired information in a specific context of use.
4. 45.2 % of the respondents consider that the mERP app has poor efficiency in finding the desired functionality in a specific context of use.
5. 35.5 % of the respondents consider that the mERP app has a poor effectiveness in finding the desired information correctly in a specific context of use.
6. 32.3 % of the respondents consider that the mERP app has a poor effectiveness in accessing the desired functionality and completing it correctly.
7. 67.7 % of the respondents consider that mERP's UIs and their components do not support the completion of desired tasks.
8. 64.5 % of the respondents consider that the mERP app is difficult to be learned and doesn't support the intuitive learning for its layouts.
9. 67.7 % of the respondents consider that the mERP app doesn't support the memorability for its layouts' components and functionalities.
10. 67.7 % of the respondents consider that the mERP app doesn't provide an appropriate, sufficient, and intuitive help approach.

Figure 3.25 depicts the highest percentage rates of the respondents' answers to questions 1 to 10 in the survey questionnaire for mERP app's end-users.

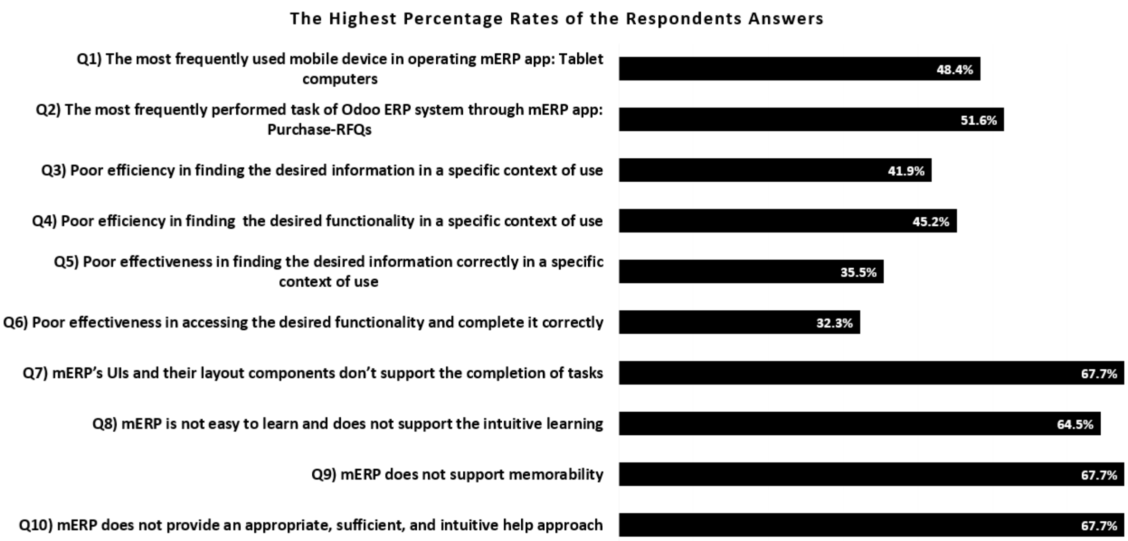


Fig. 3.25: Highest percentage rates of the respondents' answers to questions 1 to 10 in the survey questionnaire for mERP app's end-users (n=31)

In turn, a qualitative analysis was performed for the collected answers to questions 11 to 14 that were thematically analysed. Based on this analysis, the following results were obtained:

1. Some of the identified usability challenges in the previously conducted research studies in this dissertation were affirmed as can be seen from Table 3.17.
2. New usability challenges were identified in this research study, which are:

- A lack of auto-reflecting the customised UI's component in the backend ERP system. Based on the respondents' answers, the existence of this feature will be negatively impacted by the screen-sizes of mobile devices and their limitations, virtual keyboards sizes and their layouts, the motion of the end-users, and the heterogeneity of the end-users in terms of preferences, characteristics, and knowledge.
- A lack of supporting the offline mode, which is directly impacted by the status of the mobile data connectivity.

Usability challenge of mobile ERP apps	Affirmed in the respondents' answers
More time required compared with the conventional approach to complete a task	✓
Stubborn to the context of use variability (needs to be adaptive)	✓
Lack of correction and validation techniques that suit the context of use	
Lack of intuitive learning	✓
Distraction	
Bloated UIs	✓
Multitude of interaction steps	✓
Memorability	✓
Findability of the desired information and functionalities	✓
Task completion	
Guidance	
Personalisation	
Contextual help	✓
Security issues	

Tab. 3.17: Usability challenges that were affirmed in the conducted survey questionnaire for mERP app's end-users, which were previously identified in the conducted research studies in this dissertation

3.4.6.3 Discussion

Investigation of the opinions and attitudes of the mobile ERP apps' end-users towards the usability of such apps is one of the main elements that is relied upon in the followed strategy for building the desired construct of a conceptualisation for the usability challenges of mobile ERP apps. Therefore, a survey questionnaire was conducted for mERP app's end-users, which aimed to examine whether the identified usability challenges from the previously conducted research studies in this dissertation exist from their perspective. In addition, to identify any further usability challenges that were experienced by them.

The collected data from the respondents were analysed quantitatively and qualitatively, and based on these analyses, some of the identified usability challenges in the previously conducted research studies in this dissertation were affirmed (see Table 3.17). In addition, new usability challenges were identified, which are: a lack of auto-reflecting the customised UI's component in the backend ERP system, in addition to a lack of supporting the offline mode. However, these challenges are addressed by the system engineer, and can be solved on the application layer, not on the UI layer of the software application. Thus, they will not be considered in the prototypical implementation. According to these results, the final version of the desired construct is depicted in Table 3.18. This construct was discussed and presented at the In Eureka International Virtual Meeting Eureka 2016 OPTISAD (Omar & Marx Gómez, 2016a).

		Technology					**Environment**			**User**		
	Usability challenge of mobile ERP apps	Limited screen size	Limited capability of battery power	Data entry methods	Mobile data connectivity	Security	Activity (motion)	Ambient luminance	Ambient noise	Preferences	Physiological characteristics	Knowledge
Identified from the conducted structured interviews research study	More time required compared with the conventional approach to complete a task	x	x	x	x	x	x	x	x	x	x	x
	Stubborn to the context of use variability (needs to be adaptive)	x	x	x	x	x	x	x	x	x	x	x
	Lack of correction and validation techniques that suit the context of use			x			x		x	x		x
	Lack of intuitive learning									x	x	x
	Distraction	x		x			x	x	x	x		
Inherited from ERP systems based on Table 3.9	Bloated UIs	x			x	x	x	x	x	x	x	x
	Multitude of interaction steps	x	x	x	x	x	x	x	x	x	x	x
	Memorability	x					x		x	x		
	Findability of the desired information and functionalities	x		x	x		x	x	x	x	x	x
	Guidance	x					x	x	x	x		x
	Contextual help	x					x	x	x	x		x
Inherited from ERP systems based on the conducted heuristic evaluation research study	Task completion	x	x	x	x	x	x	x	x	x	x	x
	Personalisation			x						x	x	x
Identified from the conducted heuristic evaluation research study	Security issues			x		x				x		
Identified from the conducted survey questionnaire for mERP app's end-users	Lack of auto-reflecting the customised UI's component in the backend ERP system	x		x			x			x	x	x
	Lack of supporting the offline mode				x							

Tab. 3.18: Final version of the desired construct of a conceptualisation for the usability challenges of mobile ERP apps adapted from (Omar & Marx Gómez, 2016a)

3.5 Summary

This chapter aimed to construct a conceptualisation of the usability challenges of mobile ERP apps. Therefore, five research studies were conducted in order to achieve this main sub-objective.

The first research study focused on reviewing the literature in order to identify the usability challenges of mobile HCI. In this research study, three factors were identified that negatively affect the selected usability attributes of the PACMAD usability model, namely technology, environment, and the heterogeneity of the end-users. Besides, eleven usability challenges were identified that stem from these factors (See Table 3.4). Regarding the technology factor, the following usability challenges were identified: limited screen size, limited capability of battery power, data entry methods (virtual keyboards), mobile data connectivity, and security. While three usability challenges were identified that arise from the environmental factor, namely the end-users' activities (motions), ambient luminance, and ambient noise. Finally, three usability challenges were identified that stem from the heterogeneity of the end-users' factor, namely preferences, physiological characteristics, and knowledge.

The second research study focused on reviewing the literature in order to identify the usability challenges of ERP systems. This research study revealed that there are nine usability challenges of ERP systems that negatively impact the selected usability attributes of the PACMAD usability model (see Table 3.6), which are:

1. Bloated UIs.
2. A multitude of interaction steps.
3. Memorability unsupportiveness.
4. Findability of the desired information and functionalities.
5. Task completion unsupportiveness.
6. Automation of routine tasks.
7. Guidance.
8. Personalisation.
9. Contextual help.

Furthermore, the abovementioned usability challenges were examined in the conducted subsequent research studies in order to verify if they are inherited to mobile ERP apps or not.

The third research study aimed to provide a further understanding of the proliferation of mobile ERP in businesses, and to identify any usability challenges of mobile ERP apps. Therefore, a set of structured interviews was conducted with mobile ERP vendors. According to the obtained results from these interviews, the services category has the highest degree of mobile ERP adoption among the others given enterprises' categories, and the small and medium size enterprises have remarkably adopted mobile ERP among other given enterprise sizes. In addition, this research study identified the most effective reasons that motivate enterprises to start adopting mobile ERP, and one of the most important reasons that identified in this research study is "expanded real time visibility into all business activities". Furthermore, the following results were obtained in this research study regarding the ERP modules when they are accessed via mobile devices:

1. The CRM module scored the highest degree in the level of concern to access via mobile devices among other ERP modules.

2. The financial and accounting module scored the highest degree in the level of difficulty of use among other ERP modules when it is being accessed via mobile devices.
3. The inventory module scored the least acceptable module among other ERP modules when it is being accessed via mobile devices from the clients' perspective.
4. The purchases module scored the longest time in order to be learned among the others ERP modules when it is being accessed via mobile devices from the clients' perspective.

In addition, this research study revealed that Android mobile OS and tablet computers have the highest frequency of use in operating and installing mobile ERP apps. Furthermore, a set of usability challenges were identified in this research study that negatively impacts the selected attributes of the PACMAD usability model, namely:

1. A large number of activities and interactions compared with the conventional approach (using ERP via PC and laptops).
2. Difficulty in remembering the designated steps of the conducted task.
3. More time required compared with the conventional approach to complete a task.
4. The end-users are more exposed to the distractions in comparison to the usage of conventional approaches (Distractions).
5. Difficulty in finding the desired information and functions.
6. Stubborn to the context of use variability (needs to be adaptive).
7. An absence of intuitive learning.
8. A lack of an appropriate helping technique that suits the context of use.
9. An absence of guidance techniques that suit the context of use.
10. A lack of correction and validation techniques that suit the context of use.

Finally, this research study affirmed that some of the identified usability challenges of ERP systems in the second conducted literature review were inherited to mobile ERP apps (See Table 3.9), and these challenges are:

1. A large number of activities and interactions compared with the conventional approach (using ERP via PC and laptops).
2. Difficulty in remembering the designated steps of the conducted task.
3. Difficulty in finding desired information and functions.
4. A lack of an appropriate helping technique that suits the context of use.
5. A lack of guidance techniques that suit the context of use.

A developed heuristic evaluation checklist for assessing the usability of mobile ERP apps' UIs was presented in this chapter, and this checklist was employed in the fourth research study by three usability experts to assess the usability of the selected mobile ERP app (mERP app) in this dissertation. In this research study, some of the identified major usability problems were pointed out in the conducted literature review studies and structured interviews study, which are:

1. The app doesn't exploit the AUIs approach.
2. An intolerance of input data typos and offering instant corrections.
3. A lack of providing an approach that supports the learnability of the app.

4. A lack of providing sufficient help for finding the correct functionality, information, and screens.

In addition, it was affirmed in this research study that the challenges of the task completion and personalisation in ERP systems are inherited to the mobile ERP. Furthermore, a new usability challenge was identified in this research study which is the lack of supporting and maintaining some critical security issues that impact the usability of mobile ERP apps' UIs, namely:

1. A lack of providing an instant notification about any suspicious activity during the app usage.
2. A lack of logging out automatically when the end-user does not interact with the app for a long-time (idle time).

The final research study aimed to identify further usability challenges that were experienced by the end-users of the mERP app (the selected mobile ERP app), and to examine the identified usability challenges from the conducted literature review studies and structured interviews study. Therefore, a survey questionnaire of fourteen questions was developed and answered by 31 end-users of the mERP app. The collected data from the respondents were analysed quantitatively and qualitatively. Based on these analyses, some of the identified usability challenges in the previously conducted research studies in this dissertation were affirmed, which are:

1. More time required compared with the conventional approach to complete a task.
2. Stubborn to the context of use variability (needs to be adaptive).
3. A lack of intuitive learning.
4. Bloated UIs.
5. A multitude of interaction steps.
6. Memorability.
7. Findability of the desired information and functionalities.
8. Contextual help.

In addition, new usability challenges were identified in this research study, which are:

1. A lack of auto-reflecting the customised UI's component in the backend ERP system.
2. A lack of supporting the offline mode.

The next chapter will present a discussion on the means by which the AUIs may be exploited to address the identified usability challenges of mobile ERP apps in the resulted construct in this chapter.

4 Adaptive User Interfaces

Over the past quarter-century, the rapid growth and the proliferation of mobile devices have been observed, and in particular, the increased penetration of their services in every aspect of our daily life. The constant advances in mobile computing and the huge leaps in mobile HCI enabled different mobile platforms to operate context-aware applications. These types of applications enable the same application to have different behaviours, aspects, and available features according to a specific user in a specific context of use (Castillejo, 2015). Therefore, the ability of mobile devices to exploit the context-awareness make them a perfect environment to implement the methods and techniques of the AUIs approach. In particular, AUIs were identified as one of the promising solutions for addressing different usability challenges in numerous research works.

This chapter aims to discuss how the AUIs approach can be exploited in order to address the identified usability challenges of mobile ERP apps in the previous chapter, and thus, answering the research question number four:

RQ. 4) How can the AUIs approach be exploited to address the identified usability challenges of mobile ERP apps?

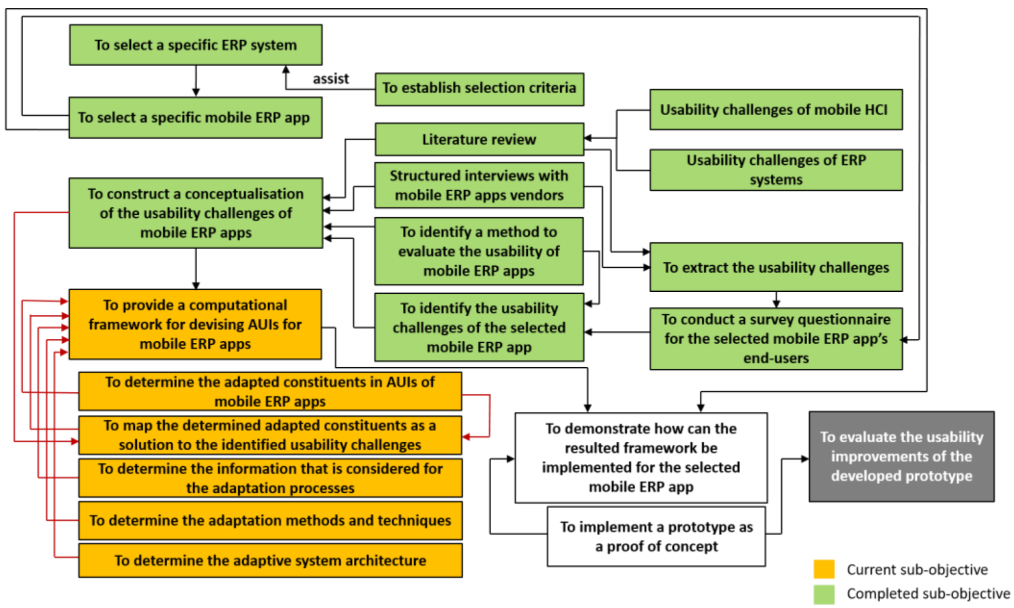


Fig. 4.1: Research objectives status; sub-objectives that will be achieved in Chapter 4

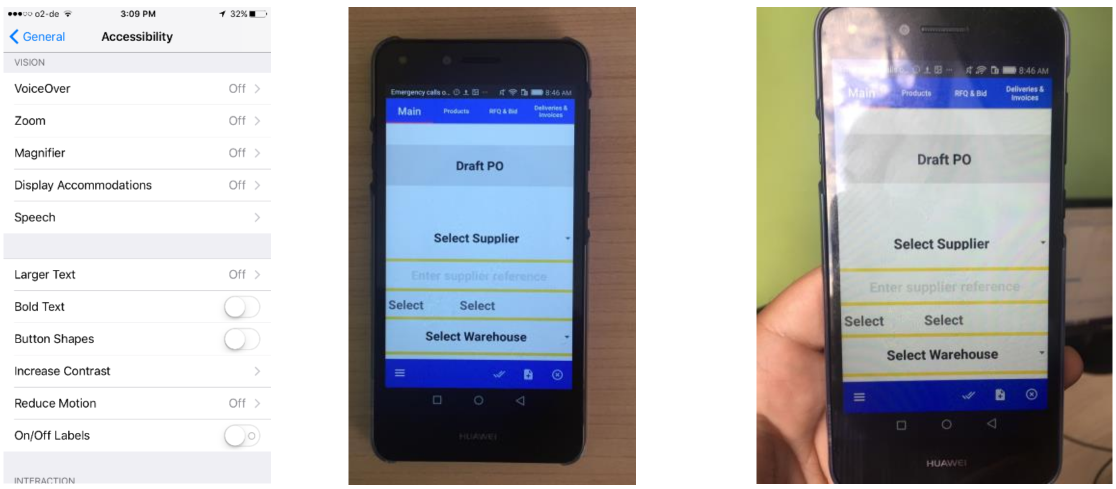
Answering the abovementioned research question requires an elaboration of a computational framework for devising AUIs for mobile ERP apps. Therefore, the elaboration of this framework and its components will be discussed in this chapter, which consists of four main sections. The first section provides an overview of the adapted systems, which is followed by an integrated overview of AUIs. Thereafter, the elaboration of the desired computational framework and its components will be discussed in section three, and followed by a summary of this chapter.

4.1 Overview of Adapted Systems

In computer systems, the systems that are used without any interaction possibilities are regularly called batch systems or non-interactive systems. In turn, systems that provide the possibility to be adjusted by the end-user are called flexible or malleable systems which rely on an adaptation of the systems (Reichenbacher, 2004).

In the literature, two variations of systems' adaptation can be found, namely adaptable and adaptive systems; the adaptable systems provide the end-user with tools to adjust the system characteristics and parameters, and thus, the adjustments are made by the end-user's explicit interference. In turn, the adaptive systems refer to the systems that are able to change their own characteristics automatically according to the end-user's needs, and thus, the interference is implicit (Oppermann, 1994; Reichenbacher, 2004). Figure 4.2 depicts an example of the difference between adaptable and adaptive systems.

However, the concept of adaptivity does not just rely on the end-user's needs; it also relies on other related information of the object that will be adapted, such as the associated environment, and the task that is being performed.



Adaptable	Adaptive Screen brightness is adapted to the illumination of the living room	Adaptive Screen brightness is adapted to the illumination of the direct sunlight

Fig. 4.2: Examples of adaptable and adaptive systems

In 2001, a comparison between adaptive and adaptable systems was proposed by (Fischer, 2001) based on six different concepts, which are: definition, knowledge, strengths, weaknesses, mechanisms required, and application domains. Table 4.1 summarises this comparison.

	Adaptive	**Adaptable**
Definition	dynamic adaptation by the system itself to current task and current user	user changes (with substantial system support) the functionality of the system
Knowledge	contained in the system; projected in different ways	Knowledge is extended
Strengths	little (or no) effort by the user; no special knowledge of the user is required	user is in control; user knows her/his task best; system knowledge will fit better; success model exists
Weaknesses	user has difficulty developing a coherent model of the system; loss of control; few (if any) success models exist (except humans)	systems become incompatible; user must do substantial work; complexity is increased (user needs to learn the adaptation component)

Mechanisms Required	models of users, tasks, and dialogs; knowledge base of goals and plans; powerful matching capabilities; incremental update of models	layered architecture; domain models and domain-orientation; “back-talk” from the system; design rationale
Application Domains	active help systems, critiquing systems, differential descriptions, user interface customization, information retrieval	information retrieval, end-user modifiability, tailorability, filtering, design in use

Tab. 4.1: Comparison between adaptive and adaptable systems (Fischer, 2001, p. 77)

Furthermore, (Reichenbacher, 2004) demonstrated the basic structure of any adaptive system as can be seen in Figure 4.3. Based on this demonstration, this type of system is based on an adaptive object that is adapted to an adaptation target through an adaptation method. Thus, this method will need information about the adaptation target in order to achieve a successful adaptation.

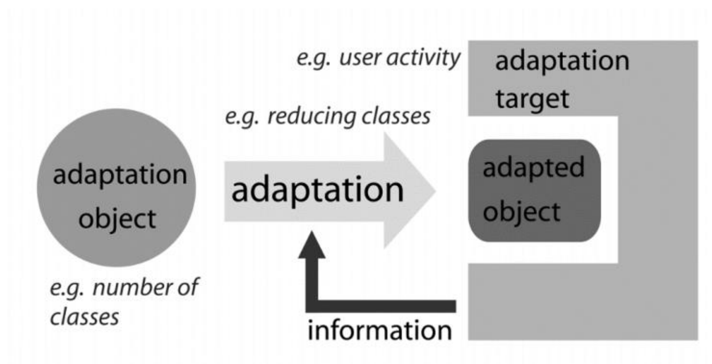


Fig. 4.3: Basic principle of adaptation systems (Reichenbacher, 2004, p. 22)

(Dieterich et al., 1993) determined four stages in the adaptation process, namely initiative, proposal, decision, and execution. Besides, they determined two possible agents to perform or control these four stages, which are the user and the system. In the depicted example in Figure 4.4 the system initiates, proposes, and executes an adaptation after the user acceptance upon the action is taken.

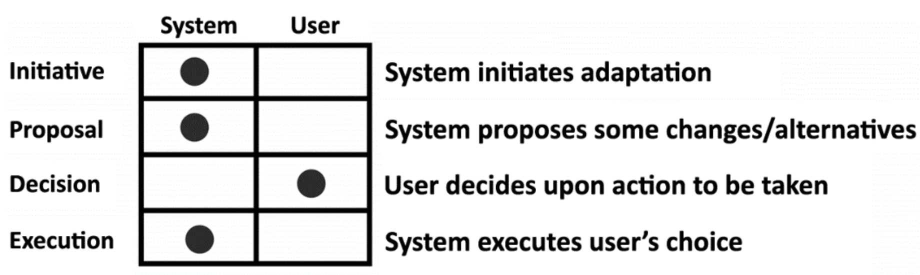


Fig. 4.4: Stages of the adaptation process and their agents that perform and control it (Dieterich et al., 1993, p. 15)

Based on this determination, 16 combinations can result from combining 2 agents with 4 stages. Some of them are not reasonable, such as making the user execute an adaptation process. Figure 4.5 depicts the most interesting adaptation types. Accordingly, the self-adaptation is the type of main interest in this research study.

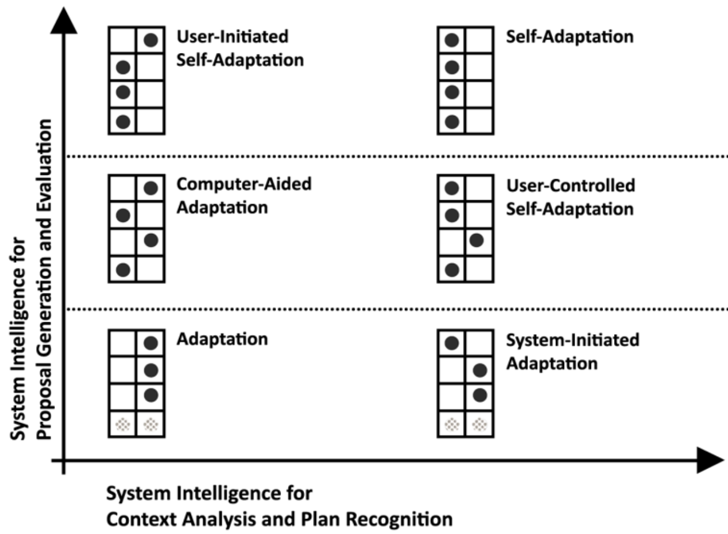


Fig. 4.5: Most interesting types of adaptation (Dieterich et al., 1993, p. 17)

AUIs are considered a part of adaptive systems (Benyon, Innocent, & Murray, 1987), and these types of UIs enable self-adaptation for their components which will be discussed in the next section.

4.2 Adaptive User Interfaces (AUIs)

4.2.1 Overview and Definitions

UI is considered an important layer of software applications, due to its key role in connecting the end-user to the application functionality (Akiki et al., 2015). Besides, it was observed that with the growth of functionality in software applications, GUIs become more complex (Bunt, Conati, & McGrenere, 2004), and this is one of the reasons why the UIs of ERP systems and their extensions such as mobile ERP apps are complex.

Earlier UIs were static, which meant the UI was built by the system designer and the end-user had to learn how to use it (Dieterich et al., 1993). Therefore, these types of UIs have a lack of handling the differences between end-users' preferences, skills, experience, and personalisation (Alvarez-Cortes, Zayas-Perez, Zarate-Silva, & Uresti, 2007; Bunt et al., 2004; Gajos, Czerwinski, Tan, & Weld, 2006). Consequently, both types of adaptations (i.e. adaptable and adaptive) were introduced to address the issues and limitations of static UIs (Bunt et al., 2004).

In adaptable UIs, the developers attempt to provide customisation tools to the end-users such as colour palettes and screen resolution tools to adapt the components of UIs (malleable, flexible UIs) (Castillejo, 2015). Figure 4.6 demonstrates an example of adaptable UIs through adapting the paragraphs' text sizes. In this example, the adaptation process will be triggered based on explicit interference by the end-user in selecting the desired text size from the text sizes menu.

Based on the identified concepts in Table 4.1, and in particular the concepts of definition, strength, and application domains, AUIs were selected to address the identified usability challenges of mobile ERP apps in the previous chapter.

As can be seen from Figure 4.7, AUI is a sub component of intelligent interfaces, since the latter are devised from the integration of an AUI with both an intelligent help system (IHS) and with an intelligent tutoring system (ITS) (Dieterich et al., 1993).

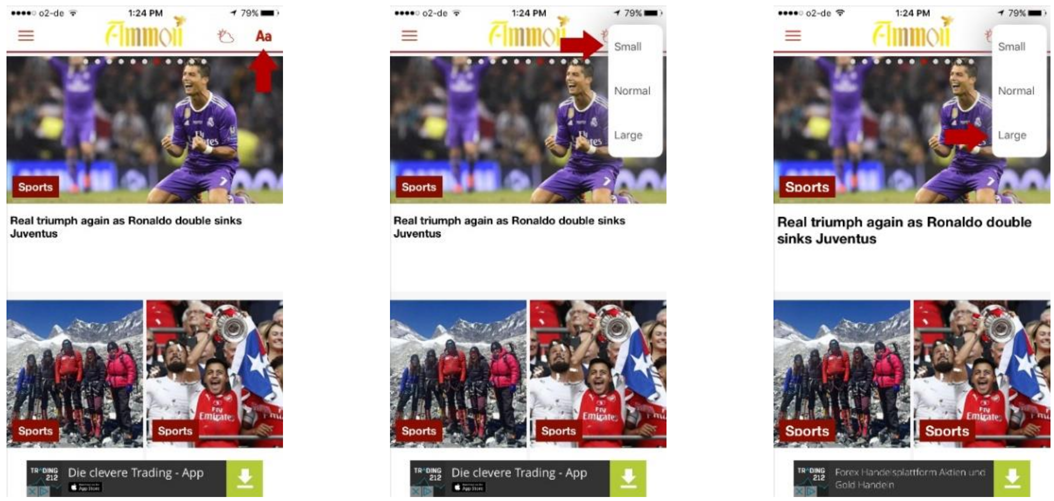


Fig. 4.6: Example of adaptable UIs (Ammon News mobile app, 2017)

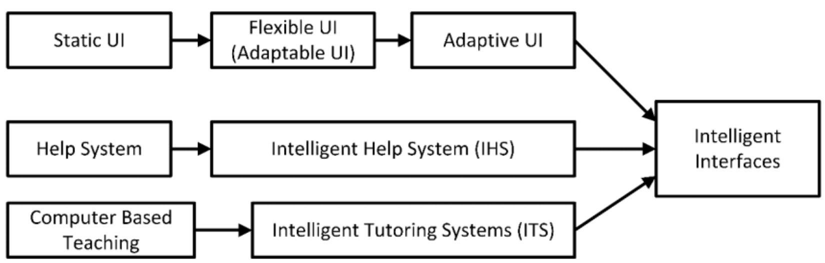


Fig. 4.7: AUIs and Intelligent Interfaces adapted from (Dieterich et al., 1993, p. 14)

Intelligent user interfaces (IUIs) research field is considered one of the HCI research fields which is comprised by a number of disciplines as depicted in Figure 4.8. The main aim of these types of interfaces is to improve the interaction and communication channel between the end-user and the machine (Alvarez-Cortes et al., 2007).

Adaptation is considered one of the core topics in the artificial intelligence (AI) research area, and many IUIs are oriented to employ AI techniques to perform adaptation (Alvarez-Cortes et al., 2007). However, adaptation research in software applications has three main threads which are important to this research study, namely adaptive systems, adaptive user interfaces, and adaptive hypermedia (AH) (Reichenbacher, 2004).

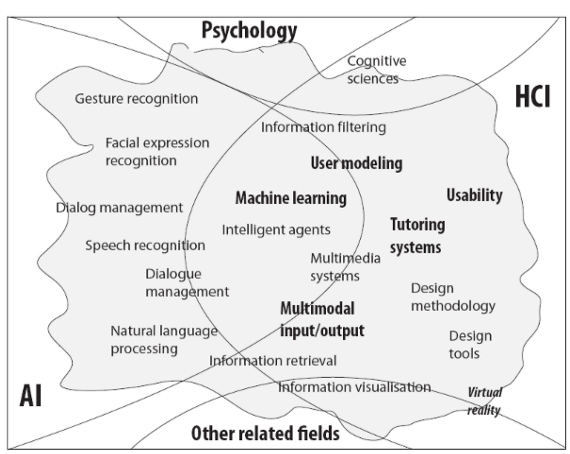


Fig. 4.8: Multi-disciplinary research area (Alvarez-Cortes et al., 2007, p. 52)

Regarding the adaptive systems, (Benyon & Murray, 1993a) defined adaptive systems as systems that have the ability to alter aspects of their structure, functionality, or interface in order to accommodate the different needs of individuals or groups of users and their changing needs over time. While (Jameson, 2009) defined a user-adaptive system as:

> "*an interactive system that adapts its behavior to individual users on the basis of processes of user model acquisition and application that involve some form of learning, inference, or decision making*" (Jameson, 2009, p. 2).

Regarding the AH, (Brusilovsky, 1996) stated that the research area of AH is within the user-adaptive systems, and it aims to increase the functionality of hypermedia by personalising it. In addition, this personalisation is realised based on building a model of goals, preferences and knowledge of the individual user, and it is used throughout the interaction for adaptation to the needs of that user.

Regarding the AUIs, several definitions can be found in the literature for AUIs. For instance, AUIs have the ability to change their components based on the end-user's needs, characteristics, knowledge, behaviour, and preferences (Dieterich et al., 1993). Figure 4.9 depicts the contents of the proposed user model by (Dieterich et al., 1993) that influences the adaptation process to provide an individualised UIs.

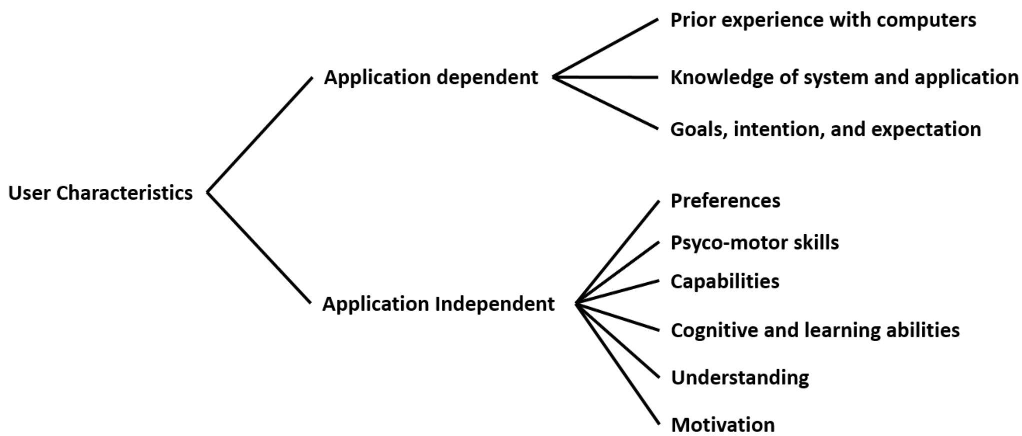


Fig. 4.9: Contents of a user model (user characteristics) (Dieterich et al., 1993, p. 31)

However, the proposed user model (characteristics) by (Dieterich et al., 1993) is not the only source of information that can influence the adaptation process, and this can be inferred from the Haas and Hettinger definition of the AUI:

> "*An adaptive interface can be defined as a set of displays, controls, a human operator, and an underlying software system that is capable of modifying the portrayal of information, the affordance of control, and the allocation of tasks to be performed, as a function of the state of the operator, the state of the system, and the environment in which both the operator and the system are immersed*" (Haas & Hettinger, 2001, p. 1).

Based on the proposed definition of the adaptive systems by (Benyon & Murray, 1993a) and the abovementioned definitions of AUIs, it can be inferred that an AUI is a part of an adaptive system (Singh, 2011). Regarding the AUIs and AH, there are some semantic differences in the terminology between AUIs and AH, but there is a consensus regarding the main structural components that are involved in the adaptation process (Reichenbacher, 2004). Furthermore, AUIs is a broader area that includes all kinds of UIs, therefore, AH belongs to this field.

Besides, AH principles and its methods and techniques can be exploited for devising AUIs.

Based on the abovementioned clarifications, the concept of adaptive is the focus of this research study, and in particular, the AUIs.

Research on AUIs emerged in the early 1980s and has been an active research area in the field of HCI (Gajos et al., 2006; Gullà, Cavalieri, Ceccacci, Germani, & Bevilacqua, 2015; Singh, 2011), due to their ability to address some of the usability issues of software systems that stem from their UIs (Pombinho, Carmo, & Afonso, 2015).

Recently, the AUIs research domain has gained a new wave of prominence, particularly, in the domain of mobile apps development, and the reasons behind this prominence are:

- Mobile UIs suffer from some usability challenges, due to their hardware specifications which impact their usability such as small screen size (Adipat & Zhang, 2005; Hoehle & Venkatesh, 2015). The AUIs approach is considered one of the promising solutions for reducing the complexity of software systems by addressing some of their usability challenges (Dieterich et al., 1993; Letsu-Dake & Ntuen, 2009). Consequently, AUIs could be utilised to reduce the complexity of mobile apps that stem from their hardware specifications, and thus, improving their usability.
- Mobile platforms are considered a fertile environment to employ adaptation methods and techniques, due to their context-awareness and mobility (Paterno, 2013).
- Mobile apps are being used by heterogeneous end-users and they are operated in a variable context (Paterno, 2013). Thus, building multiple UIs manually to accommodate this heterogeneity and variability is difficult, costly, and might not be known at design-time (Akiki et al., 2015). AUIs have the ability to accommodate such heterogeneity and context variability at a running time (Akiki et al., 2015; Paterno, 2013).

However, adapting UIs to the context of use and end-users' preferences is considered one of the most challenging questions of mobile computing (Mitrovic, Royo, & Mena, 2005). Therefore, this research study attempts to answer this question in this chapter through proposing a computational framework for devising AUIs for mobile ERP apps.

4.2.2 Benefits and Disadvantages of AUIs

Many researchers confirmed the ability of AUIs to improve the usability of software systems, such as (Akiki, 2014), (Singh, 2011), (Reichenbacher, 2004), and (Letsu-Dake & Ntuen, 2009). This confirmation stems from the benefits that can be gained from AUIs regarding the usability after achieving the AUIs goals, and these goals are (Dieterich et al., 1993):

1. Presenting an easy, efficient, and effective UI.
2. Reducing the complexity of software systems to make it usable.
3. Presenting what the user wants to see.
4. Speeding up usage.
5. Simplifying usage.
6. Fitting to the heterogeneous user groups and considering the increasing experience of the end-user.

In addition, other goals might be found in the literature such as (Browne, Totterdell, & Norman, 1990; Stephanidis, Karagiannidis, & Koumpis, 1997):

1. Minimising end-user’s errors.
2. Maximising end-user’s satisfaction.
3. Reduction of computational resources.

Moreover, AUIs attempt to solve some of the problems that cannot be handled suitably by the traditional UIs such as (Alvarez-Cortes et al., 2007; Cortes, Zirate, Uresti, & Zayas, 2009; Shneiderman, 1997):

1. **Create personalised systems**

   AUIs can provide a personalised method of interaction based on recognising the end-user’s behaviour patterns, preferences, and working methods within the software application. This personalisation aims to facilitate the communication between the end-user and the software application.

2. **Filtering problems and information over-load**

   AUIs can reduce the information overflow related to finding information in complex systems or large databases by filtering out irrelevant information, and thus, reducing the end-user cognitive load.

3. **Provide help for new programs**

   AUIs can correct the end-user’s misconceptions or inappropriate usage of software applications by explaining new concepts and providing information to facilitate the required tasks.

4. **Take charge of tasks on behalf of the user**

   AUIs can automate the end-user’s routine tasks by observing the end-user’s current task, understand it and recognise the end-user’s intent, and then automate it. Thus, allowing the end-user to focus on other activities.

5. **Supporting other interaction mechanisms**

   AUIs can provide multi-modals interfaces that aim to find new paradigms for input/output interaction between systems and end-users, in particular, for the usage of complex computational systems by people with disabilities.

However, research has shown several disadvantages of AUIs that might negatively impact and violate many of the positive usability principles of a software system (Höök, 2000), and these disadvantages are (Höök, 2000; Tsandilas & Schraefel, 2004):

- **Coping with uncertainty**

  User goals cannot be predicted with complete certainty, and thus, these goals and the parameters of a user model need to be estimated with some probability (Tsandilas & Schraefel, 2004).

- **Transparency and predictability**

  Adaptive systems struggle with transparency, due to the lack of providing an understanding of their inner workings of adaptation processes to their end-users (Höök, 2000). While predictability disadvantage stems from the inconsistency between the end-users input and output (Höök, 2000).

- **Controllability**

  The controllability disadvantage stems from the failing of AUIs in providing their end-users with a feeling of control over the process of adaptation, and thus, reducing the effect of incorrect system decisions (Tsandilas & Schraefel, 2004).

- **Privacy and trust**

  Adaptive systems containing a user model, and these systems force their end-users to accept that the system holds a representation of some aspect of them. Some AUIs require from their end-users to share their preferences with a user community, which leads to privacy issues (Höök, 2000).

4.3 Computational Framework for Devising AUIs for Mobile ERP Apps

One of the main sub-objectives of this research study is to provide a computational framework to guide the developers of mobile ERP apps in devising AUIs, and this framework should have the ability to address the identified usability challenges in the proposed construct in Table 3.18. Besides, a framework can be formally defined as a reusable, semi complete structure that when specialised produces custom applications to reduce investments and development costs, and its components are extensible for specific domains (Motti & Vanderdonckt, 2013). Therefore, the targeted framework should fulfil these further objectives.

In order to elaborate the targeted framework five sub-objectives are required to be achieved, namely:

1. To determine the adapted constituents (components) in AUIs that can be adapted in mobile ERP apps.
2. To map the determined adapted constituents in the previous objective as a means to address the identified usability challenges in Chapter 3.
3. To determine the knowledge models that can be used in the adaptation processes in the proposed computational framework.
4. To determine the adaptation methods and techniques that can implement the determined adapted constituents in the first objective.
5. To determine an adaptive system architecture that can be used in the context of this research study.

(Dieterich et al., 1993) proposed five fundamental questions that need to be answered in order to determine the design space for AUIs, which are:

1. Who should adapt and what should their role be in the adaptation process?
2. What levels of interaction should be adapted (for example presentation or functionality)?
3. What information should be considered when looking for opportunities for adaptation?
4. What goals should be furthered by the chosen level of adaptation when triggered by the information under consideration?
5. When should the changes be made?

However, (Brusilovsky, 1996) proposed a classification for AH methods and techniques that can be seen in Figure 4.10. Based on this classification, the identified dimensions are quite typical for the analysis of adaptive systems in general, and this can be noticed in the proposed questions by (Dieterich et al., 1993).

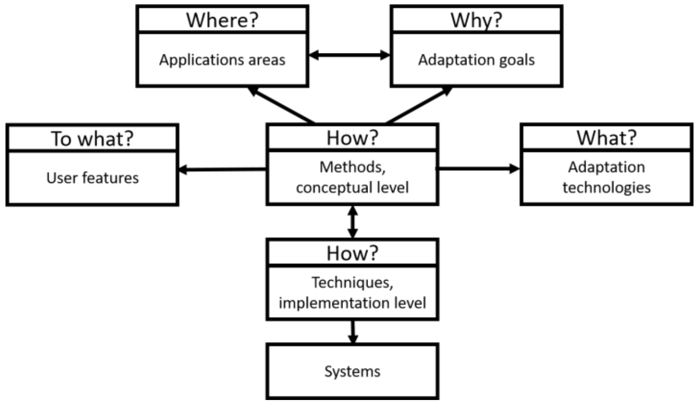


Fig. 4.10: Proposed classification for AH methods and techniques by (Brusilovsky, 1996, p. 3)

Furthermore, (Knutov, Bra, & Pechenizkiy, 2009) determined the sequence in which the determined questions by (Brusilovsky, 1996) should be asked and answered in order for occurring the adaptation process successfully. Figure 4.11 depicts this proposed sequence.

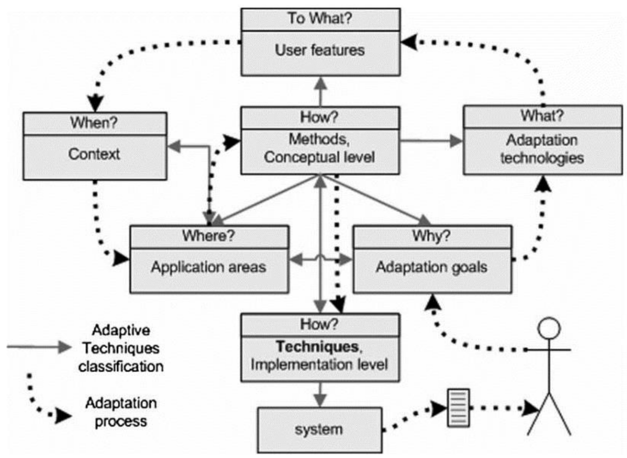


Fig. 4.11: Classification of AH methods and techniques, adaptation process highlights (Knutov et al., 2009, p. 8)

Based on the previously highlighted questions models, the proposed framework should have the ability to answer the following questions regarding mobile ERP apps:

1. **Who should adapt? (Who?)**

   This question aims to determine who triggers or initiates the adaptation process, and since AUIs were selected in this research study to address the identified usability challenges of mobile ERP apps, the mobile ERP app is the agent who initiates the adaptation process in the proposed computational framework.

2. **Why do we need adaptation? (Why?)**

   This question aims to determine the goal of performing a specific adaptation process, and this goal should address one or more of the identified usability challenges in Table 3.18.

3. **What can we adapt? (What?)**

   This question aims to determine the adapted constituents for the adaptation processes. The identified adapted constituents that can take a place in AUIs for mobile ERP apps will be presented in sub-section 4.3.1.

4. **What can we adapt to? (To What?)**

   This question aims to determine the knowledge models that are required for an adaptation process. The proposed knowledge models that can be used to perform adaptation processes successfully in mobile ERP apps will be presented in sub-section 4.3.2.

5. **When can we apply adaptation? (When?)**

   This question aims at determining the state in which the adaptation process can be performed, which is at a running time in the proposed computational framework, and it is triggered by a specific event in the context of use.

6. **Where can we apply adaptation? (Where?)**

   This question aims at determining in which application and system components the adaptation processes can take place. Thus, sub-section 4.3.4 will illustrate the determined application components where the adaptation processes can occur, and present the proposed adaptive system architecture that illustrates in which system components the adaptation processes can be performed.

7. **How do we adapt? (How?)**

   This question aims at determining in which way (methods and techniques) the adaptation can be performed. The taxonomy of these methods and techniques will be presented in sub-section 4.3.3.

Thus, each of the abovementioned questions will be discussed in detail in the following sub-sections.

4.3.1 Adapted Constituents (What?)

This sub-section attempts to answer the following research question:

> *RQ. 4.1) What are the adapted constituents in AUIs that can be used for mobile ERP apps?*

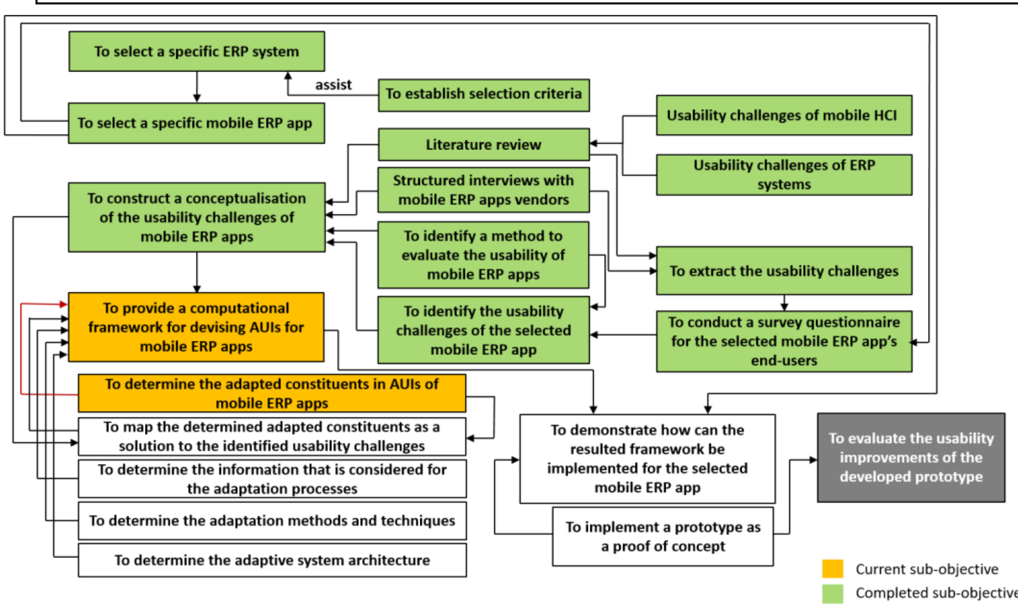


Fig. 4.12: Research objectives status; identifying the adapted constituents in AUIs for mobile ERP apps

(Dieterich et al., 1993) determined the adapted constituents in AUIs which mean the parts of a system that can be adapted in order to answer the question: “What can we adapt?” and to achieve the aforementioned goals of AUIs in sub-section 4.2.2, and these constituents are:

1. The ability to correct errors and inaccurate input.
2. Providing active help.
3. Providing presentation of input to the end-users by switching among several predefined interaction styles.
4. System presentation of information by filtering or by switching among presentation styles.
5. Access to capabilities.
6. Task simplification by automating the routine tasks for the individual user.

In the demonstration phase of this research study, the Android platform was selected to develop a prototype as a proof of concept that aims to demonstrate the identified components of the proposed computational framework in this section. This selection was based on the gained experience by the researcher in developing mobile apps for such a platform. In addition to the obtained results from the conducted structured interviews with mobile ERP vendors, and the survey questionnaire for mERP App’s end-users, which have indicated that the Android OS is frequently used in operating mobile ERP apps

In Android-based applications, activities are considered one of the fundamental application components that enable the end-users to interact with the app functionalities and navigate within it (Android, 2017a). While layout defines the visual structure for a UI, such as the UI for an activity or app widget (Android, 2017c). A layout describes the syntactic sequence of human-computer interaction through UI components, and the sequence of actions that should be performed in order to achieve a specific goal. Therefore, layouts in the Android-based applications are referred to the dialogs in the proposed computational framework.

In the proposed computational framework, three application components of mobile ERP apps are adapted at a running time based on the context of use, which are: activities, dialogs, and UI widgets. Therefore, the adaptation in the proposed computational framework is understood as follows:

1. Invoking the appropriate activity based on the current context of use.
2. Invoking the appropriate dialog based on the current context of use for the invoked activity.
3. Adapting the UI widgets based on the current context of use.

The abovementioned adaptation dimensions are used in the proposed computational framework to realise the determined adapted constituents by (Dieterich et al., 1993) in AUIs.

After reviewing the literature, three prominent types of adaptation can be distinguished in order to realise the abovementioned adapted constituents and dimensions, namely content adaptation, presentation adaptation, and navigation adaptation (Brusilovsky, 1996; Dieterich et al., 1993; Knutov et al., 2009; Reichenbacher, 2004; Zarikas, 2007).

- **Content adaptation**

  The content adaptation aims at adapting the information content in order to realise personalisation, and to view the appropriate information for a specific end-user and/or a specific device for a specific activity in a specific environment (context of use) (Reichenbacher, 2004; Zarikas, 2007). Thus, the information content is adapted according to the end-user's goals, knowledge, own preferences and needs, and the actions that the end-user acts on the interface (Gullà et al., 2015; Knutov, 2012).

- **Presentation adaptation**

  The presentation adaptation aims at providing the most appropriate presentation and visualisation of the UI's components for a specific end-user and/or a specific device for a specific activity in a specific environment (context of use) (Paterno, 2013; Ramachandran, 2009; Reichenbacher, 2004; Zarikas, 2007). However, this type of adaptation is not totally independent from the content adaptation and the navigation adaptation, but the latter types are influenced by some of the methods and techniques of the presentation adaptation (Knutov et al., 2009). Thus, this influence will be clearly demonstrated in the proposed taxonomies for the adaptation methods and techniques for mobile ERP apps in sub-section 4.3.3.

- **Navigation adaptation**

  The navigation adaptation aims at assisting the end-users in finding the correct path within the app in order to accomplish a specific goal (task) (Ramachandran, 2009). This type of adaptation has proved its effectiveness in terms of browsing and learning efficiency (Ahmad, Basir, & Hassanein, 2004). In this adaptation type, the navigational links are adapted and presented to the end-users according to their current goal, knowledge about the task, and other relevant characteristics (Ramachandran, 2009).

At this point, the adapted constituents in AUIs and the adaptation types that are able to realise these adapted constituents have been identified. Therefore, the following research question can be answered:

> *RQ. 4.2) How can the determined adapted constituents in research question 4.1 be exploited as a means to address the identified usability challenges of mobile ERP apps in Table 3.18?*

By answering the abovementioned research question, the second identified objective for elaborating the targeted computational framework for devising AUIs for mobile ERP apps will be achieved.

Based on the definition of the aforementioned adaptation types and their explained objectives, these types of adaptation can be employed to address the identified usability challenges in the proposed construct in Table 3.18. Table 4.2 illustrates the mapping of the identified adaptation types as a solution to the identified usability challenges of mobile ERP apps.

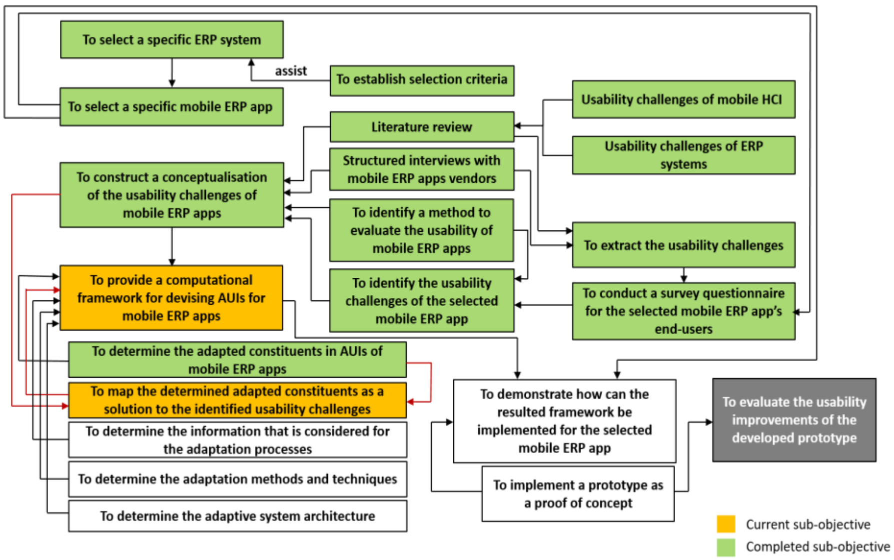


Fig. 4.13: Research objectives status; mapping the identified adapted constituents in AUIs as a solution to the identified usability challenges of mobile ERP apps

	Technology					**Environment**			**User**		
Usability challenge of mobile ERP apps	Limited screen size	Limited capability of battery power	Data entry methods	Mobile data connectivity	Security	Activity (motion)	Ambient luminance	Ambient noise	Preferences	Physiological characteristics	Knowledge
More time required compared with the conventional approach to complete a task	C,P,N	C,P,N	C,P	C	C	C,P,N	C,P,N	C,P,N	P	C,P	C,P,N
Stubborn to the context of use variability (needs to be adaptive)	C,P,N	C,P,N	C,P	C	C	C,P,N	P	P,N	P	C,P	C,P,N
Lack of correction and validation techniques that suit the context of use			C,P			C,P		C,P			C,P
Lack of intuitive learning											C,P,N
Distraction	P,N		P			C,P,N	C,P,N	C,P,N			
Bloated UIs	C,P,N	C		C	C	C,P,N	P	C,P,N			C,P,N
Multitude of interaction steps	C,P,N	C,P	C	C,P	C,P	C,P,N	P,N	C,P,N	C,P	C,P	C,P,N
Memorability	C,P					C,P,N		C,P,N	C,P,N		
Findability of the desired information and functionalities	C,P,N		C	P,N		P,N	P,N	P,N	P,N	P,N	C,P,N
Contextual guidance	P,N					P,N	P,N	C,P	P,N		P,N
Contextual help	C,P					C,P	P	C,P	C,P		C,P,N
Task completion	C,P,N	C,P	C,P	C	C,P	C,P,N	C,P,N	C,P,N	C,P	P,N	C,P,N
Personalisation			P						C,P	C,P	C,P
Security issues			C,P		C,P				C,P		

Tab. 4.2: Adaptation types as a solution for the usability challenges of mobile ERP apps. C: Content adaptation, P: Presentation adaptation, N: Navigation adaptation (Omar & Marx Gómez, 2017a, p. 83)

In the literature, different methods and techniques can be found to realise each one of the identified adaptation types, and these methods and techniques utilise different knowledge resources in order to realise adaptation processes successfully. Accordingly, the next sub-section presents the proposed knowledge models that will be utilised to realise the adaptation processes successfully for mobile ERP apps in this research study.

4.3.2 Knowledge Models Considered in AUIs Processes (To What?)

This sub-section attempts to determine the knowledge models that will be utilised for the adaptation processes in the context of this research study, and thus, answering the following research question:

RQ. 4.3) What is the information required for realising the adaptation processes successfully in the context of this research study?

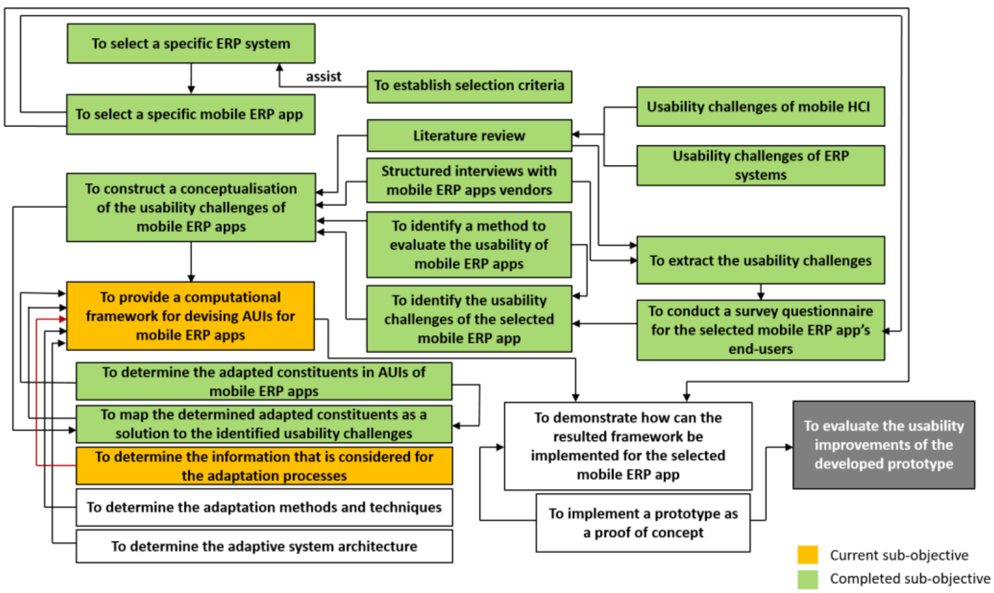


Fig. 4.14: Research objectives status; determining the knowledge models that will be utilised for adaptation processes in the context of this research

In the AUIs, the adaptation processes are influenced by various essential sources of knowledge (information) in order to adapt the components of the UIs successfully. These knowledge sources can be represented in the form of models which can be implicitly contained in the interface program code or explicitly defined as a knowledge base or part of one (Dieterich et al., 1993).

After an intensive reviewing of the literature, it has been noted that there are several models that can be utilised for devising AUIs. Table 4.3 illustrates the related works to AUIs that were analysed in this research study and the utilised models in these works.

In AUIs research, at least three models are proposed and utilised to perform adaptation processes, namely a user model, a task model, and a dialog model (Dieterich et al., 1993). Besides, sometimes an application model is considered. In addition, an adaptation model and its elements such as levels and methods of adaptation are often included in connection with a dialog model (Dieterich et al., 1993). As can be seen from Table 4.3, the most frequently utilised models for devising AUIs are: a user model, a task model, a dialog model, a domain model, an adaptation model, a presentation model, a device model, and a context model.

Author(s)	Domain (solution)	Models															
		User	Task	Dialog	Domain	Adaptation	Application	Presentation	Interaction	Platform	Device	System	Context	Environment	Goal	Resource	Group
(Dieterich et al., 1993)	Survey of the state of the art in AUIs	✓	✓	✓	✓	✓											
(Puerta, 1997)	Model-Based Interface Designer environment	✓	✓	✓	✓		✓	✓									
(Keeble, Macredie, & Williams, 2000)	Agent-based human-computer interaction and AUIs	✓			✓				✓								
(Ghédira, Maret, Fayn, & Rubel, 2002)	AH	✓			✓												
(Menkhaus & Pree, 2002)	Mobile computing		✓					✓		✓							
(Gajos & Weld, 2004)	Automated design tools	✓			✓						✓						
(Reichenbacher, 2004)	Mobile cartography	✓	✓		✓	✓						✓	✓				
(Vasilyeva, Pechenizkiy, & Puuronen, 2005)	eHealth	✓	✓			✓								✓			
(Zarikas, 2007)	Structuring the decision making of an adaptive or intelligent interface.	✓				✓							✓				
(Casas et al., 2008)	Intelligent systems	✓							✓				✓				
(Singh, 2011)	AUIs for ERP systems	✓	✓	✓	✓			✓									
(Knutov, 2012)	AH	✓			✓	✓	✓	✓					✓		✓	✓	✓
(Akiki, 2014)	Enterprise apps	✓	✓		✓	✓				✓				✓			
(Castillejo, 2015)	Mobile apps	✓				✓					✓		✓				
(Feng & Liu, 2015)	Mobile LBS	✓	✓		✓			✓	✓								
(Zheng, Ormandjieva, & Fan, 2015)	Mobile E-commerce	✓	✓		✓									✓			

Tab. 4.3: Related works to AUIs that were analysed and the models that have been utilised in them

As it stated earlier in Chapter 3, this research study exploits the concepts of context-aware computing to solve the main research problem. Therefore, the information regarding the context of use will be utilised in the proposed computational framework, and this information will be represented and stored in sub-models to form the desired context model that will be utilised to adapt the UIs' components.

- **Definitions of context and context-aware computing**

The word context is defined in the Merriam-Webster dictionary[23] as "*the interrelated conditions in which something exists or occurs*". However, this definition is considered a general one, and doesn't assist in understanding the concept of context in the computing environment (Chen & Kotz, 2000).

Regarding the computing environment, several definitions of context were introduced, and according to (Dey, 2001), these definitions can be classified into:

1. Definitions that define context by example such as (Schilit & Theimer, 1994) who refer to context as location, the collection of nearby people and objects, and the changes to those objects. From Dey's perspective, these types of definitions are difficult to apply.
2. Definitions that define context by simply providing synonyms for context, such as referring to context as the environment or situation. For instance, the definition that was provided by (Ward, Jones, & Hopper, 1997).

However, the proposed definition of context by (Dey, 2001) is considered the most popular definition in the literature which stipulates that:

> "*Context is any information that can be used to characterise the 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, 2001, p. 5).

The abovementioned definition enables application developers to easily enumerate the context components for a given application scenario, and thus, it is easy to be applied compared to the definitions that employ definitions by example, or definitions that provide synonyms (Dey, 2001). Furthermore, Dey's definition remains the most generic definition among other definitions of the context (Guermah, Fissaa, Hafiddi, Nassar, & Kriouile, 2014). Consequently, Dey's definition is adopted in this research study to construct the context model for the proposed computational framework.

Regarding the context-aware computing, the first definition for these types of software applications was introduced in 1994 by (Schilit & Theimer, 1994), which is:

> "*Context-aware computing is the ability of a mobile user's applications to discover and react to changes in the environment they are situated in*" (Schilit & Theimer, 1994, p. 23)

These types of applications adapt their components based on their usage location, the nearby people and objects, and the changes to these objects by time (Schilit & Theimer, 1994). In turn, Dey defines context-aware computing as:

> "*A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task*" (Dey, 2001, p. 5).

- **Context information**

Context information is commonly referred to as a context parameter (Dey, 2001).

[23] http://www.merriam-webster.com/dictionary/context.

"*If a piece of information can be used to characterise the situation of a participant in an interaction, then that information is context*" (Dey, 2001, p. 5).

The following example explains Dey's definition of context by illustrating when a piece of information is considered belonging to the context or not.

"*Take the canonical context-aware application, an indoor mobile tour guide, as an example. The obvious entities in this example are the user, the application and the tour sites. We will look at two pieces of information – weather and the presence of other people – and use the definition to determine whether either one is context. The weather does not affect the application because it is being used indoors. Therefore, it is not context. The presence of other people, however, can be used to characterise the user's situation. If a user is travelling with other people, then the sites they visit may be of particular interest to them. Therefore, the presence of other people is context because it can be used to characterise the user's situation*" (Dey, 2001, p. 5).

- **Categories and acquisition of context information**

Context information has been utilised in different computing domains, such as mobile computing, pervasive and ubiquitous computing, and e-commerce, and thus, each domain employs and approaches context from its viewpoint (Poulcheria & Costas, 2012). Therefore, there is a limitation of the consensus on the classification of context information (Ntawanga, Calitz, & Barnard, 2015). For instance, in the domain of mobile computing, the emphasis is on the computational information that refers to device characteristics, such as memory capacity and processing power, and network characteristics, such as latency and bandwidth. These characteristics are acquired by logical sensors, such as OS APIs. While in the domain of pervasive and ubiquitous computing, the emphasis is on the individual environmental parameter that is mostly acquired by the available physical sensors, such as location, presence, motion, and temperature (Poulcheria & Costas, 2012).

However, (Coursaris & Kim, 2006) presented a framework that provides a qualitative review of empirical mobile usability studies. As can be seen from the depicted Figure 4.15, four contextual factors were identified that impact mobile usability, namely user, environment, task/activity, and technology. These factors are tightly coupled to the context of this research study and its main objective. Besides, these factors have been widely adopted by researchers in the domain of mobile computing and context-aware computing, such as (Ntawanga et al., 2015), (Poulcheria & Costas, 2012), and (Barnard, Yi, Jacko, & Sears, 2007). Therefore, these factors will be modelled as sub-models to form the desired context model that will be utilised to realise the adaptation processes successfully in the proposed computational framework. Furthermore, each one of these sub-models has its own parameters, and each parameter has its own mechanism for acquiring information. For instance, illumination is one of the parameters of the environment model in the proposed computational framework, and acquiring information for this parameter is achieved by sensing the ambient light level through the built-in photometer sensor in the mobile device. Table 4.4 lists the utilised parameters in the related works to the context modelling, which were analysed in this research study.

In the literature, context information is classified into static and dynamic information based on the time interval that elapses before the value of the information is changed (Ntawanga et al., 2015; Poulcheria & Costas, 2011; Vieira, Caldas, & Salgado, 2011). Thus, the value of static information cannot be changed during the interaction between the end-user and the software application such as the screen size of the mobile device where the app is operated (Ntawanga et al., 2015). In turn, the value of dynamic information can be changed several times during the

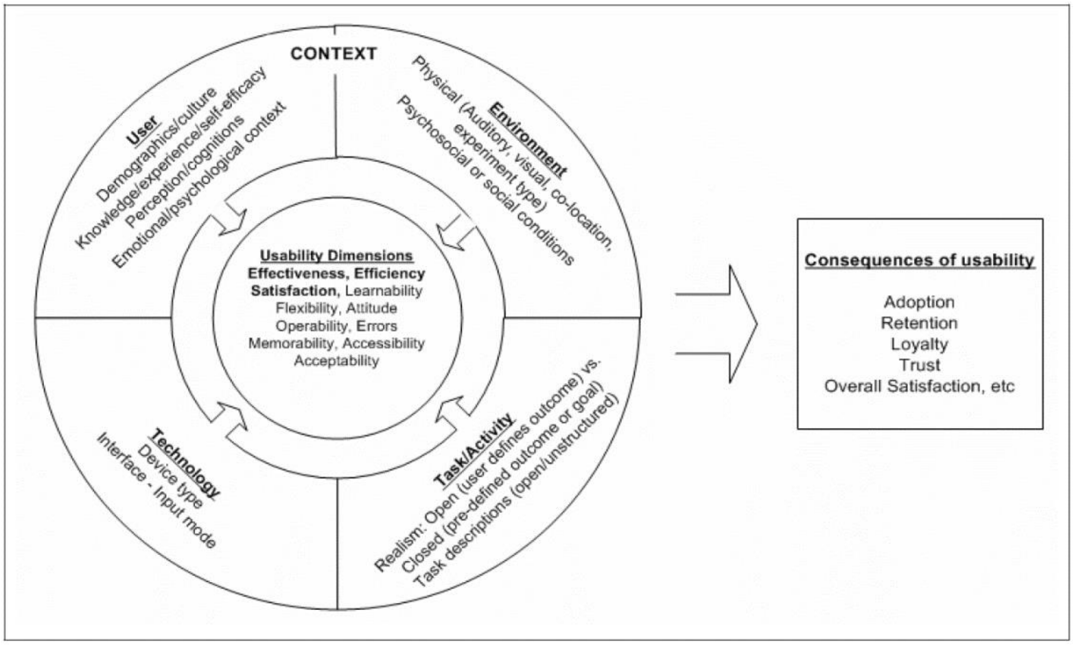


Fig. 4.15: Proposed qualitative review framework of empirical mobile usability studies by (Coursaris & Kim, 2006, p. 3)

interaction between the end-user and the software application such as the strength of internet connection (Ntawanga et al., 2015).

In addition, the information for building up the desired sub-models can be acquired explicitly or implicitly. For instance, the type of handedness (i.e. right handed or left handed) is required to be determined explicitly from the end-user in the proposed computational framework. In turn, some of the end-user's preferences can be implicitly determined through reasoning his/her interaction pattern. For instance, the ability of the app to infer the end-user's favourite item from a list of provided items through observing the frequently selected item by the end-user.

Context modelling can be achieved through several approaches, and the following are the most relevant approaches (Guermah et al., 2014):

1. **Key-value models**

   This approach is considered the simplest data structure for modelling contextual information (Guermah et al., 2014). For instance, (Schilit, Adams, & Want, 1994) modelled the context by identifying a context element (i.e. key) such as location, with an environment variable (i.e. value) such as location information. However, this approach lacks the capabilities for advanced structuring for supporting efficient context retrieval algorithms (Guermah et al., 2014).

2. **Markup scheme models**

   This approach consists of modelling contextual information as a hierarchical data structure composing of markup tags with attributes and content (Guermah et al., 2014). Some of these markup tags are defined as an extension to the standards of the Composite Capabilities/Preferences Profile (CC/PP) (Nilsson, Hjelm, & Ohto, 2000) and User Agent Profile (UAProf) (WAPFORUM, 2017). This hierarchical data structure of contextual information enables it to become reachable by the resource description framework (RDF) and XML serialisation (Guermah et al., 2014).

Author(s)	Domain (solution)	Context Parameters								
		Activity	**High-level information**	**Infrastructure (technology)**	**Location**	**Nearby resources**	**Nearby people**	**Physical environment**	**Time**	**User' parameters (user)**
(Chen & Kotz, 2000)	Mobile Computing				✓				✓	
(Jameson, 2001)	Context Modelling	✓	✓		✓					✓
(Henricksen, Indulska, & Rakotonirainy, 2002)	Pervasive Computing	✓	✓	✓		✓				
(Held, Buchholz, & Schill, 2002)	Pervasive Computing			✓						✓
(Gu, Pung, & Zhang, 2004b)	Smart Environment		✓							
(Chen, Finin, & Joshi, 2005)	Pervasive Computing	✓	✓	✓	✓	✓	✓	✓	✓	✓
(Yamabe, Takagi, & Nakajima, 2005)	Mobile Computing	✓	✓		✓			✓	✓	✓
(Barnard et al., 2007)	Mobile Computing	✓			✓			✓		
(Baltrunas et al., 2011)	Recommender Systems	✓			✓	✓		✓	✓	✓
(McAvoy, Chen, & Donnelly, 2012)	Smart Environments	✓		✓	✓		✓	✓	✓	✓
(Asif & Krogstie, 2012)	Context Modelling	✓			✓				✓	✓
(Poulcheria & Costas, 2012)	M-commerce			✓	✓			✓	✓	✓
(Castillejo, 2015)	Mobile Computing				✓	✓		✓	✓	✓
(Feng & Liu, 2015)	Mobile LBS	✓		✓	✓	✓	✓	✓	✓	✓
(Zheng et al., 2015)	Mobile E-commerce				✓			✓	✓	✓
(Ntawanga et al., 2015)	Mobile Computing			✓	✓				✓	✓

Tab. 4.4: Contextual parameters in the analysed works that are related to context modelling

3. **Graphical models**

   Unified Modelling Language (UML) is considered a popular general-purpose modelling tool which has a powerful graphical component (Guermah et al., 2014). For instance, (Bauer, Kutsche, & Ehrmanntraut, 2003) modelled the contextual aspects related to air traffic management as UML extensions.

4. **Object oriented models**

   This approach aims to adopt the main benefits of any object-oriented approach such as encapsulation and reusability, to address the problems which stem from the dynamics of the context in ubiquitous environments (Guermah et al., 2014).

5. **Logic based models**

   In this approach, a concluding expression or fact may be derived from a set of other expressions or facts through achieving logical conditions, and this process is also known as reasoning (Guermah et al., 2014). Thus, the context is identified as facts, expressions, and rules in a logical based context model. In a logic based system, the contextual information (facts or inferred from the rules in the system respectively) is added to, or updated in, or deleted from the context model.

6. **Ontology based models**

   In this approach, the context can be modelled as ontology, where context may be considered as a certain kind of knowledge (Guermah et al., 2014).

Based on the clarification of the abovementioned approaches, the logic based models approach was selected for context modelling in the proposed computational framework.

As stated in the previous section, the desired context model that will be utilised to realise the adaptation processes in the proposed computational framework consists of the following sub-models, namely user, environment, task/activity, and technology. Thus, these sub-models and their parameters will be discussed and presented in the following sub-sections.

4.3.2.1 User Model

The user model is the first sub-model of the desired context model. Information about the end-user of a software application is considered one of the key sources of information which directly influences the adaptation processes, and thus, the information in this model is processed by the adaptive system to provide an individualised UI (Dieterich et al., 1993). Such information represents the related characteristics and preferences of the end-user, and it describes the nature of his/her interaction with the system (Benyon & Murray, 1993b). A user model should be represented as a separate piece of knowledge instead of representing it hard-wired in the program code to allow dynamic update (Dieterich et al., 1993).

In the adaptive systems research, a user model can be defined from the HCI perspective and the AI perspective (Castillejo, 2015). From the HCI perspective, (Pohl, 1999) defines a user model as:

> "*an a-priori model of the users of a computer system that the system designer has in mind, or to the assumed models that users will probably develop of the system and the tasks they can perform using the system*" (Pohl, 1999, p. 1).

While from the AI perspective, (Wahlster & Kobsa, 1989) defines a user model (in the context of a dialog system) as:

"*A user model is a knowledge source in a natural-language dialog system which contains explicit assumptions on all aspects of the user that may be relevant to the dialog behavior of the system. These assumptions must be separable by the system from the rest of the system's knowledge*" (Wahlster & Kobsa, 1989, p. 3).

As can be seen from the frequent utilisation of the user model in Table 4.4, and from the abovementioned definitions, the presence of a user model in the adaptive systems is a necessity in order to support the inferences about the end-user. Thus, this supports the process of devising AUIs in terms of personalisation and individualisation. Therefore, Pohl's definition of a user model is adopted in the context of this research study.

According to (Dieterich et al., 1993), one of the first classification schemes of the user models was presented by (Rich, 1979), and this scheme was refined by (Kass & Finin, 1988), (Schwab, 1989), and (Brajnik, Guida, & Tasso, 1990). Based on these proposed schemes, three dimensions can be identified that attribute any user model, namely granularity, temporal extent, and representation (Dieterich et al., 1993). Figure 4.16 depicts the implemented approaches of these dimensions in the construction process of the desired user model in the proposed computational framework.

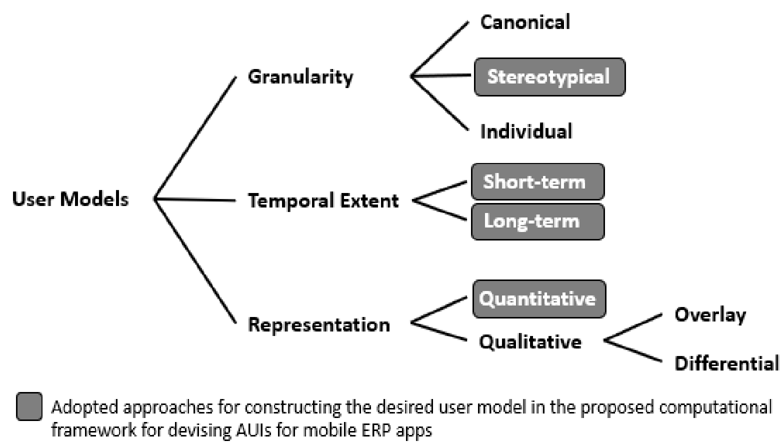


Fig. 4.16: Classified dimensions of user models adapted from (Dieterich et al., 1993)

Regarding the granularity dimension, the approaches in this dimension are classified into canonical, stereotypical, and individual. In the canonical approach, a single user model is provided for all users. While in the individual approach, a user model is provided for each individual user. In between, is the stereotypical approach which provides models for groups of users which have some characteristics in common (Dieterich et al., 1993). The canonical approach is the simplest approach among the others because it can be completed during the implementation phase by the designer. However, this approach has limited value in the systems that are being used by heterogeneous end-users. While in the individual approach, the construction of user models could be expensive and tedious to achieve. Therefore, the stereotypical approach is often adopted to construct a user model (Bodendorf, 1990; Cote, 1990; Dieterich et al., 1993; Mason & Thomas, 1984). Based on these clarifications, the stereotypical approach was employed for constructing the user model in the proposed computational framework, due to:

1. The heterogeneity of the end-users of mobile ERP apps which excludes the opportunity of using the canonical approach.
2. The stereotypical approach is simpler than the individual approach regarding the construction of the user model since mobile ERP apps are being used by many end-users.

Regarding the temporal extent dimension, this dimension describes the temporal extent of data that can be acquired during a session for the user model, and thus, the extent of the acquired data can be classified into short-term extent or long-term extent. Regarding the short-term extent, the data remains in the current session or context of use. While in the long-term extent, the acquired data remains beyond the current session or context of use, and it is saved on a permanent storage medium. Consequently, both classifications were considered in the user model in the proposed computational framework, due to the following reasons:

1. Regarding short-term data, mobile ERP apps are operated in a variable context, and thus, the data of some aspects of mobile ERP apps' end-users need to be saved to a short extent. For instance, the data regarding the interaction of the end-user with the app in a current context of use.
2. Regarding the long-term data, the data of some aspects of mobile ERP apps' end-users need to be saved to a long extent, such as thumb characteristics, hand type, and visual acuity.

Regarding the representation dimension, this dimension represents the knowledge of the end-user through a quantitative model or a qualitative model. The quantitative model contains data such as error rate, the number of help requests, or the amount of time that was spent in completing a specific task by as specific end-user. In turn, the qualitative model represents the end-user's knowledge through the overlay models and the differential models. In the overlay models, the end-user's knowledge is measured relatively to the expert end-user. While the differential models contain the differences of the end-user's knowledge.

In adaptive systems research, several researchers pointed out the properties that can be used to describe the desired user model in their artefacts. Table 4.5 lists the end-user properties that were considered in the related works to AUIs, which were analysed in this research study. However, it should be noted that the user model sometimes covers the context model's functionality, or vice versa (Zarikas, 2007), and thus, it has been included within the summarised properties in Table 4.5.

In the proposed computational framework, the following end-user parameters are considered in the desired user model in order to realise personalisation:

1. **Physiological characteristics**

   The information about this parameter represents the general physiological characteristics of the end-user, such as eye colour, height, and weight (Golemati, Katifori, Vassilakis, Lepouras, & Halatsis, 2007). However, the following physiological characteristics are considered in the user model for the proposed computational framework:

   - **Thumb characteristics**

     Thumb characteristics such as circumference and length are considered parameters of the desired user model to determine the most comfortable area of touch by using one-hand for a specific end-user. The end-user's thumb circumference can be small, medium, or big, and the length of it can be short, medium, or long. Accordingly, the information regarding thumb circumference and length are static and influence the presentation adaptation.

   - **Hand type**

     The information about the hand type (left-handed or a right-handed) of the end-user is a static information, and it is considered one of the parameters of the desired user model, and it influences the presentation adaptation.

Author(s)	Domain (solution)	End-user properties																								
		Activities	Capabilities	Characteristics	Contact	Context	Education	Emotions	Experience	Facial expression	Goal	Health	Interaction	Interests	Knowledge	Location	Living conditions	Mental state	Motion	Motivation	Nutrition	Personal	Personality	Preferences	Profession	Thing
(Gregor, Newell, & Zajicek, 2002)	Inclusive design		✓						✓																	
(Gauch, Chaffee, & Pretschner, 2003)	Personalisation													✓												
(Razmerita, Angehrn, & Maedche, 2003)	KMS	✓							✓		✓			✓	✓							✓		✓		
(Reichenbacher, 2004)	Mobile cartography	✓	✓			✓			✓					✓	✓							✓		✓	✓	
(Hatala & Wakkary, 2005)	Context-aware												✓	✓		✓						✓				
(Pereira, 2005)	Multimedia adaptation							✓																		
(Heckmann, Schwartz, Brandherm, Schmitz, & Wilamowitz-Moellendorff, 2005)	Ubiquitous applications	✓	✓	✓	✓			✓	✓	✓	✓	✓		✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	
(Persad, Langdon, & Clarkson, 2007)	Inclusive design	✓	✓																							
(Golemati et al., 2007)	User profiling	✓	✓	✓	✓		✓		✓					✓			✓					✓		✓	✓	✓
(Casas et al., 2008)	AUI		✓						✓																	
(Singh, 2011)	ERP Systems												✓													
(Skillen et al., 2012)	Personalisation, and context-aware	✓	✓			✓						✓		✓		✓						✓		✓		
(Knutov, 2012)	AH	✓	✓	✓							✓		✓	✓	✓					✓		✓		✓		
(Castillejo, 2015) [24]	AUIs for mobile devices		✓	✓	✓				✓				✓									✓				
(Zheng et al., 2015)	AUIs for mobile E-commerce								✓																	

Tab. 4.5: End-user properties that were considered in the analysed works that are related to AUIs

[24] Castillejo includes further end-user properties in his user model ontology, such as: display, audio, interface, and view.

- **Visual acuity**

  The visual acuity for a specific end-user is a static information and it is considered one of the parameters of the desired user model, which it can be low, medium, or high, and it influences the presentation adaptation.

2. **Interaction**

   Some patterns of the end-users' interactions with the mobile ERP apps' activities[25] and views[26] are considered parameters of the desired user model. Therefore, the information regarding these interactions is dynamic, and it is stored in the desired user model to influence the adaptation processes. For instance, (Singh, 2011) exploited the end-user's interaction in his prototype to provide the good defaults[27] HCI pattern by calculating the most recently used item (MRU) and the most frequently used item (MFU) within a list of given items. Therefore, these patterns of personalisation are applied in the proposed computational framework, and the required information for them was modelled to realise the content adaptation type.

3. **Knowledge**

   The end-user's knowledge for a specific activity can be represented by a quantitative model or a qualitative model (Dieterich et al., 1993). In the quantitative model, quantitative data such as the end-user's error rate, the number of help requests, or the amount of time spent to complete a specific task are contained in the user model. While within the qualitative model, the knowledge is represented through overlay models, and the data for these models are measured relatively to the expert end-user.

   In the proposed computational framework, the quantitative model is followed to determine the end-user's knowledge of a specific task, and this determination is achieved through acquiring information for the end-user's error rate, the amount of time spent to complete a specific task, and the number of UIs' widgets that got focused. In addition, the acquired information for these parameters is dynamic, and it is updated during the usage of the app. These parameters influence all the identified AUIs types.

4. **Preferences**

   This parameter refers to what the end-user likes or dislikes (Golemati et al., 2007). In the proposed computational framework, the end-user can prevent a specific adaptation process from being initialised, due to the impression of dislike from his/her previous experience with the results of such an adaptation process.

Table 4.6 summarises the modelled parameters and their dynamism types in the desired user model in the proposed computational framework to realise the end-users' personalisation of the mobile ERP apps.

[25] Android defines activities as application components and one of the fundamental building blocks of apps on the Android platform. They serve as the entry point for an end-user's interaction with an app, and are also central to how a user navigates within an app (as with the Back button) or between apps (as with the Recent button) (Android, 2017a).

[26] Views in Android are the UI components that the end-user can interact with, such as list view, text view, button view and other (Android, 2017d).

[27] Good defaults is one of the HCI pattern that is proposed by (Tidwell, 2011) to suggest values based on the end-user's interaction over a period of time.

User model parameter	Sub-parameters	Static	Dynamic
Physiological characteristics	Thumb circumference	✓	
	Thumb length	✓	
	Hand type	✓	
	Visual acuity	✓	
Interaction	MRU		✓
	MFU		✓
Knowledge	Error rate		✓
	Time		✓
	Number of UIs' widgets that got focused		✓
Preferences	Prevention of a specific adaptation process	✓	

Tab. 4.6: Modelled parameters and their dynamism types in the desired user model

User Modelling

At the same level in defining a user model, user modelling can be defined based on two perspectives: from the HCI perspective and from the AI perspective (Castillejo, 2015).

Regarding the HCI perspective, (Pohl, 1999) defines user modelling as:

> "*The process of gathering information about the users of computer systems and of making this information available to systems which will exploit it to adapt their behavior or the information they provide to the specific requirements of individual users has been termed user modeling*" (Pohl, 1999, p. 1).

While from the AI perspective, (Wahlster & Kobsa, 1989) define user modelling in the context of a dialog system as:

> "*A user modeling component is that part of a dialog system whose function is to incrementally construct a user model; to store, update and delete entries; to maintain the consistency of the model; and to supply other components of the system with assumptions about the user*" (Wahlster & Kobsa, 1989, p. 3).

In the literature, several pioneer researchers inspired the current user modelling approaches, such as (Kass & Finin, 1988), (Wahlster & Kobsa, 1989), (Norcio & Stanley, 1989), (Kok, 1991), and many others. Based on their contributions, three approaches can be distinguished in gathering information for a user model, namely the explicit, the implicit, and the mixed-mode acquisition (Kobsa, 1993). In the explicit approach, the system asks the end-user explicitly to enter information about him/her. While in the implicit approach, the system performs user modelling based on the inferences from monitoring the end-user's interaction with the system, and finally, the mix-mode approach which employs both the explicit and the implicit approaches in the user modelling. Table 4.7 summarises the followed approach for modelling each of the determined parameters of the desired user model in the proposed computational framework.

User model parameters	Sub-parameters	Modelling approach
Physiological characteristics	Thumb circumference	Explicit
	Thumb length	Explicit
	Hand type	Explicit
	Visual acuity	Explicit

Interaction	MRU	Implicit
	MFU	Implicit
Knowledge	Error rate	Implicit
	Time	Implicit
	Number of UIs' widgets that got focused	Implicit
Preferences	Prevention of a specific adaptation process	Explicit

Tab. 4.7: Utilised modelling approaches for the determined parameters of the desired user model

4.3.2.2 Environment Model

The environmental model is the second sub-model of the desired context model, which aims to model the environment during the usage of the mobile ERP app. According to (Coursaris & Kim, 2006) and (Ntawanga et al., 2015), environment-specific context information can be classified into:

1. Physical information, such as location, visual distraction, and audio distraction.
2. Social information, such as co-location, and interaction.
3. Technical information, such as bandwidth, and connectivity.

Sensors play a key role in acquiring environment-specific context information, and they can be classified into physical sensors and logical sensors (Ntawanga et al., 2015). The physical sensors acquire the physical information of the environment-specific context, such as acceleration, temperature, and gravity through electronic hardware components built into the mobile device (Android, 2016b; Gu, Pung, & Zhang, 2004a; Ntawanga et al., 2015; Schmidt et al., 1999). While the logical sensors derive information from one or more physical sensors or from some form of software in order to detect the context of information use, such as the linear acceleration sensor and the gravity sensor (Android, 2016b; Gu et al., 2004a; Ntawanga et al., 2015; Poulcheria & Costas, 2012).

Presently, most mobile devices are equipped with several different types of sensors such as Android-powered devices to measure the information for different physical parameters. Table 4.8 tabulates the categories of environment physical parameters that can be derived from different types of sensors in Android-powered devices.

Therefore, sensors play a key role in acquiring the available dynamic information of the environment during the interaction with the mobile ERP app, and this acquired information is interpreted to be exploited in different adaptation processes in the proposed computational framework.

In the proposed computational framework, the information regarding acceleration, ambient light level (illumination), sound intensity, and network connection speed and status will be acquired to characterise the environment-specific context of use of mobile ERP apps.

Category	Sensor name	Type	Description	Common uses
Motion sensors These sensors measure acceleration forces and rotational forces along three axes.	Accelerometer	Hardware	Measures the acceleration force in m/s2 that is applied to a device on all three physical axes (x, y, and z), including the force of gravity.	Motion detection (shake, tilt, etc.).
	Gravity	Software or Hardware	Measures the force of gravity in m/s2 that is applied to a device on all three physical axes (x, y, z).	Motion detection (shake, tilt, etc.).
	Gyroscope	Hardware	Measures a device's rate of rotation in rad/s around each of the three physical axes (x, y, and z).	Rotation detection (spin, turn, etc.).
	Linear Acceleration	Software or Hardware	Measures the acceleration force in m/s2 that is applied to a device on all three physical axes (x, y, and z), excluding the force of gravity.	Monitoring acceleration along a single axis.
Environmental sensors These sensors measure various environmental parameters, such as ambient air temperature and pressure, illumination, and humidity.	Barometer (Pressure)	Hardware	Measures the ambient air pressure in hPa or mbar.	Monitoring air pressure changes.
	Thermometer (Temperature)	Hardware	Measures the ambient room temperature in degrees Celsius (°C).	Monitoring air temperatures.
	Photometer (Light)	Hardware	Measures the ambient light level (illumination) in lx.	Controlling screen brightness.
	Relative Humidity	Hardware	Measures the relative ambient humidity in percent (%).	Monitoring dewpoint, absolute, and relative humidity.
Position sensors These sensors measure the physical position of a device.	Orientation	Software	Measures degrees of rotation that a device makes around all three physical axes (x, y, z).	Determining device position.
	Rotational Vector	Software or Hardware	Measures the orientation of a device by providing the three elements of the device's rotation vector.	Motion detection and rotation detection.
	Proximity	Hardware	Measures the proximity of an object in cm relative to the view screen of a device. This sensor is typically used to determine whether a handset is being held up to a person's ear.	Phone position during a call.
	Magnetometer	Hardware	Measures the ambient geomagnetic field for all three physical axes (x, y, z) in µT.	Creating a compass.

Tab. 4.8: Sensor types supported by the Android platform (Android, 2016b)

4.3.2.3 Technology Model

The third sub-model of the desired context model is the technology model. This model aims to model specifications and capabilities of the mobile device (device model). Therefore, these specifications and capabilities are used to determine the boundaries of the adaptation processes and the consumable resources for these processes. This independent model plays a key role in reducing human interactions by adapting UI content for different contexts (Lemlouma & Layaida, 2004).

In the literature, several techniques can be found for modelling a wide range of device capabilities, such as Composite Capability/Preference Profiles (CC/PP), UAProf, Device Description Repository (DDR), and Ontologies (Castillejo, 2015).

Regarding the CC/PP profile technique, this technique is a World Wide Web Consortium[28] (W3C) standard system to characterise device capabilities and user preferences, which can be used to influence the adaptation of content presented to this device. The CC/PP profile refers to the document or documents that can be interchanged between devices, and each document contains a description about the capabilities of a device (W3C, 2004). The RDF is used to create such profiles that contain one or more components, such as a hardware platform, software platform, and individual application. Besides, each component contains one or more attributes, such as displayWidth and displayHeight for the hardware platform component. Table 4.9 lists the advantages and drawbacks for this technique.

Advantages	**Drawbacks**
Good infrastructure for modelling devices	Device dependent
Content negotiation flexibility	It requires a more mature user preferences definition
Using CC/PP, Web based device developers and user agents can define accurate profiles for their products. Web servers and server proxies can use these profiles to perform the adaptation	
Open to new protocol proposals for profile exchanging	

Tab. 4.9: Advantages and drawbacks of CC/PP technique (Castillejo, 2015, p. 57)

Regarding the UAProf technique, this technique aims at capturing capability and preference information for wireless devices, such as vendor, model, screen size, and multimedia capabilities. This information can be used to influence the adaptation of content presented for the specific device. The UAProf technique is related to the CC/PP specification and it is created by the W3C. The extensions of UAProf files are rdf or xml, and they are commonly served with mimetype application/xml. These files are based on RDF format, which means that the document schema is extensible (Butler, 2001; Castillejo, 2015; W3C, 2003).

Utilising UAProf is performed as follows (Castillejo, 2015):

1. A header containing a URL and the device's UAProf is sent within an HTTP request by the device to the server side.
2. The server receives the sent header and analyses the contained UAProf to perform the appropriate content adaptation process to the device's display size.
3. Finally, the server performs the appropriate content adaptation and serves the adapted items to the device.

However, this technique has the following drawbacks:

1. Some devices do not have a UAProf.
2. Some UAProfs are not available.

[28] The World Wide Web Consortium (W3C) is an international community that develops open standards to ensure the long-term growth of the Web (W3C, 2017). Further information about the W3C can be found online at https://www.w3.org/.

3. Schema or data of UAProf can contain errors.
4. The data within each field in an UAProf lacks industry-wide data quality standard.

Regarding the DDR technique, this technique can be utilised to acquire data about the characteristics, capabilities, and properties of all known mobile devices. This concept was proposed by the W3C Device Description Working Group (DDWG), and the two most popular DDRs are the Wireless Universal Resource File (WURFL) and openDDR (Castillejo, 2015). WURFL is a set of Application Programming Interfaces (APIs) and XML configuration file that contains data about device capabilities and features of all known mobile devices (Scientiamobile, 2016). Regarding the openDDR repository, it is a result of openDDR project that was created by a group of web and mobile developers that were aware of the importance of an up-to-date DDR, and of good APIs to access it (OpenDDR Project, 2017). Table 4.10 lists the advantages and drawbacks of the WURFEL and OpenDDR techniques.

DDR	Advantages	Drawbacks
WURFL	Upgradeable to new versions	Errors in data
	A hierarchy which allows to infer values	Many empty values
	Many capabilities modelled	
	Very easy to configure	
	Powerful API	
OpenDDR	Free to use, even commercially	Limited number of capabilities
	Growing community	Default values for unknown data

Tab. 4.10: DDRs comparisons (Castillejo, 2015, p. 59)

Finally, the ontology technique has the ability to model devices. One of the remarkable ontologies is the Standard Ontologies for Ubiquitous and Pervasive Applications (SOUPA). This ontology is designed to model and support pervasive computing applications (Chen, Perich, Finin, & Joshi, 2004).

However, information about the following parameters will be acquired in the proposed computational framework for mobile devices that operate mobile ERP apps:

1. Software characteristics, which include OS name and version.
2. Hardware characteristics, which include brand, model number, battery plan, memory plan, RAM capacity, screen size, and sensors availability (accelerometer, photometer, orientation, fingerprint, microphone, front facing camera, and back facing camera).

At the same level of the proposed user model, Table 4.11 illustrates the determined parameters and their dynamism types of the desired device model in the proposed computational framework. Besides, it illustrates the followed modelling approach for each determined parameter.

Device model parameters	Sub-parameters	Static	Dynamic	Modelling approach
Software characteristics	OS name	✓		Explicit
	OS version	✓		Explicit
Hardware characteristics	Brand	✓		Explicit
	Model	✓		Explicit
	Battery plan		✓	Implicit
	Memory plan		✓	Implicit
	RAM capacity		✓	Implicit
	Screen size	✓		Explicit
	Sensors availability	✓		Explicit

Tab. 4.11: Determined parameters of the desired device model in the proposed computational framework

4.3.2.4 Task Model

The fourth sub-model of the desired context model aims to model the tasks of the mobile ERP app. Tasks in the interactive applications aim to define how the end-user can achieve a specific goal in a specific application domain, and the achievement of this goal requires a modification of the state of a system or performs a query to it (Paternò, Mancini, & Meniconi, 1997). Each goal can be correlated with one or multiple tasks, and each task can be correlated with a specific goal (Paternò, 2004). Thus, a task model is employed to represent the tasks and their related information in the interactive systems.

The task model aims to provide (Menkhaus & Fischmeister, 2003; Paternò et al., 1997; Reichenbacher, 2004):

1. A formal description of the service that the end-user accesses.
2. A description of the tasks and their constituent activities to achieve a specific goal.
3. A hierarchical organisation of information regarding the trigger of a task, its precondition and post condition, with the changing needs of the user over time in a software system.

The task model belongs to the semantic design level[29] (Menkhaus & Fischmeister, 2003; Schlungbaum, 1996), and it is built through the following three phases (Paternò et al., 1997):

1. A hierarchical logical decomposition of the tasks that are represented by a tree-like structure.
2. Identifying the temporal relationships among the decomposed tasks at the same level.
3. Identifying the objects that correlate to each task, and the actions that enable them to communicate with each other. This identification process is achieved layer-by-layer.

According to (Paternò et al., 1997), tasks can be classified based on the allocation of their performance in any application domain into:

1. User tasks: these kinds of tasks are performed entirely by the end-user, and they require cognitive or physical activities without interacting with the system. For instance, when the user reads a list of flights that satisfy some of his/her predefined constraints and selects one of them for his/her journey.

[29] (Schlungbaum, 1996) distinguishes three phases in the process of model-based UI design, namely the semantic level design, the syntactic level design, and the lexical level design.

2. Application tasks: these kinds of tasks are executed by the system that receives information from the system and supplies it to the end-user. For instance, compiling a program and notifying the end-user when errors are detected.
3. Interaction tasks: these kinds of tasks are performed by the user's interactions with the system, such as formulating a query to a data base and executing it.
4. Abstract tasks: these kinds of tasks require complex actions, and their performance does not completely descend from one of the three previous types of tasks.

In the proposed computational framework, the interaction tasks are modelled, because modelling such tasks is considered an important component that can influence the adaptation processes for different modalities and platforms (Krogsaeter & Thomas, 1994; Reichenbacher, 2004; Tran, Vanderdonckt, Kolp, & Faulkner, 2009). Furthermore, this component directly influences the navigation adaptation type, which is proposed to address the summarised usability challenges of mobile ERP apps in Table 4.2, and this influence can be achieved through (Ohigashi & Omori, 2006; Paternò, 2004):

1. Predicting the transitional state of the task, and thus, provide task assistance through providing appropriate guidance to complete the task.
2. Automatically generating task-oriented help to support the end-user during a session.

The diagrammatic notation ConcurTaskTrees (CTT) is used to model the tasks and sub-tasks of a software system. Therefore, CTT was employed to model the creation of RFQ task in the purchases module of the mERP app (the selected mobile ERP app). The reasons behind employing this type of diagrammatic notation are (Paternò, 2004):

1. It enables designers to concentrate on the activities that will be performed by the end-users.
2. Its ability to represent the tasks and their sub-tasks in a hierarchical structure, and thus, provide a deeper granularity which allows the large and small task structures to be reused. Besides, this hierarchical structure allows reusable task structures to be defined at low and high semantic levels.
3. Using a graphical syntax is often easier to interpret, due to the syntax of ConcurTaskTrees which represents the logical structure of tasks through a treelike form.
4. Its ability to define a rich set of potential temporal operators between the tasks.
5. Its ability to allocate tasks, whether it is user tasks, applications tasks, interaction task, or abstract tasks.
6. Its ability to identify objects and task attributes. After identifying the tasks, it is substantial to determine the objects that have to be manipulated to support the task completion performance. These objects fold into UI objects and application domain objects.

However, after reviewing the most significant research works that employed the task model to realise AUIs, such as (Brusilovsky & Cooper, 2001), (Menkhaus & Fischmeister, 2003), (Oppermann, 1994), (Reichenbacher, 2004), (Singh, 2011), (Tran et al., 2009), and (van Tonder & Wesson, 2008), the following parameters were selected to characterise the desired task model in the proposed computational framework:

1. Preconditions.
2. Task sequence.

3. Sub-tasks (if applicable).
4. Goal.
5. Task type.

Moreover, a CTT for the creation RFQ task in the purchases module of the mERP app was constructed, and it was analysed. The results from this analysis assisted in determining the abovementioned parameters. Figure 4.17 depicts an excerption of the constructed CTT of the creation RFQ task in the purchases module of the mERP app.

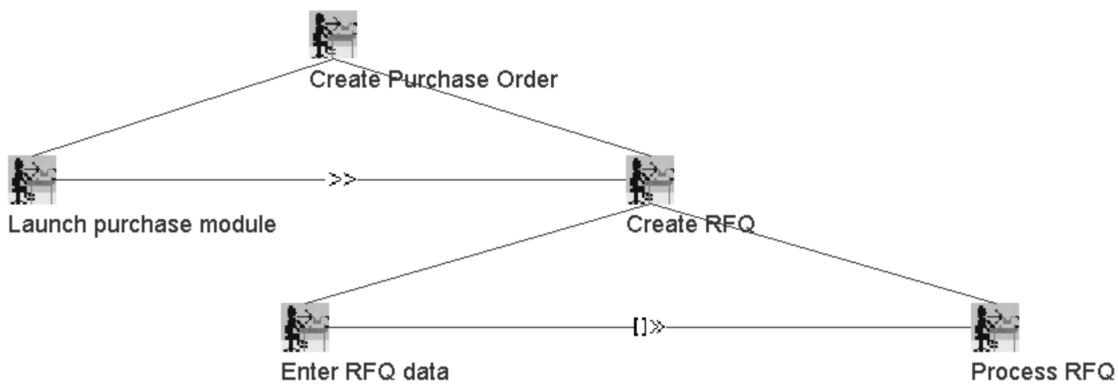


Fig. 4.17: Excerption of the analysed CTT of the creation RFQ task in the purchasing module of the mERP app

The information regarding the determined parameters of the task model is static and it is explicitly identified by the adaptation engineer.

In addition to the previously discussed sub-models that form the context of use of mobile ERP apps, further models were considered in the proposed computational framework to assist the realisation of adaptation processes successfully, namely the dialog model, the domain model, the presentation model, and the adaptation model.

4.3.2.5 Dialog Model

A dialog model aims to describe the syntactic sequence of human-computer interaction through UI components, and to identify the sequence of the set of tasks and actions that should be performed in order to achieve a specific goal (Menkhaus & Fischmeister, 2003; Puerta, 1997). In addition, this model determines the following functionalities (Puerta, 1997):

1. When the functions can be invoked by the end-user, and the triggering mechanisms of these functions, such as selecting a button, swiping down, and long tapping in the mobile context.
2. Specifying the type of interaction media which can be divided into input modalities and output modalities. Microphone, handwriting with a stylus, touch screen, and camera are examples of input modalities in mobile devices. In turn, graphical display, audio speakers, and vibration are examples of output modalities in mobile devices.
3. When the end-user can select or specify a UI component for input.
4. When the system can query and afford information by using various UI components.

The dialog model is hierarchically organised as the task model that includes a sequence of windows including a set of UI components and a set of transitions that enable navigation from one window to the next (Menkhaus & Fischmeister, 2003).

Although the dialog model and the task model participate in describing the organisation of the end-user's interaction with the application, both differ at the level of abstractions. This differentiation means that the task model represents the tasks and activities that need to be performed. In turn, the dialog model represents how these activities are organised in the UI, which set of tasks are available at a specific moment in time to form a dialog, and how are the dialogs associated (van den Bergh & Coninx, 2004).

4.3.2.6 Domain Model

(Benyon, 1996) defines a domain model as:

> "*Within HCI there is an increasing awareness of the importance of developing abstract representations - or models - of the area of activity which is to be the subject of the system. Such a representation is known as a domain model, or an application model*" (Benyon, 1996, p. 1).

The domain model must be built based on some conceptualisation of the domain that represents how the conceptual representation of an application domain is structured (Benyon, 1996; Knutov, 2012). Within the scope of UI generation, this model provides the required knowledge to create a UI such as the objects, their attributes, and the relationships among these objects (Tran et al., 2009). Therefore, this model provides essential data for the objects that will be adapted by using the identified triple adaptation types, which are the content adaptation, the presentation adaptation, and the navigation adaptation.

The domain model is usually constructed by using the information acquired during the business and functional requirements phase of SDLC, and then the task model and user model are derived from this model (Ahmed & Ashraf, 2007). Furthermore, the domain model is not used separately from other models to generate the UI, but it incorporates with other models, such as the task, user, and dialog models (Tran et al., 2009).

Consequently, the proposed computational framework utilises the domain model that was built by the system designer of the mobile ERP app to determine the objects that will be adapted in a specific context of use.

4.3.2.7 Presentation Model

The essence of a presentation model is to specify the visual appearance of the interaction objects (or widgets) in the different dialog states (Puerta, 1997), and this is achieved through mapping the conceptual elements of the dialog model onto platform specific elements (Menkhaus & Fischmeister, 2003). Therefore, the presentation and the dialog model are interconnected, and thus, some model-based UIs development consider them together (Puerta, 1997).

In review of the literature, two types of presentation models can be distinguished, namely abstract and concrete presentation models (Da Silva, 2000; van den Bergh & Coninx, 2004). In the abstract presentation model (APM) the UI is described in terms of abstract objects, and thus, this model provides a conceptual description of the structure and the behaviour of the visual components of the UI. While in the concrete presentation model (CPM), the visual components of the UI (widgets) are described in details (Da Silva, 2000). However, it can be derived from the definition of the APM that it is more closely related to the dialog model, and thus, it was integrated with the dialog model in the proposed computational framework. Meanwhile, the CPM has been considered the presentation model that associates a specific component style for a specific widget or component for a specific dialog in a specific context of use.

4.3.2.8 Adaptation Model

The adaptation model represents a set of rules that determine how the adaptation should be realised (Bra et al., 2003).

In the proposed computational framework, the identified rules in the adaptation model (adaptation rules) follow the ECA (Event-Condition-Action) rules structure. This structure aims to automatically perform actions in response to provided events in case the stated conditions for them are satisfied. In addition, this structure has the following benefits (Poulovassilis, Papamarkos, & Wood, 2006):

1. Enhancing the modularity and maintainability of the application, due to its ability to define and manage an application's reactive functionality within a single rule base instead of being encoded in diverse programs.
2. The ECA rules structure has a high-level and declarative syntax. Therefore, this structure enables analysis and optimisation techniques, which could not be achieved if the same functionality were defined directly in programming language code.

The general syntax of an ECA rule is:

on *event* **if** *condition* **do** *actions*

The event part indicates when the rule should be triggered. While the condition part represents the logical test that if satisfied or evaluated to true, causes a specific action to be performed. Finally, the actions part specifies the actions to be performed if the condition is satisfied.

In the proposed computational framework, the identified adaptation rules in the adaptation model influence the determined adaptation dimensions and types. The assigned conditions for these rules are logically evaluated through matching the acquired and interpreted contextual information with the predefined rules and their premises in the adaptation model. Thus, a successful evaluation of a rule triggers a specific action in order to realise one or more of the identified triple adaptation types.

In sub-section 4.3.2, the knowledge models that are used in the proposed computational framework were determined and explained in order to realise adaptation processes successfully. Based on the information in these models the adaptive object is adapted to the adaptation target through adaptation methods and techniques. Therefore, these methods and techniques will be presented in the next sub-section to adapt the UIs' components of mobile ERP apps successfully.

4.3.3 Adaptation Methods and Techniques (How?)

After an intensive reviewing of the literature, a knowledge gap was identified in finding a taxonomy of adaptation techniques that is specific to the domain of mobile ERP apps. To bridge this gap, this sub-section proposes an adaptation taxonomy that could be used in designing AUIs for mobile ERP apps, and thus, answering the following research question:

> *RQ. 4.4) What are the adaptation methods and techniques that can be used to realise the determined adapted constituents as a solution in section 4.3.1?*

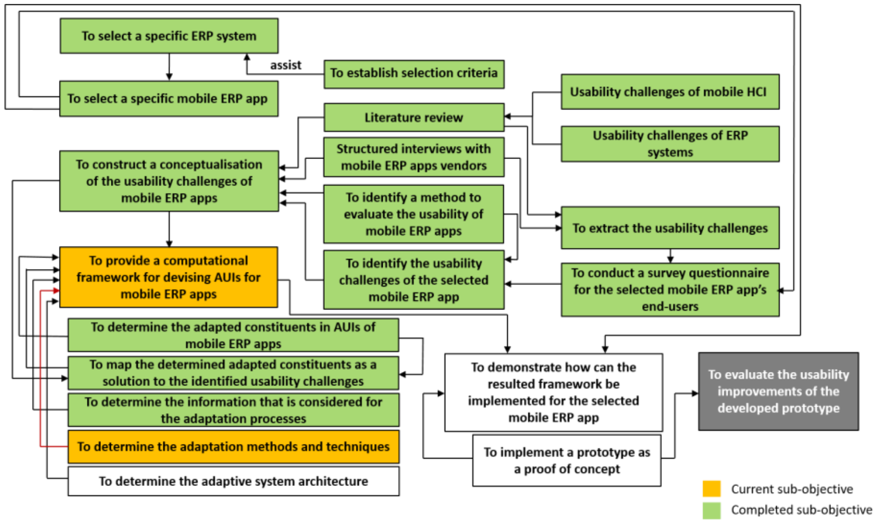


Fig. 4.18: Research objectives status; determining the adaptation methods and techniques for mobile ERP apps

A taxonomy of adaptation techniques was proposed by (Knutov et al., 2009) to answer the question “How?” which aims at describing the adaptation methods and techniques on a conceptual and implementation level. Therefore, their taxonomy provides different methods and techniques for hypermedia systems in order to realise the triple adaptation type. Figure 4.19 illustrates the proposed taxonomy by (Knutov et al., 2009).

However, (Singh & Wesson, 2011) stated that such a taxonomy does not exist for ERP systems. Therefore, they proposed a new taxonomy to overcome this limitation by adapting the originally proposed taxonomy by (Knutov et al., 2009) to guide and support the design and implementation of AUIs for ERP systems. This adaptation is based on the selection of only the adaptation techniques originally proposed in (Knutov et al., 2009) taxonomy that could be used to address the identified usability challenges of ERP systems in their research work.

In the proposed taxonomy by (Singh & Wesson, 2011), the existing approaches and techniques originally proposed for hypermedia systems by (Knutov et al., 2009) were substituted by the existing HCI design patterns which were proposed by (Tidwell, 2011) that aim to improve the usability of desktop applications. These patterns were selected on the basis of their comprehensiveness and applicability to desktop systems. Figure 4.20 illustrates the proposed adaptation taxonomy by (Singh & Wesson, 2011) for ERP systems. In this Figure, the selected components from (Knutov et al., 2009) taxonomy are illustrated in blue, and the new proposed components by (Singh & Wesson, 2011) are illustrated in orange.

Both taxonomies were analysed and adapted to the domain of mobile ERP apps, and they were enriched with further methods, techniques, and mobile HCI patterns. This enrichment relied on:

1. Analysing and reviewing several catalogues of HCI patterns such as the proposed catalogue by (Tidwell, 2011). Although these patterns are used for both desktop applications and highly interactive websites, some of these patterns are valid as mobile HCI patterns.
2. Analysing and reviewing the proposed mobile design patterns by (Neil, 2014).
3. Analysing several guidelines and best practices for mobile UI designs, such as (Hoober & Berkman, 2011), (Vázquez-Ramírez, Marín-Vega, & Alor-Hernández, 2013), and (Nielsen & Budiu, 2013).

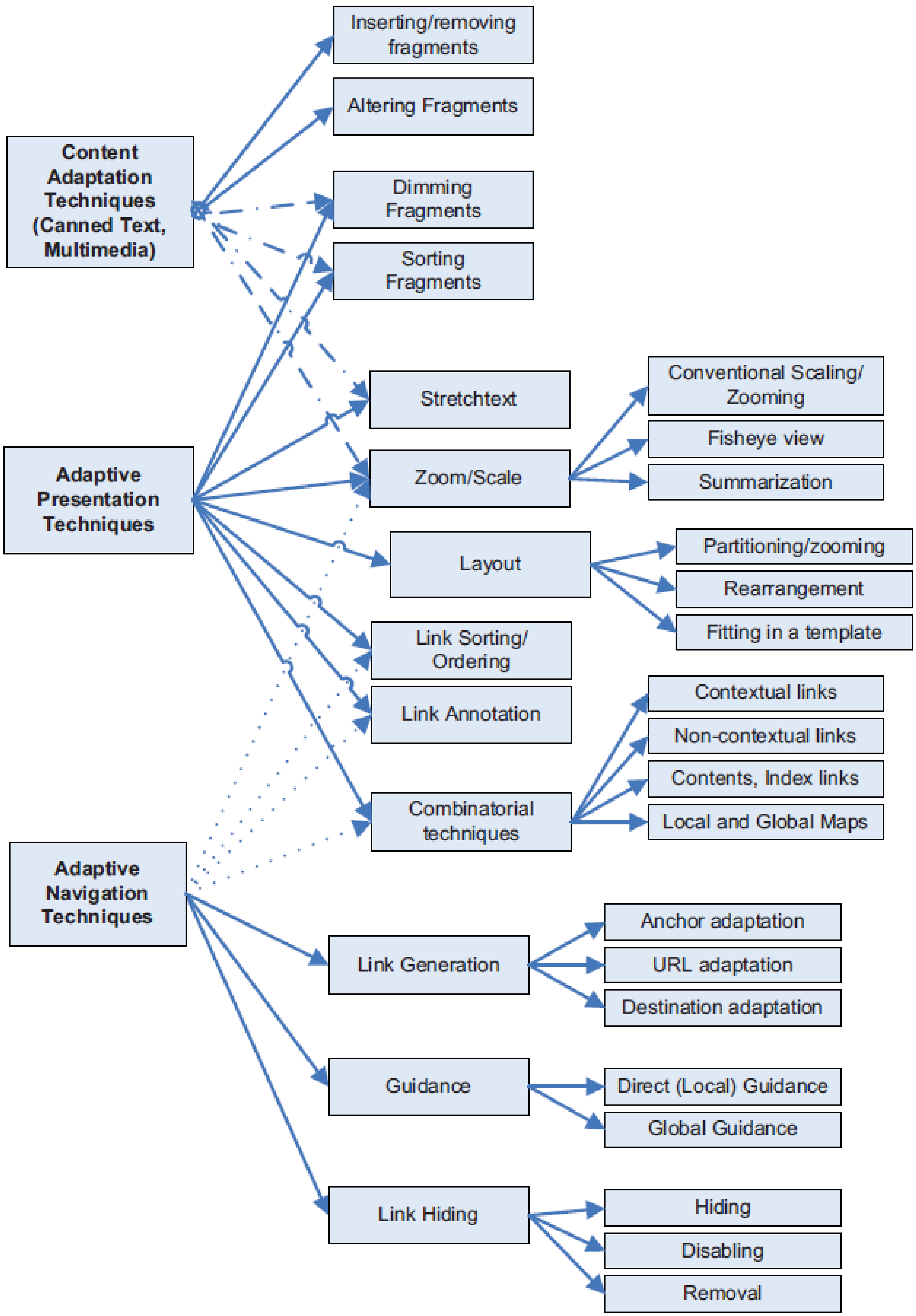


Fig. 4.19: Proposed taxonomy of adaptation methods and techniques for AH systems by (Knutov et al., 2009, p. 26)

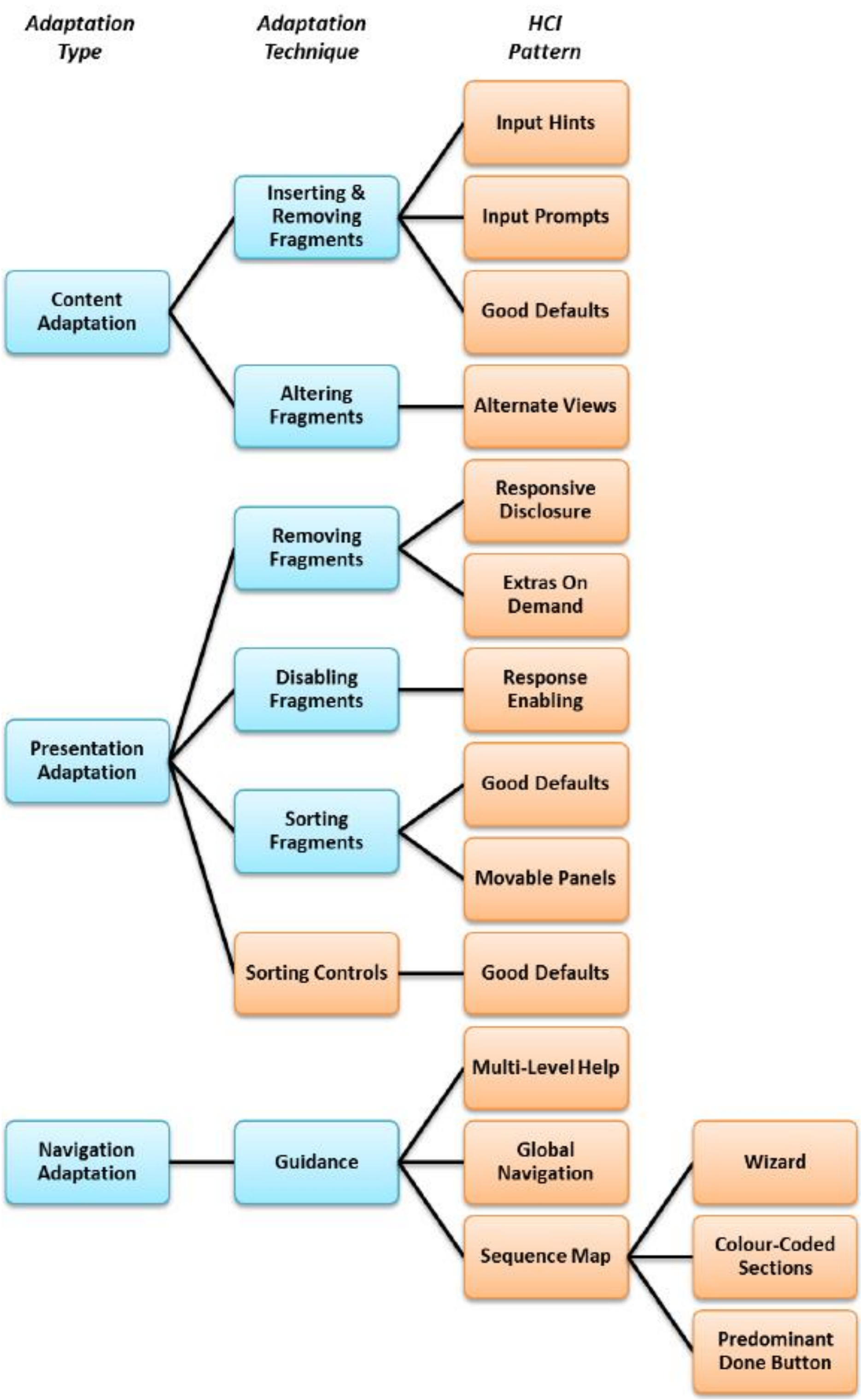


Fig. 4.20: Proposed adaptation taxonomy for ERP systems by (Singh & Wesson, 2011, p. 282)

The resulted taxonomies for the identified triple adaptation types are illustrated in Figures 4.21, 4.22, and 4.23 respectively. The first versions of these taxonomies were presented and discussed in Eureka International Virtual Meeting 2016 (Omar & Marx Gómez, 2016a).

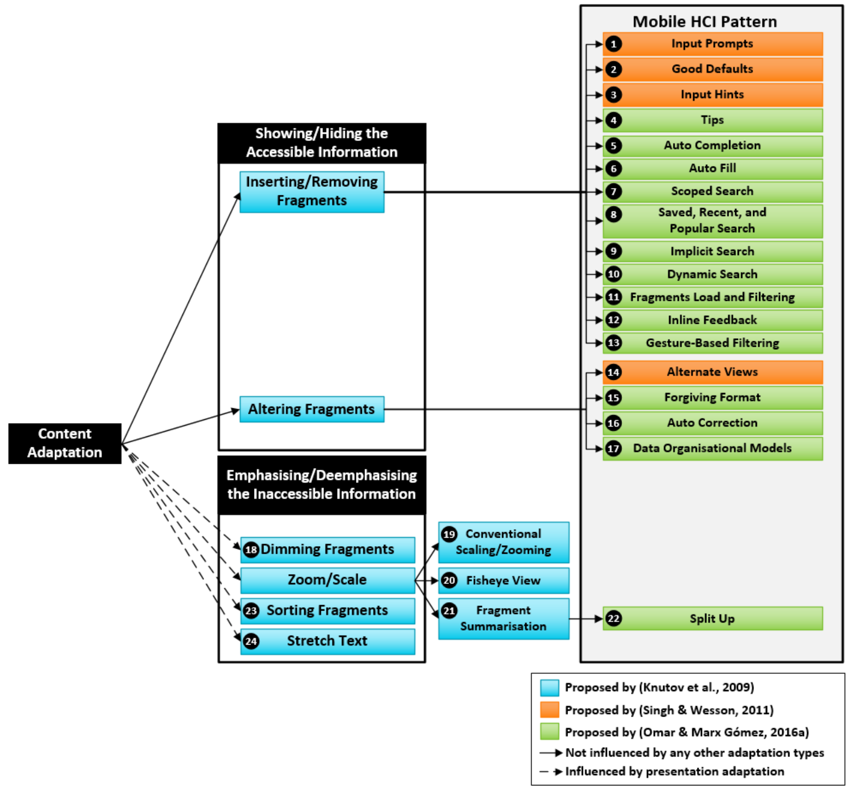


Fig. 4.21: Updated version of the proposed taxonomy of content adaptation methods and techniques by (Omar & Marx Gómez, 2016a)

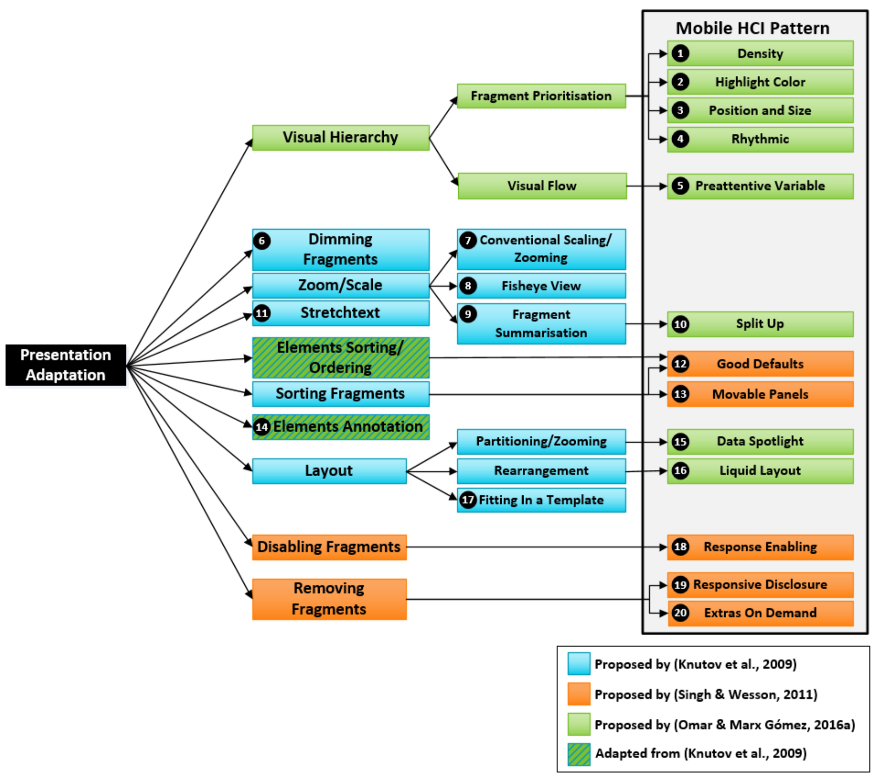


Fig. 4.22: Updated version of the proposed taxonomy of presentation adaptation methods and techniques by (Omar & Marx Gómez, 2016a)

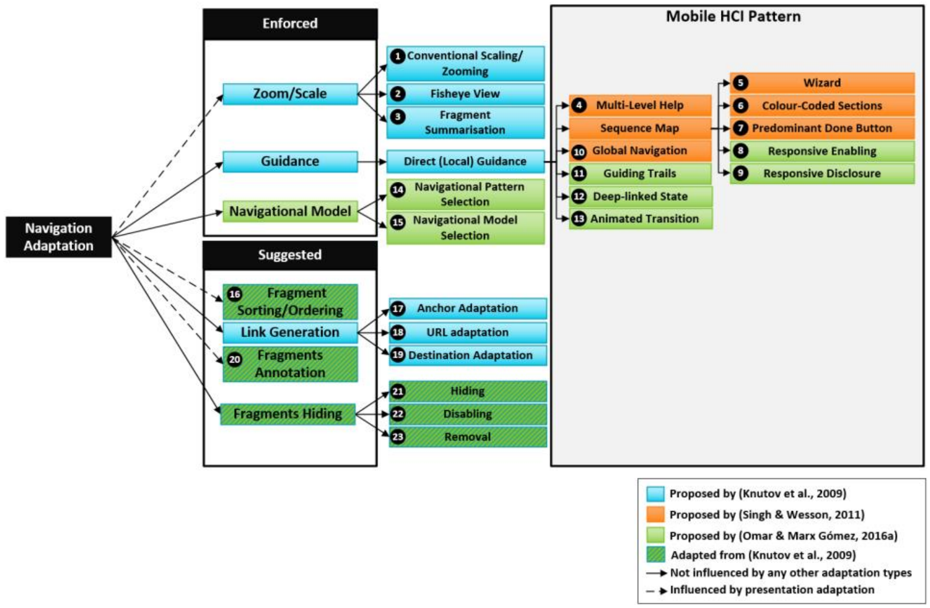


Fig. 4.23: Updated version of the proposed taxonomy of navigation adaptation methods and techniques by (Omar & Marx Gómez, 2016a)

For instance, the content adaptation is proposed in Table 4.2 to address the challenge of a multitude of interaction steps which is negatively impacted by the limited screen size of mobile devices. Therefore, one or more of the following mobile HCI patterns in the proposed taxonomy of content adaptation could be applied to address this challenge:

- Input Prompts.
- Good Defaults.
- Auto Completion.
- Auto Fill.
- Scoped Search.
- Saved, Recent, and Popular Search.
- Implicit Search.
- Dynamic Search.
- Fragments Load and Filtering.
- Gesture-based Filtering.
- Forgiving Format.
- Auto Correction.

On the same level, the adaptive presentation is proposed in Table 4.2 to address the challenge of distraction, which is increased by the motion of the end-user during the usage of a mobile ERP app. Therefore, one or more of the following mobile HCI patterns in the proposed presentation adaptation taxonomy could be applied to address this challenge:

- Density.
- Position and Size.
- Rhythmic.
- Good Defaults.
- Data Spotlight.
- Highlight Colour.
- Response Enabling.
- Response Disclosure.
- Extras on Demand.

Likewise, the adaptive navigation is proposed in Table 4.2 to address the challenge of lacking contextual guidance. Therefore, one or more of the following mobile HCI patterns in the proposed navigation adaptation taxonomy could be applied to address this challenge:

- Wizard.
- Responsive Enabling.
- Responsive Disclosure.
- Guiding Trails.
- Hiding Elements.
- Disabling Elements.

Table 4.12 depicts the ids of some mobile HCI patterns that could be used to realise the identified triple adaptation types as solutions to address the identified usability challenges of mobile ERP apps.

Identified usability challenges of mobile ERP apps	Technology															Environment									User								
	Limited screen size			Limited capability of battery power			Data entry methods			Mobile data connectivity			Security			Activity (motion)			Ambient luminance			Ambient noise			Preferences			Characteristics			Knowledge		
	C	P	N	C	P	N	C	P	N	C	P	N	C	P	N	C	P	N	C	P	N	C	P	N	C	P	N	C	P	N	C	P	N
More time required compared with the conventional approach to complete a task	2	2	5	1	19	7	16	3		8			13			15	3	9	2	3	5	16	2	11		3		16	3		4	2	5
Stubborn to the context of use variability (needs to be adaptive)	2	19	5	1	2	9	16	3		11			13			15	3	5		3			2	11		3		15	15		4	2	5
Lack of correction and validation techniques that suit the context of use							16	2								16	2					16	2								3	15	
Lack of intuitive learning																															6	15	8
Distraction		3	5					3								1	19	5	15	3	7	6	2	11									
Bloated UIs	11	19	5	6						8			13			6	18	9		3		5	2	11							18	14	5
Multitude of interaction steps	2	6	16	6	15		5			8	3		24	2		2	2	9		2	9	2	2	9	14	2	20	15	15	9	18	3	5
Memorability	23	15														4	2	11				4	2	11	4	2	11						
Findability of the desired information and functionalities	2	2	11				5				15	16				2	2	11		15	13		2	7		2	11		6	9	3	3	16
Contextual guidance		2	5														3	9		15	7		14	7		3	7					3	11
Contextual help	3	2														17	2	11		3		14	2		14	3					3	2	4
Task completion	2	2	9	11	3		16	3		8			13	1		15	2	5	1	2	11	1	2	11	2	3		2	2	11	4	2	5
Personalisation								3																	3	3		4	3		3	15	
Security issues							14	19					13	1											14	19							

Tab. 4.12: Proposed solutions for the identified usability challenges

The goal from the proposed adaptation taxonomies for the identified triple adaptation types (content, presentation, and navigation) was to be a means of guiding the developers of mobile ERP apps in designing AUIs. In order to support this guidance and to realise these taxonomies. The following sub-section presents the proposed adaptive system architecture for mobile ERP apps that can incorporate the components of the proposed computational framework for devising AUIs in mobile ERP apps.

4.3.4 Proposed Adaptive System Architecture (Who? Where? When?)

After an intensive reviewing of the literature, a knowledge gap was identified in finding an appropriate adaptive system architecture that can realise the identified adaptation dimensions in sub-section 4.3.1, which are:

1. Invoking the appropriate activity for the current context of use.
2. Invoking the appropriate dialog for the current context of use for the invoked activity.
3. Adapting the UI widgets to the current context of use.

Furthermore, the adaptive system architecture should:

1. Deploy the identified components of the proposed computational framework in the previous sub-sections.
2. Perform data processing to support the identified triple adaptation types, and supporting their proposed taxonomies in terms of:
    - Acquiring contextual information.
    - Interpreting the acquired contextual information to be used in adaptation processes.
    - Organising the flow of data among the interconnected components of the proposed computational framework.
3. Synchronise the updated information of knowledge models by the adaptive engineer in the mobile ERP server with the mobile ERP app instances.
4. Synchronise the updated information of knowledge models with the backend ERP system in order to be retrieved in case of loss or corruption.

Therefore, this sub-section proposes an adaptive system architecture for mobile ERP apps that can achieve the abovementioned goals, and thus, answering the following research question:

> *RQ. 4.5) What is the appropriate adaptive systems architecture that can be employed to realise adaptation processes successfully in the context of this research study?*

The proposed adaptive system architecture and its components were presented at The 2nd International Conference on the Applications of Information Technology in Developing Renewable Energy Processes and Systems (IT-DREPS 2017) and published in its proceedings (Omar & Marx Gómez, 2017a).

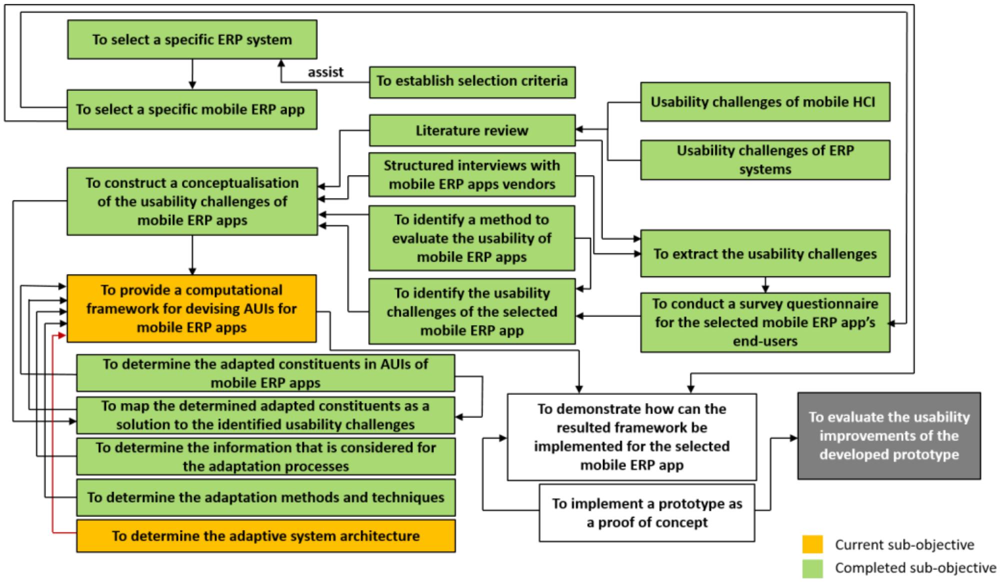


Fig. 4.24: Research objectives status; determining an adaptive system architecture for mobile ERP apps

As stated earlier in this chapter, (Dieterich et al., 1993) identified four stages for any adaptation process, namely initiative, proposal, decision, and execution. By adapting these stages to the context of this research study, the adaptation processes that support the aforementioned adaptation dimensions and types are achieved by the following three steps:

1. Firstly, monitoring and acquiring the contextual information regarding the current task. This task is being performed by a current end-user, who in turn is using a specific mobile device with its current status of resources, in a current environment.
2. Secondly, analysing and interpreting some of the acquired contextual information, and thus, it can be easily understood by the adaptive system. For instance, an accelerometer might sense a 300 m/s^2, and this value is not understood by the identified adaptation rules. Therefore, it is analysed and interpreted into “Fast Walking” based on predefined thresholds for the acceleration ranges in the environment sub-models.
3. Finally, based on the resulted model from the previous step, several actions are triggered to perform the aforementioned dimensions of adaptivity.

One of the most popular reference models for adaptive systems is the MAPE-K (Monitor, Analyse, Plan, Execute, Knowledge) (Arcaini, Riccobene, & Scandurra, 2015). Based on understanding this reference model, and the aforementioned dimensions and goals of the targeted adaptive system architecture with the identified steps for performing an adaption process, an adaptive system architecture was proposed for mobile ERP apps, which is depicted in Figure 4.25. This system architecture is composed of three main components, namely the mobile ERP application, the mobile ERP server, and the back-end ERP system which is Odoo ERP system.

Regarding the mobile ERP application component, this component is composed of three main layers, namely the modelling layer, the adaptation layer, and the knowledge models layer.

The modelling layer aims to model the context of use, and thus, it is composed of two modules that cooperate with each other to achieve this goal, which are the monitoring and acquiring module, and the analyser module. The monitoring and acquiring module aims to acquire the contextual information regarding the task, which is being performed by a specific end-user, who is using a specific mobile device with its current status of resources, in a specific environment. On the other hand, the analyser module aims at interpreting some of the acquired contextual

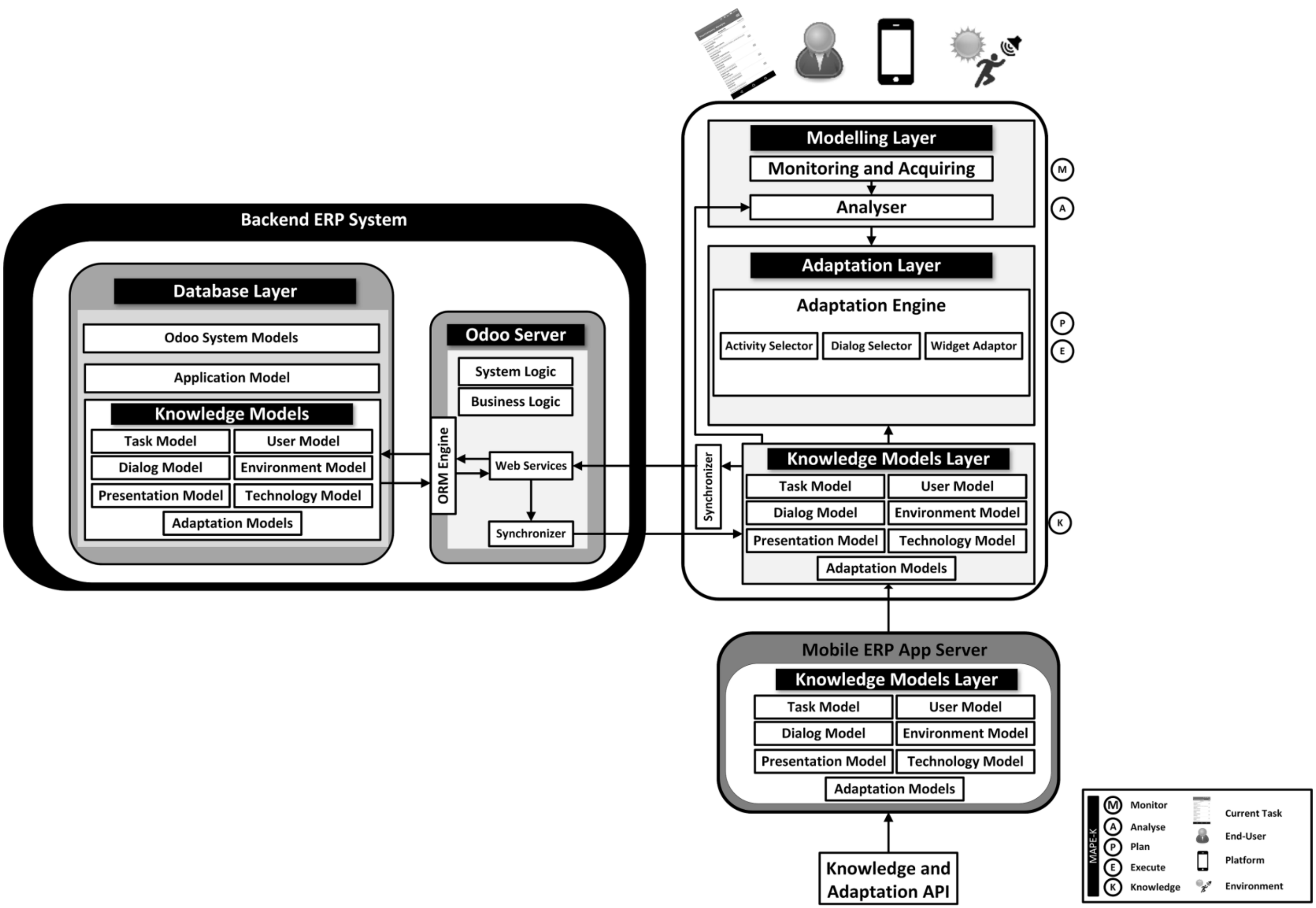


Fig. 4.25: Proposed adaptive system architecture for mobile ERP apps (Omar & Marx Gómez, 2017a, p. 84)

information in order to be easily understood by the adaptive system. This interpretation is performed based on mapping the acquired information to the corresponding meaningful values that are stored in the knowledge models layer.

The second layer in the mobile ERP application component is the adaptation layer, this layer aims at performing the identified adaptation dimensions and types based on the resulted model from the modelling layer. This layer is composed of the adaptive engine module, which aims at:

1. Checking whether the adaptation process is prevented by the end-user based on his/her predefined preferences in the user model.
2. Selecting the appropriate rule from the adaptation models to perform the identified adaptation dimensions and types.

In addition, the adaptive engine module is composed of three components, which are: the activity selector, the dialog selector, and the UIs' widget adaptor. The activity selector component aims to select the appropriate activity from the identified activities of the current task based on the current context of use. While the dialog selector component aims to select the appropriate dialog from the identified dialogs for the selected activity based on the current context of use. Finally, the UIs' widget adaptor aims to continuously adapt a specific widget in the selected dialog based on the constant change of the context of use.

The final layer in the mobile ERP application component is the knowledge models layer. This layer stores the required knowledge models for the adaptation processes. The information contained in these models can be updated by the adaptive engineer via the third component of the proposed adaptive system architecture, which is the knowledge and adaptation API component in mobile ERP app server.

Furthermore, a synchroniser component is proposed to synchronise the updated information in the knowledge models in mobile ERP app with the back-end ERP system. Therefore, they can be resynchronised again in case the mobile device gets damaged, lost or changed.

Regarding the second main component which is the back-end ERP system (Odoo), this component maintains a copy of the knowledge models of the mobile ERP app, and thus, these models can be resynchronised again in case the ERP system is accessed from another mobile device.

4.4 Summary

In this chapter, an integrated overview of AUIs was presented, which supported the development of the computational framework for devising AUIs for mobile ERP apps.

The developed framework aimed to address the identified usability challenges in the resulted construct from Chapter 3. Therefore, the developed components of this framework have taken into account the addressing of these challenges.

The adapted constituents in AUIs for mobile ERP apps were determined in this chapter, and these constituents are:

1. The ability to correct errors and inaccurate input.
2. Providing active help.
3. Providing presentation of input to the end-users by switching among several predefined interaction styles.

4. System presentation of information by filtering or by switching among presentation styles.
5. Access to capabilities.
6. Task simplification by automating the routine tasks for the individual user.

In addition, three adaptation dimensions were identified to realise the abovementioned constituents, which are:

1. Invoking the appropriate activity, based on the current context of use.
2. Invoking the appropriate dialog, based on the current context of use for the invoked activity.
3. Adapting the UI widgets, based on the current context of use.

Furthermore, the three prominent types of adaptation were highlighted in this chapter, namely the content adaptation, the presentation adaptation, and the navigation adaptation. These types of adaptation are used in the developed framework to realise the determined adapted constituents and dimensions for mobile ERP app to address the identified usability challenges in the resulted construct as can be seen from Table 4.2.

In this research study, four contextual factors were determined that impact the mobile ERP usability, namely user, environment, task/activity, and technology. Therefore, these factors and their impacts are considered in the developed framework by the determined knowledge models, and these models are: the user model, the environment model, the technology model, and the task model. These models are utilised to realise the adaptation processes for the aforementioned adaptation constituents, dimensions, and types. In addition to these models, the dialog model, the domain model, the presentation model, and the adaptation model are considered for realising these adaptation processes.

Three taxonomies of adaptation methods and techniques for mobile ERP apps were developed and presented in this chapter to support the realisation of the three identified adaptation types (content, presentation, and navigation), and these taxonomies are depicted in Figures 4.21, 4.22, and 4.23. In addition, an adaptive system architecture was proposed to implement all the identified components of the developed computational framework as can be seen from Figure 4.25.

In the next chapter, a prototypical implementation of the developed computational framework will be presented.

5 Adaptive User Interfaces for mERP App

AUIs have been proposed in this research study as a means to address the identified usability challenges of mobile ERP apps in the resulted construct in Chapter 3. Therefore, a computational framework was elaborated for engineering and devising AUIs for mobile ERP apps to address these challenges. This framework and its components were clarified theoretically in the previous chapter. In order to complement this clarification, a demonstration of how this framework can be implemented for the selected mobile ERP app (mERP app) will be presented in this chapter. This demonstration will be a guide for the developers of mobile ERP apps when the AUIs approach is adopted by them in developing mobile ERP apps. Thus, this chapter attempts to answer the following research question:

RQ. 5) How can the identified computational framework be implemented for the selected mobile ERP app (mERP app)?

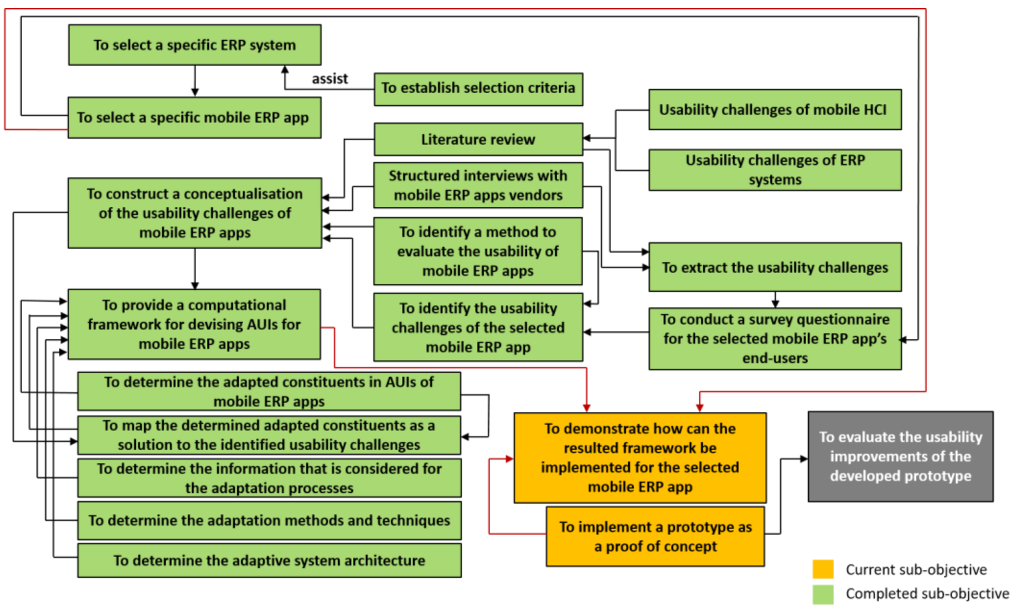


Fig. 5.1: Research objectives status; sub-objectives that will be achieved in Chapter 5

5.1 Purchase Orders in Odoo ERP System and mERP app

In chapter 2, the Odoo ERP system was selected for experimental purposes in this research study based on the fulfilment of the proposed criteria in the developed model for selecting an ERP system to conduct a mobile ERP research on it by following the design science research paradigm. In addition, the creation of a purchase order and RFQs of the purchases module were selected to develop a prototype for them. This selection was determined based on the results of the conducted research studies on: a sample of the determined target organisations of this research study, and the end-users of the selected mobile ERP app (mERP app), and these results are:

1. Their wide access via the mERP app, and this was revealed from the conducted survey questionnaire for mERP app's end-users.
2. The purchases module scored the longest time to be learned, and is considered one of the most difficult module among other ERP modules when it is accessed via mobile

devices from the clients' perspective. These results were revealed from the conducted structured interviews with mobile ERP vendors.

Figures 5.2, 5.3, and 5.4 depict screenshots of the RFQ form in the purchases module of Odoo ERP system, and Figure 5.5 depicts screenshots of the RFQ form in the purchases module of the mERP app.

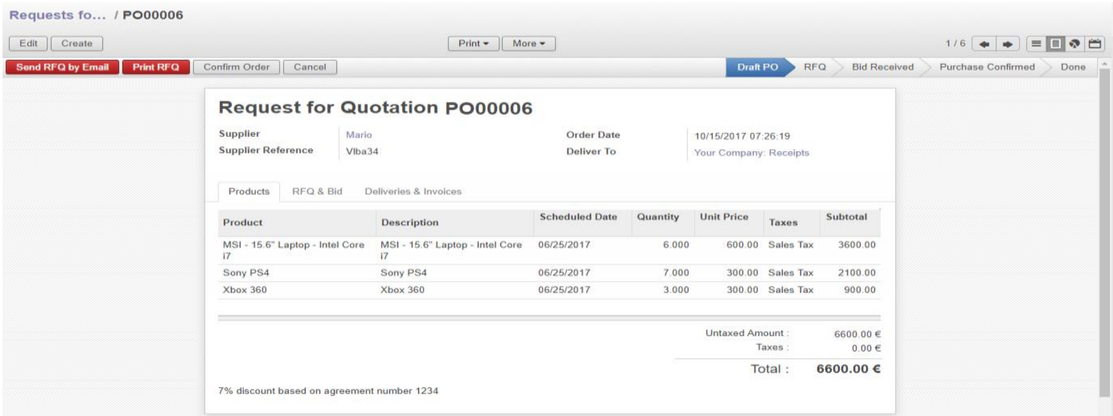


Fig. 5.2: Screenshot of the main required information and products details of the RFQ form in the purchases module of the Odoo ERP system

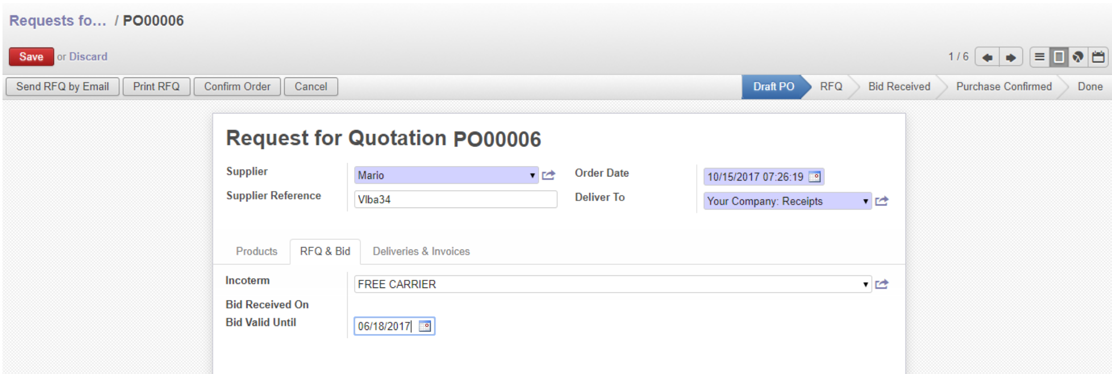


Fig. 5.3: Screenshot of the RFQ & Bid tab of the RFQ form in the purchases module of the Odoo ERP system

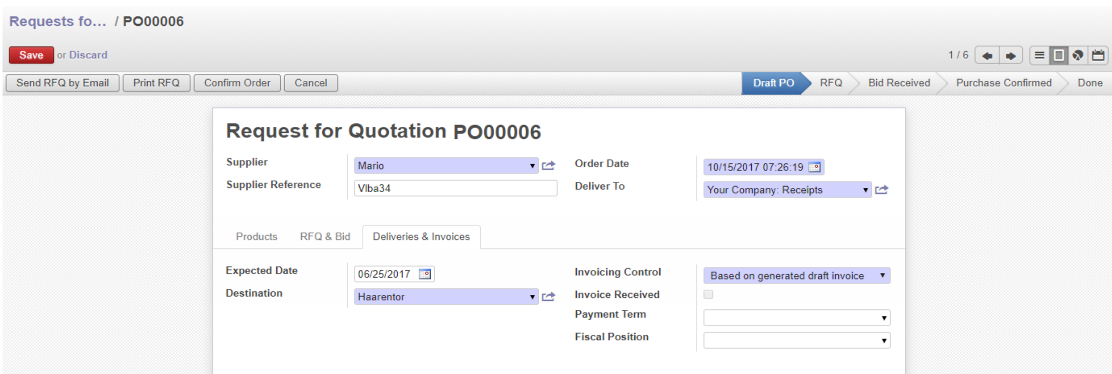


Fig. 5.4: Screenshot of the Deliveries and Invoices tab of the RFQ form in the purchases module of the Odoo ERP system

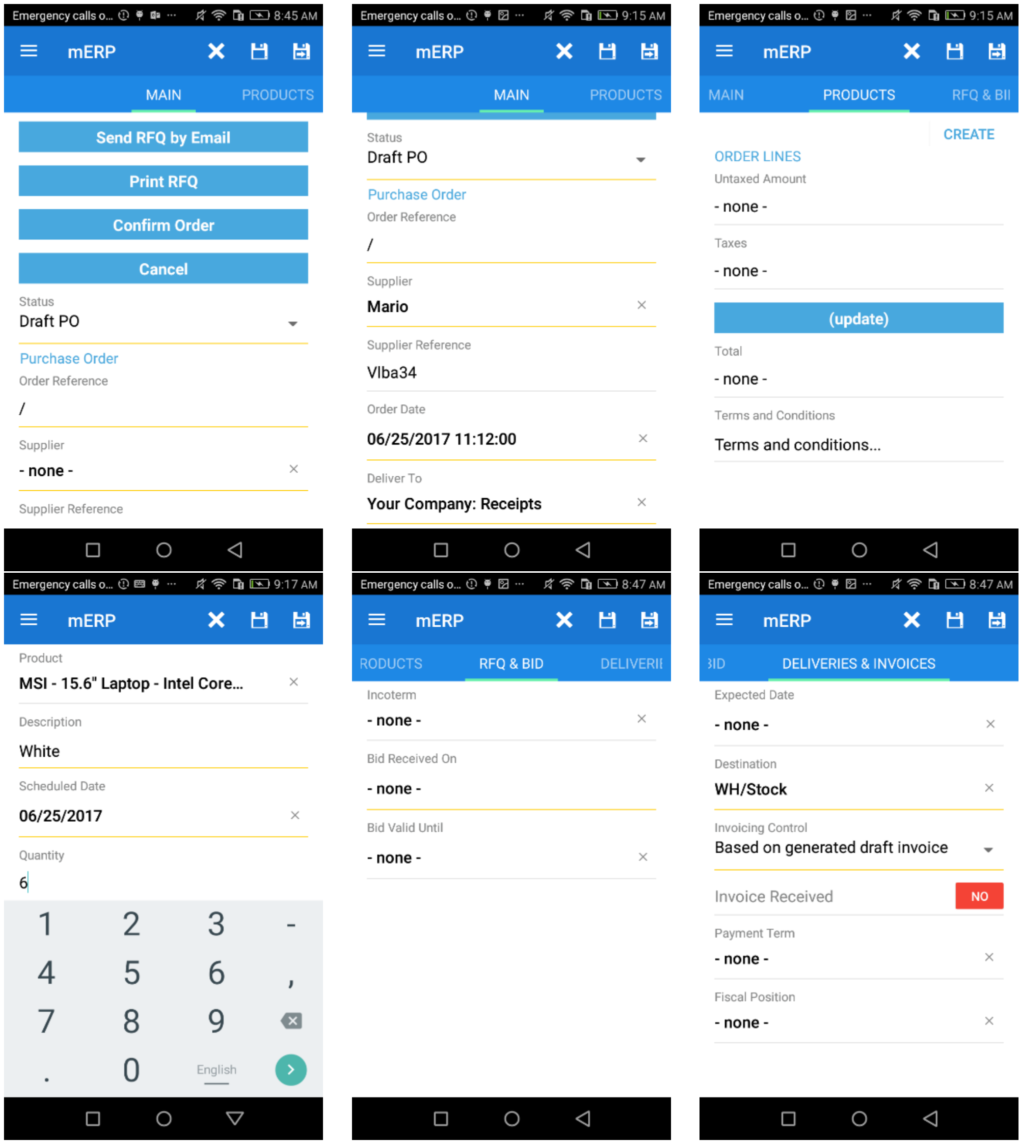


Fig. 5.5: Screenshots of the RFQ form in the purchases module of the mERP app

In chapter 3, a set of usability challenges were identified that negatively impacts the usability of the mERP app, and these challenges were identified from the following conducted research studies:

1. The conducted heuristic evaluation for the mERP app.
2. The conducted survey questionnaire for the mERP App's end-users.

Based on these research studies, the following usability challenges of the mERP app were identified:

1. More time required compared with the conventional approach to complete a task.
2. Stubborn to the context of use variability (needs to be adaptive).
3. A lack of correction and validation techniques that suit the context of use.
4. A lack of intuitive learning.

5. Bloated UIs.
6. A multitude of interaction steps.
7. Memorability.
8. Findability of the desired information and functionalities.
9. Contextual help.
10. Task completion.
11. Personalisation.
12. Security issues.

In order to address the abovementioned usability challenges, a prototype was developed which incorporates the developed computational framework in Chapter 4. Thus, the next section demonstrates how this framework can be implemented for the mERP app.

5.2 Prototype as a Proof of Concept

A prototype of the RFQ form in the purchases module of the mERP app was developed as a proof of concept by using Java language in order to be run on Android mobile OS, due to the inaccessibility of the source code of the mERP app, which was needed to be modified to:

1. Incorporate the developed computational framework.
2. Modify its source code to measure the determined usability metrics for conducting the evaluation experiments that will be explained in the next chapter.

Consequently, two versions of the developed prototype were developed, which are the adaptive version and the non-adaptive version.

In the previous chapter, the dimensions of the adaptation processes that can support the realisation of the identified adaptation types (content, presentation, and navigation) were identified, which support the UI adaptation based on the current context of use at a running time, and these dimensions are:

1. Invoking the appropriate activity based on the current context of use.
2. Invoking the appropriate dialog based on the current context of use for the invoked activity.
3. Adapting the UI widgets based on the current context of use.

Furthermore, three steps of the adaptation processes were identified in the previous chapter to support the abovementioned dimensions, which are:

1. Monitoring and acquiring contextual information regarding the current task, which is performed by a current end-user, who is using a specific mobile device with its current status of resources, in a current environment.
2. Analysing and interpreting the acquired contextual information from the previous step for it to be easily understood by the adaptive system.
3. Triggering the related adaptation rules based on the resulted model from the previous step to perform one or more of the aforementioned dimensions of adaptivity.

In the following sub-sections, the abovementioned steps will be demonstrated, and how they were followed in the adaptive version of the developed prototype.

5.2.1 Monitoring and Acquiring Contextual Information

As stated earlier in Chapter 4, the context of use of a mobile ERP app is defined by the current task, which is performed by a current end-user, who is using a specific mobile device with its current status of resources, in a current environment. Therefore, these contextual entities will be monitored, and the information for their parameters will be acquired. This process is performed by the monitoring and acquiring module of the modelling layer in the proposed adaptive system architecture in Chapter 4. Therefore, the acquiring process for each of the identified contextual entities will be explained in the following sub-sections.

5.2.1.1 Modelling of the Currently Performed Task

The currently performed task is the first entity of the determined contextual entities of mobile ERP apps, which assists in modelling the current context of use of mobile ERP apps in the proposed computational framework. This task is recognised by the monitoring and acquiring module of the proposed adaptive system architecture in chapter 4. Therefore, this module retrieves the assigned unique identifier (id) of the currently performed task through the running activity from the activity model, which was already selected based on the current context of use. In addition, each task has a sequence attribute that indicates the previous task that must be completed first by storing the id for it.

Consequently, the retrieved id of the currently performed task can be used in the realisation of the three identified adaptation dimensions.

For instance, the “procure materials” is one of the identified goals that can be achieved in the developed prototype of the mERP app as can be seen from Figure 5.6, and this goal can be achieved by completing two identified tasks in the “task” table respectively, which are: the “login” task, which has an id=2 and sequence=1, and the “create purchase order” task, which has an id=3 and sequence=2. Once the activity is invoked for the “login” task, the id for this task is recognised by the adaptive system, which is 2. This value is used to determine the next task that will be performed based on mapping it to the values in the sequence attribute in the “task” table, and thus, the id of the next task that will be performed after the completion of the login activity is 3, which is the “create purchase order” task.

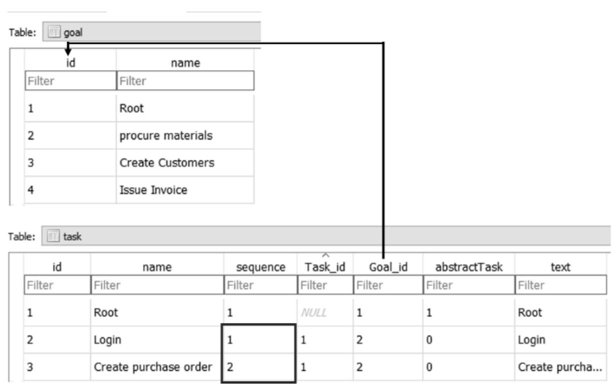


Table: goal

id	name
Filter	Filter
1	Root
2	procure materials
3	Create Customers
4	Issue Invoice

Table: task

id	name	sequence	Task_id	Goal_id	abstractTask	text
Filter	Filter	Filter	Filter	Filter	Filter	Filter
1	Root	1	NULL	1	1	Root
2	Login	1	1	2	0	Login
3	Create purchase order	2	1	2	0	Create purcha...

Fig. 5.6: Referential integrity constraints between the task, and goal tables in the proposed relational database schema

Consequently, the activity selector and dialog selector components of the adaptive engine module use the retrieved id of the next task (id=3) as one of its contextual parameters to determine the appropriate activity and dialog that will be invoked to complete this task. This is an example of the logic based models approach which demonstrates how to use the currently performed task entity to invoke the appropriate activity and dialog as the proposed adaptation dimensions in the proposed computational framework. Listing 5.1 lists an excerpt from the written code of the Login activity class to invoke the appropriate activity for the next task based on the current context of use once the login activity is completed.

```
…
//get the current taskId of Login activity
c = myDbHelper.query2("task","id","name","Login");
if (c.moveToFirst()) {
    appContext= Login.this.getSharedPreferences("APP_CONTEXT",MODE_PRIVATE);
    editor= appContext.edit();
    editor.putInt("taskId",Integer.parseInt(c.getString(0)));
    editor.commit();
}
c.close();
…
//get next taskId after finishing successfully the Login activity
Cursor cNextTask = myDbHelper.query2("task","id","sequence",String.valueOf(taskId));
if (cNextTask.moveToFirst()) {
    NextTaskId=Integer.parseInt(cNextTask.getString(0));
}
cNextTask.close();
…
// Initiate the ActivitySelector module in the adaptive engine
ActivitySelector activitySelector = new ActivitySelector(Login.this,
getApplicationContext(),
        NextTaskId,
        appContext.getString("visualAcuity","low"),
        appContext.getString("ThumbLength","short"),
        appContext.getString("HandType","right"),
        appContext.getString("ThumbCircumference","small"),
        userLoginKnowledge, connectionState, accId, soundIntensity, lightId, batStatus,
memoryStatus);
String activityName=activitySelector.getActivityName();
Intent intent = new Intent();
String resourcePackageName = getApplicationContext().getPackageName();
intent.setClassName(resourcePackageName,resourcePackageName +
".activities."+activityName);
startActivity(intent);
…
```

Listing 5.1: Excerpt from the written code in the Login class

5.2.1.2 End-user Modelling

The current end-user who is using the mobile ERP app is the second entity of the determined contextual entities of mobile ERP apps. Thus, this entity is recognised by the proposed adaptive system by the monitoring and acquiring module to realise the identified three adaptation dimensions.

The current end-user is recognised by the adaptive system through his/her id. Therefore, the following end-user's parameters will be retrieved from the user model based on the determined id of the end-user.

Physiological Characteristics

In chapter 4, the physiological characteristics of the end-users of mobile ERP apps were determined to construct the user model in the proposed computational framework, which are: thumb circumference, thumb length, hand type, and visual acuity. The data for these parameters are explicitly acquired from the end-user once the developed prototype of mERP is installed as can be seen from Figure 5.7. The information of these parameters is retrieved once the end-user has successfully logged in to the developed prototype, and thus, the monitoring and acquiring module utilises this information to build the contextual model.

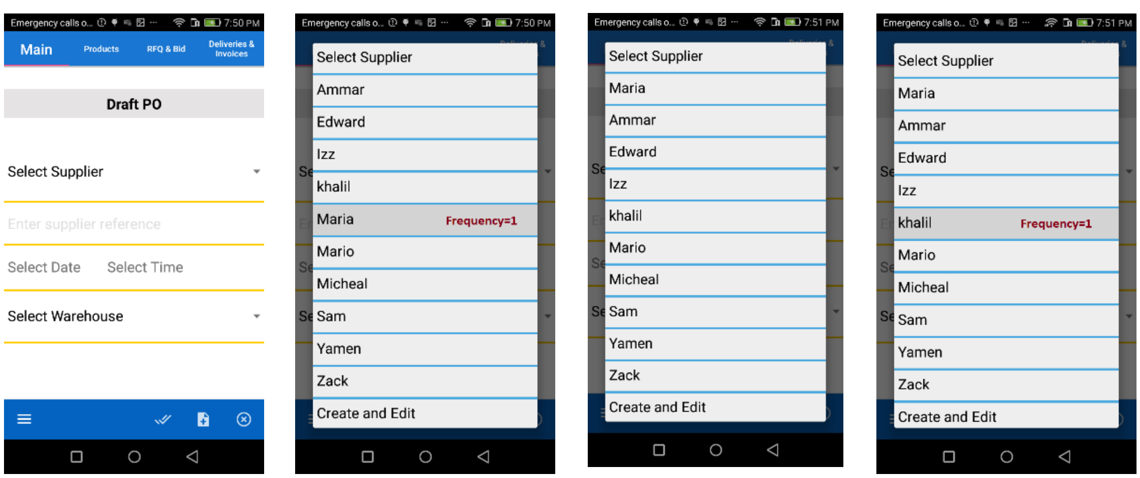
Fig. 5.7: Screen shoot of the modelling process for the physiological characteristics of the end-users in the developed prototype

Interaction

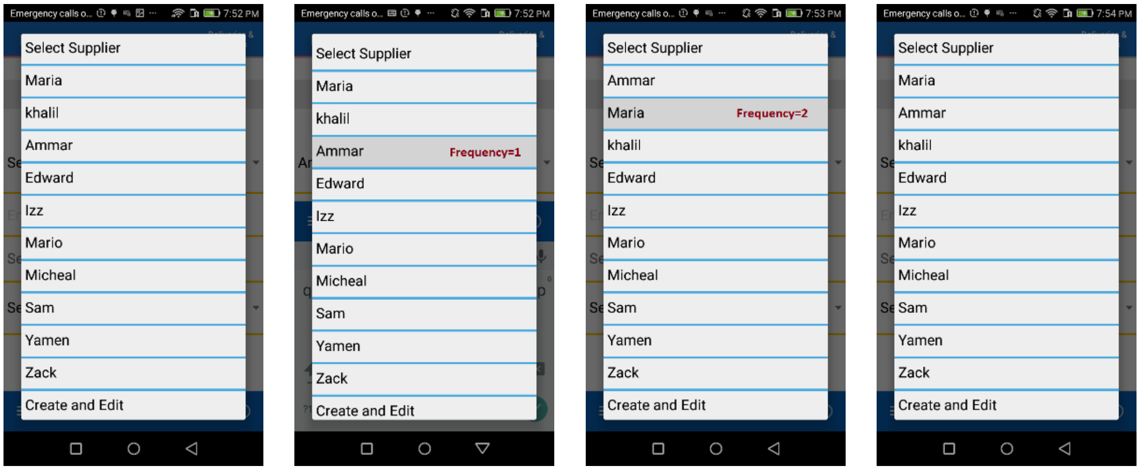
As stated in Chapter 4, two interaction patterns of the end-user are modelled in the proposed computational framework, which are:

- The MRU item by the end-user for a given list of items.
- The MFU item by the end-user for a list of given items.

Thus, the developed adaptive system saves these items for a specific dialog's component for a specific end-user, and once it is rendered again for the same end-user, the MRU and MFU items will be positioned at the beginning of the list in order to minimise the required interaction steps in the selection of the items. Figure 5.8 illustrates a complete example of using the MFU item pattern for the spinner of suppliers in the developed prototype, and this interaction pattern is considered one of the identified mobile HCI patterns in the proposed content adaptation taxonomy in Chapter 4 to realise the content adaptation of UI's widgets. In addition, Listings 5.2 and 5.3 list excerpts from the written codes to implement this mobile HCI pattern.



Andreas joined create new purchase order activity	Andreas selected the supplier Maria	Andreas joined create purchase order activity again and open the spinner of suppliers	Andreas selected the supplier Khalil



Andreas joined create purchase order activity again and open the spinner of suppliers	Andreas selected supplier Ammar	Andreas joined create purchase order activity again and open the spinner of suppliers and select the supplier Maria	Andreas joined create purchase order activity again and open the spinner of suppliers

Fig. 5.8: Complete example of using MFU item pattern in the developed prototype

```
…
public void onItemSelected(AdapterView<?> parent, View view, int position, long id) {
…
        c = myDbHelper.query3("select * from interaction where   ERPUser_id='"+userId+"'
and Presentation_id='fragment_rfq2main_suppliers' and item_title='"+supName+"'");
        if(c.getCount()==0) {
            sqLiteDatabase = myDbHelper.getWritableDatabase();
            myDbHelper.insertInteraction(size, supName, 1, userId,
"fragment_rfq2main_suppliers", sqLiteDatabase);
        }
        else
        {
            c2= myDbHelper.query3("select frequency from interaction where
ERPUser_id='"+userId+"' and Presentation_id='fragment_rfq2main_suppliers' and
item_title='"+supName+"'");
            if(c2.moveToFirst()) {
                String Freq = c2.getString(0);
                int newFreq = Integer.parseInt(Freq) + 1;
                sqLiteDatabase = myDbHelper.getWritableDatabase();
myDbHelper.updateInteraction(supName,newFreq,userId,"fragment_rfq2main_suppliers",sqLiteDa
tabase);
…
```

Listing 5.2: Excerpt from the written code that shows the implementation of MFU item pattern

```
…
//Retrieving the userId for the logged in end-user from the SharedPreference
appContext = getActivity().getSharedPreferences("APP_CONTEXT", MODE_PRIVATE);
editor = appContext.edit();
userId=appContext.getInt("userIdLogin",0);
…
//Retrieving items for the suppliers spinner and sorting them by frequency
c = myDbHelper.query3("select * from interaction where ERPUser_id='"+userId+"' and
Presentation_id='fragment_rfq2main_suppliers' order by frequency desc");
if (c.moveToFirst()) {
    do {
        s_ids.add(String.valueOf(c.getInt(1)));
        s_names.add(c.getString(2));
    } while (c.moveToNext());
}
c.close();
…
```

Listing 5.3: Excerpt from the written code that shows the initialisation of the new items for the spinner of suppliers when it's rendered again for the current end-user

Knowledge

As stated earlier in Chapter 4, the quantitative model is used to determine the end-user's knowledge for a specific task in the proposed computational framework. Therefore, two contextual parameters are monitored and acquired by the developed adaptive system for the currently performed task, which are: the error rate and the spent amount of time to complete this task by a specific end-user. According to this acquired information, the knowledge class for the end-user who achieved this task successfully will be determined by the adaptive system. This determination is based on a set of predefined rules by the AUIs engineer for a specific task. Figure 5.9 depicts the identified rules in the "taskknowledgerule" table for the "the create purchase order" task. Besides, Listing 5.4 lists an excerpt from the written code for utilising these rules in order to determine the knowledge class based on the recorded error rate and the spent amount of time to complete the "the create purchase order". Based on the determined knowledge from these rules, the value of the "knowledgeCategory_id" attribute in the "userknowledgetask" will be updated for the end-user as can be seen from Figure 5.10.

Table: taskknowledgerule

	id	Task_id	KnowledgeCategory_id	errorRate	totalTime
	Filter	Filter	Filter	Filter	Filter
1	1	2	1	5	300
2	2	2	2	3	180
3	3	2	3	1	120

Fig. 5.9: Predefined rules for the knowledge classification for the "the create purchase order" task

```
..
/*
ne: the defined error rate for the class of novice end-users as a low-threshold to complete a
specific task in the taskknowldgerule table.

nt: the defined required time for the class of novice end-users as a low-threshold to complete a
specific task in the taskknowldgerule table.

me: the defined error rate for the class of moderate end-users as a low-threshold to complete a
specific task in the taskknowldgerule table.

mt: the defined required time for the class of moderate end-users as a low-threshold to complete a
specific task in the taskknowldgerule table.

ee: the defined error rate for the class of expert end-users as a low-threshold to complete a
specific task in the taskknowldgerule table.

et: the defined required time for the class of expert end-users as a low-threshold to complete a
specific task in the taskknowldgerule table.
*/
String knowledge= ((errorRate >=ne) || (time>=nt)) ? "novice": (((errorRate >=me) && (errorRate<ne))
|| ((time>=mt) && (time <nt)))?"moderate": (((errorRate >=ee) && (errorRate< me)) || ((time>=et) &&
(time <mt)))?"expert":"unclassified";
..
```

Listing 5.4: Excerpt from the written code to determine the knowledge class for a specific task

For instance, the record which has an id equal to 4 in the "userknowledgetask" table in the Figure 5.10 has a "knowledgeCategory_id" attribute equal to 1. This means the end-user who has an id equal to 4 in the "ERPUser_id" attribute in this record belongs to the novice end-users class for the "the create purchase order" task, which is indicated by the "Task_id" attribute that has an id equal to 2. This interpretation is based on mapping both the taskId=2 and userId=4, which were acquired by the monitoring and acquiring module, to the "userknowledgetask" table in the created database to retrieve the value of the "KnowledgeCategories_id" attribute in this table, which is 1, and this value means a novice class based on mapping it to the id attribute in the "knowldgecategory" table. Figure 5.11 depicts two patterns for helping the end-users based on their knowledge class.

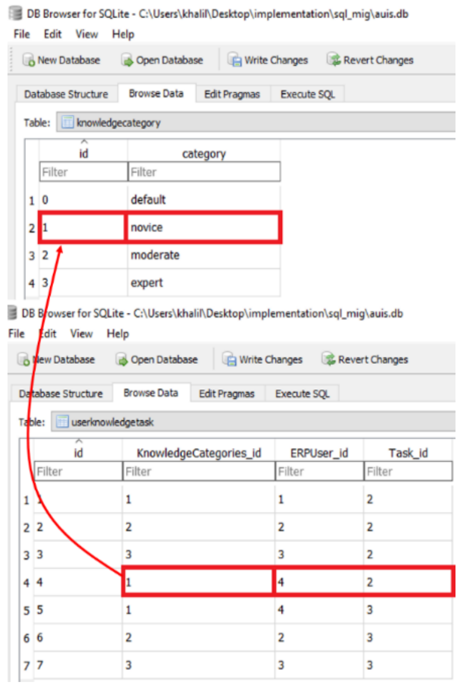


Fig. 5.10: Referential integrity constraints between the “userknowledgetask” and “knowldgecategory” tables in the proposed relational database schema

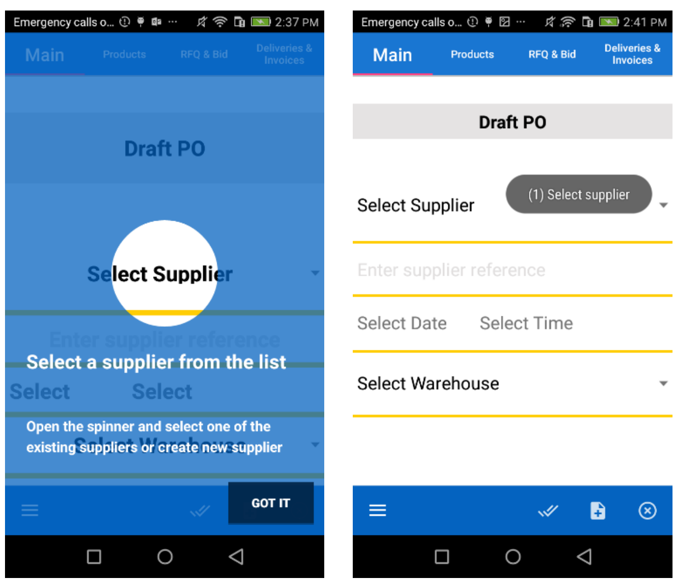


Fig. 5.11: Two helping patterns for the end-users to create RFQ; the screenshot on the left is for novice end-users, and the one on the right is for moderate end-users

Preferences

In the developed computational framework, each end-user can prevent a specific adaptation process from implementation, and thus, the adaptive system validates the determined end-user preferences before implementing any adaptation process. For instance, the stored record in the “adaptiveprev” table in Figure 5.12 indicates that the end-user who has an id equal to 4 prevents the rule action that has an id equal to 3 in the “ruleaction” table from being performed.

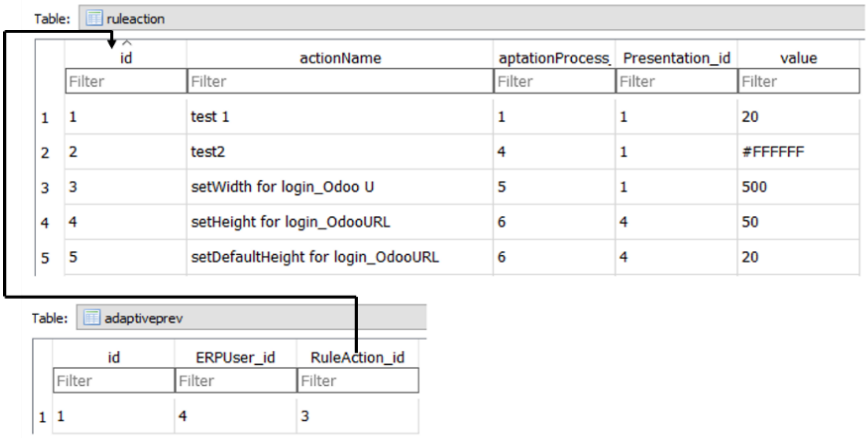


Table: ruleaction

	id	actionName	aptationProcess_	Presentation_id	value
1	1	test 1	1	1	20
2	2	test2	4	1	#FFFFFF
3	3	setWidth for login_Odoo U	5	1	500
4	4	setHeight for login_OdooURL	6	4	50
5	5	setDefaultHeight for login_OdooURL	6	4	20

Table: adaptiveprev

	id	ERPUser_id	RuleAction_id
1	1	4	3

Fig. 5.12: Referential integrity constraints between the "adaptiveprev", and "ruleaction" tables in the proposed relational database schema

5.2.1.3 Device Modelling

In the developed computational framework, the percentage of the available memory and the battery level are observed for the mobile device, which is considered the third determined contextual entity of mobile ERP apps. This observation is carried out by the monitoring and acquiring module of the modelling layer in the proposed adaptive system architecture. Figure 5.13 depicts screenshots that show the available memory percentage and the remaining battery percentage level at a running time in the mobile device, which was used to operate the developed prototype. Listings 5.5 lists an excerpt from the written code of the developed MemoryInfo class that shows how the available memory percentage is acquired programmatically. Besides, Listing 5.6 lists an excerpt from the written code of the developed Broadcast class that shows how the battery percentage level is acquired programmatically.

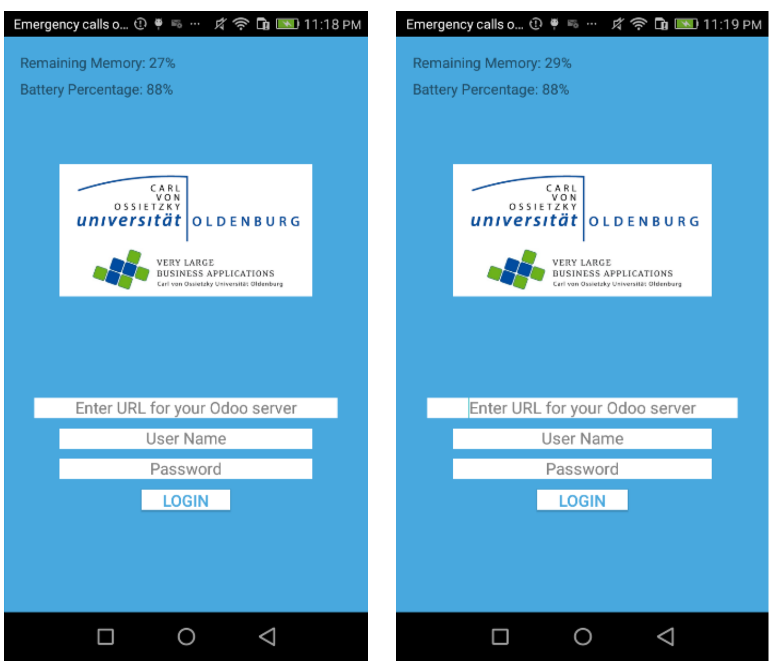


Fig. 5.13: Acquired information regarding the available memory percentage and the battery percentage level of the mobile device at a running time

```
…
public MemoryInfo(Activity activity)
{
    this.activity=activity;
    activityManager = (ActivityManager) activity.getSystemService(ACTIVITY_SERVICE);
    memoryInfo = new ActivityManager.MemoryInfo();
    activityManager.getMemoryInfo(memoryInfo);
    double availMem=(double)memoryInfo.availMem/1048576;
    double totaMem= (double)memoryInfo.totalMem/1048576;
    double memAvailPercent= (availMem/ totaMem)*100;
    memory=Integer.parseInt(twoDForm.format(memAvailPercent));
…
```

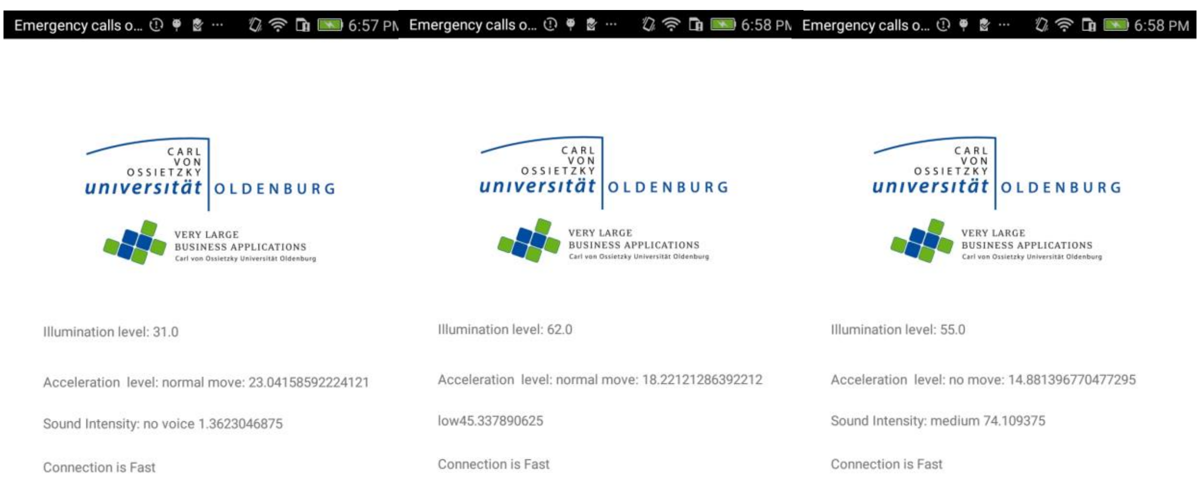
Listing 5.5: Excerpt from the written code of the developed MemoryInfo class

```
…
public void onReceive(Context context, Intent intent) {
    IntentFilter ifilter = new IntentFilter(Intent.ACTION_BATTERY_CHANGED);
    Intent batteryStatus = context.registerReceiver(null, ifilter);
    int level = batteryStatus.getIntExtra(BatteryManager.EXTRA_LEVEL, -1);
    int scale = batteryStatus.getIntExtra(BatteryManager.EXTRA_SCALE, -1);
    float batteryPct = (level / (float) scale) * 100;
…
```

Listing 5.6: Excerpt from the written code of the developed Broadcast class

5.2.1.4 Environment Modelling

Presently, most mobile devices are equipped with different types of sensors to acquire environment-specific context information, such as Accelerometer, Photometer (Light), and Microphone in Android-powered devices. Thus, these sensors are used to collect the information for the last determined contextual entity of mobile ERP apps, which is the environment. The information for this entity's parameters is acquired by the monitoring and acquiring module to characterise the environment-specific context of use of the developed prototype of the mERP app. These parameters for the environment entity were determined for the environment model in Chapter 4, which are: acceleration, ambient light level (illumination), and sound intensity. Figure 5.14 depicts the acquired information for the determined environmental parameters in different environmental contexts of use. In addition, the information regarding the network connection speed and status is programmatically acquired with the assistance of the ConnectivityManager class in Android. Listing 5.7 lists an excerpt from the written code to detect the connection speed and status with the assistance of the developed Connectivity class.



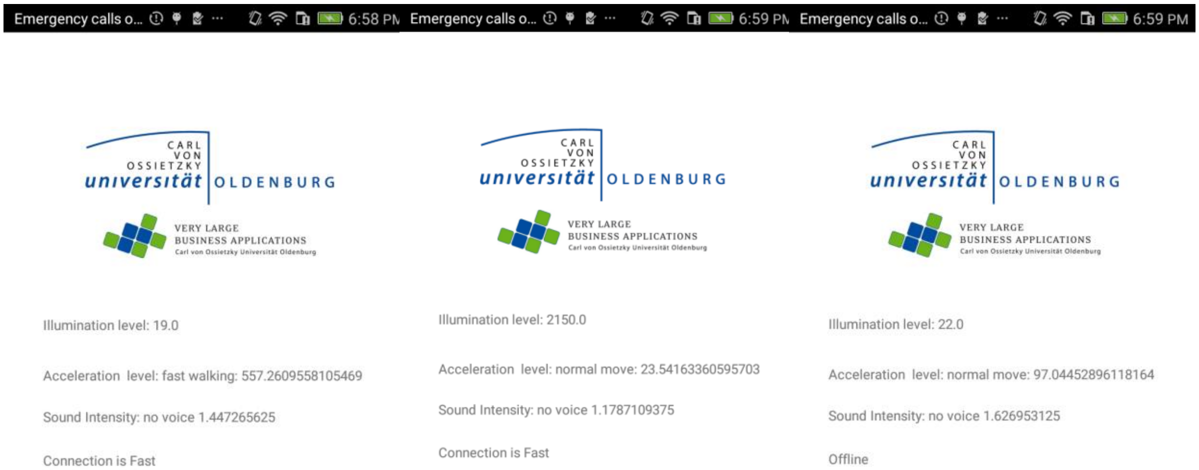


Fig. 5.14: Different screenshots that show the acquired environment-specific context information in different environmental contexts of use

```
…
con= new Connectivity();
…
protected void onResume()
{
…
        isConnected=con.isConnected(context);
        isConnectedFast=con.isConnectedFast(context);
        if(isConnected)
        {
            if(isConnectedFast)
             {
               connectionState=4;
             }
            else{
               connectionState=2;
             }
        }
        else
        {
            connectionState=1;
        }
…
```

Listing 5.7: Excerpt from the written code to detect the connection speed and status

The built-in accelerometer sensor in Android-powered devices measures the acceleration force in m/s^2 that is applied to a device on all three physical axes (x, y, and z), including the force of gravity (Android, 2016b). In the developed prototype, this sensor is used to detect the mobile device motion state, such as shake, tilt, end-user walking, end-user running, and others as can be seen from Figure 5.15. Furthermore, the median filter technique was applied in order to get the closest value that represents the current acceleration of the mobile device. Therefore, the median for the last 10 detected acceleration is calculated. Listing 5.8 lists an excerpt from the written code of the developed AccelerometerSensor class to measure the mobile device acceleration, and to filter the acquired information.

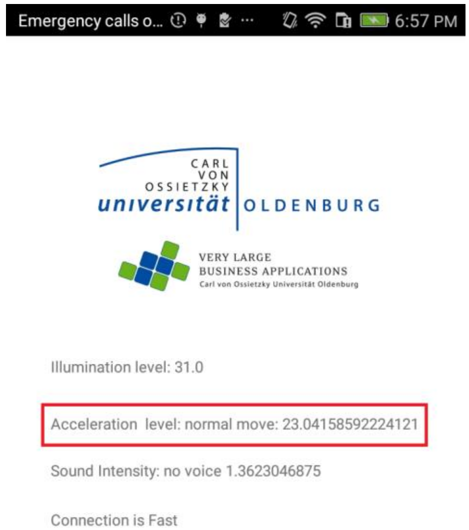


Fig. 5.15: Measured acceleration value of the mobile device at a specific time

```
…
public AccelerometerSensor(Context context, Activity activity) {
    handler = new Handler();
    mSensorManager = (SensorManager) context.getSystemService(Context.SENSOR_SERVICE);
    accSensor = mSensorManager.getDefaultSensor(Sensor.TYPE_ACCELEROMETER);
    this.activity=activity;
…
public void setListener(AccSensorListener listener) {this.listener = listener;}
public boolean register() {
    return mSensorManager.registerListener(this, accSensor,
SensorManager.SENSOR_DELAY_NORMAL);
}
…
public void onSensorChanged(SensorEvent event) {
    if (flag) {
        if (listener != null) {
            listener.onAccSensorChanged(sp);
            float x = event.values[0];
            float y = event.values[1];
            float z = event.values[2];
            long curTime = System.currentTimeMillis();
            if ((curTime - lastUpdate) > 10) {
                long diffTime = (curTime - lastUpdate);
                lastUpdate = curTime;
                float speed = Math.abs(x + y + z - last_x - last_y - last_z) / diffTime *
10000;
                list.add(speed);
                if(list.size()==10) {
                    Collections.sort(list);
                    calMedian();
                }
                last_x = x;
                last_y = y;
                last_z = z;
            }
        }
        flag=false;
    }
 }
public void calMedian()
{    double median;
    if (list.size() % 2 == 0)
        median = ((double)list.get(list.size()/2) + (double)list.get(list.size()/2 -
1))/2;
    else
        median = (double) list.get(list.size()/2);
…
```

Listing 5.8: Excerpt from the written code of the developed AccelerometerSensor class

The built-in light sensor in Android-powered devices measures the ambient light level (illumination) of it, and its unit of measurement is the lx (Android, 2017b). In the developed prototype, the ambient light level is sensed every second as can be seen from Figure 5.16, and this interval can be extended for a longer period to perform sensing again. Listing 5.9 lists an excerpt from the written code of the developed Light class for sensing the ambient light level every second.

Fig. 5.16: Measured illumination value of the mobile device at a specific time

```
…
public LightSensor(Context context, Activity activity) {
    mSensorManagerx = (SensorManager) context.getSystemService(Context.SENSOR_SERVICE);
    lightManager = mSensorManagerx.getDefaultSensor(Sensor.TYPE_LIGHT);
    lp = activity.getWindow().getAttributes();
    this.activity=activity;
…
public void setListener(LightSensorListener listener) {
    this.listener = listener;
}

public boolean register() {
    return mSensorManagerx.registerListener(this, lightManager, 1000000);
}
@Override
public void onSensorChanged(SensorEvent event) {
  …
}

@Override
public void onAccuracyChanged(Sensor sensor, int accuracy) {

}

public void unregister() {
    mSensorManagerx.unregisterListener(this);
}
…
```

Listing 5.9: Excerpt from the written code of the developed Light class

As can be seen from Figure 5.17, the microphone of the mobile device is used by the developed prototype to detect the ambient sound intensity level in dB. Listing 5.10 lists an excerpt from the written code to detect the ambient sound intensity. Furthermore, the median filter technique was applied in order to get the closest sound intensity value that represents the current ambient sound of a mobile device. Therefore, the median for the last 10 detected sound intensity levels is calculated. Listing 5.11 lists an excerpt from the written code to apply the median filter technique for the detected sound intensities.

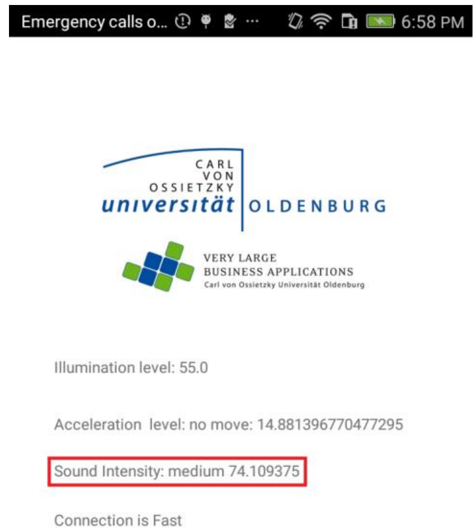


Fig. 5.17: Measured ambient sound intensity value of the mobile device at a specific time

```
…
audio = new AudioRecord(MediaRecorder.AudioSource.MIC, sampleRate,
        AudioFormat.CHANNEL_IN_MONO,
        AudioFormat.ENCODING_PCM_16BIT, bufferSize);
audio.startRecording();
thread = new Thread(new Runnable() {
    public void run() {
        while(thread != null && !thread.isInterrupted()){
            try{Thread.sleep(SAMPLE_DELAY);}catch(InterruptedException
ie){ie.printStackTrace();}
            readAudioBuffer();
            runOnUiThread(new Runnable() {
                @Override
                public void run() {
                    soundlist.add(lastLevel);
                    if(soundlist.size()==10) {
                        Collections.sort(soundlist);
                        calSoundMedian();
                    }
                }
            });
        }
    }
});
thread.start();
…
private void readAudioBuffer() {
    try {
        short[] buffer = new short[bufferSize];
        int bufferReadResult = 1;

        if (audio != null) {
            // Sense the voice...
            bufferReadResult = audio.read(buffer, 0, bufferSize);
            double sumLevel = 0;
            for (int i = 0; i < bufferReadResult; i++) {
                sumLevel += buffer[i];
            }
            lastLevel = Math.abs((sumLevel / bufferReadResult));
        }
    } catch (Exception e) {
        e.printStackTrace();
    }
}
…
```

Listing 5.10: Excerpt from the written code to detect the ambient sound intensity

```
…
public void calSoundMedian()
{
    double median;
    if (soundlist.size() % 2 == 0)
        median = (soundlist.get(soundlist.size()/2) + soundlist.get(soundlist.size()/2 -
1))/2;
    else
        median = soundlist.get(soundlist.size()/2);

    if(median > lowTh1 && median <= lowTh2){
        soundIntensity=1;
    }
    else if(median > mediumTh1 && median <= mediumTh2){
        soundIntensity=2;
    }else if(median > highTh1 && median <= highTh2){
        soundIntensity=3;
    }
    soundlist.clear();
}
…
```

Listing 5.11: Excerpt from the written code to apply the median filter technique for the detected sound intensities

5.2.2 Analysing the Acquired Contextual Information

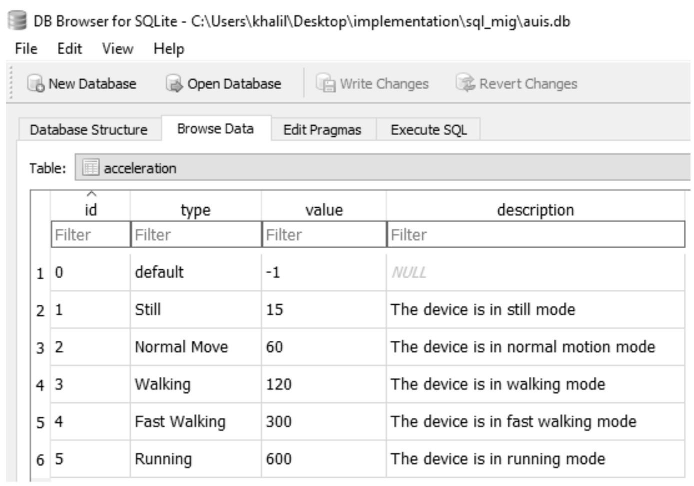
Some of the acquired information for some of the parameters of the determined contextual entities of the mobile ERPs apps cannot be understood by the adaptive engine's components (activity selector, dialog selector, and UIs' Widget Adaptor). Thus, this information is interpreted into more semantic representations by the analyser module of the modelling layer in the proposed adaptive system architecture. This interpretation process is achieved by mapping the acquired information for a specific parameter to the predefined classifications for this parameter by the adaptive engineer in the knowledge models, which are stored in the created database by using SQLite RDBMS in the developed prototype. For instance, Table 5.1 presents the acquired contextual information for the end-user "Ali" whose id is 4 while he is performing the "create purchase order" task (id=3). Some of this information cannot be understand by the adaptive engine's components, which are: acceleration, sound intensity, illumination, battery percentage level, and available memory percentage. Therefore, the analyser module takes the role to interpret this information into more semantic representations in order to realise the identified adaption dimensions.

Contextual parameters	Acquired value
Task id	3
User id	4
Visual acuity	low
Thumb length	short
Hand type	right
Thumb circumference	small
Knowledge category id	1
Connection state id	4
Acceleration	180 m/s^2
Sound intensity	19 dB
Illumination	400 lx
Battery percentage level	77%
Available memory percentage	30%

Tab. 5.1: Example that depicts the acquired contextual information for the end-user Ali while he is performing the create purchase order task

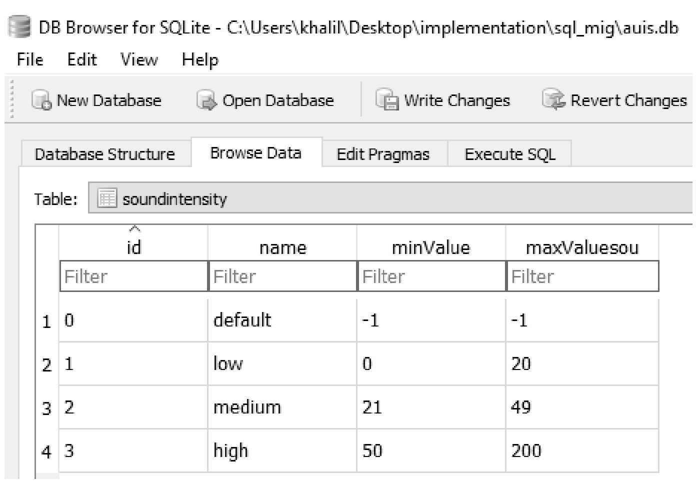
As can be seen from Table 5.1, the acquired acceleration value in the given example is 180 m/s^2, and this value belongs to the “the device is in the walking mode” class, which has an id equal to 3. This interpretation is based on mapping the acquired value of 180 m/s^2 to the populated values of the predefined classifications by the adaptive engineer in the “acceleration” table. Therefore, this acquired acceleration class has an id equal to 3 (more than or equal to 120 and less than 300), and this value will be understandable by the adaptive engine’s components. Figure 5.18 depicts the predefined classifications of the acceleration, which are used in the mapping process that are performed by the analyser module. However, the values for these classifications were identified based on several empirical tests that were conducted in this research study to observe the closest value of acceleration that represents each of the identified classes.

As for the acquired sound intensity in the given example, the value of 19 dB belongs to the “low” class, which has an id equal to 1. This interpretation is based on mapping the acquired value of 19 dB to the populated values of the predefined classifications in the “soundintensity” table in the created database. Figure 5.19 depicts the utilised classifications of sound intensity by the analyser module to interpret the acquired sound intensity. However, the values for these classifications were identified based on several empirical tests which were conducted in this research study to observe the closest value of the ambient sound intensity that represents each of the identified classes.



	id	type	value	description
	Filter	Filter	Filter	Filter
1	0	default	-1	NULL
2	1	Still	15	The device is in still mode
3	2	Normal Move	60	The device is in normal motion mode
4	3	Walking	120	The device is in walking mode
5	4	Fast Walking	300	The device is in fast walking mode
6	5	Running	600	The device is in running mode

Fig. 5.18: Predefined classifications for acceleration



	id	name	minValue	maxValuesou
	Filter	Filter	Filter	Filter
1	0	default	-1	-1
2	1	low	0	20
3	2	medium	21	49
4	3	high	50	200

Fig. 5.19: Predefined classifications for ambient sound intensity

Regarding the acquired information for ambient light level (illumination) of the mobile device, the value of 400 lx belongs to the “Office lighting” class in the “luminance” table, which has an id equal to 9. This interpretation is based on the predefined classifications of the illumination levels under various conditions in Figure 5.20. These classifications were adapted from (Wikipedia, 2017), which are compiled from different resources. In addition, the illumination values for these classifications were validated through several empirical tests in different illumination situations in this research study. For each class, the determined value in “brightness” attribute indicates the brightness percentage level that will be used in the adaptation process for the screen brightness adjustment.

Table: luminance

	id	name	minValue	maxValue	brightness
	Filter	Filter	Filter	Filter	Filter
1	0	default	NULL	NULL	NULL
2	1	Moonless overcast night sky (starlight)	0.0	0.0001	1.0
3	2	Moonless clear night sky with air glow	0.0001	0.0026	1.0
4	3	Full moon on a clear night	0.27	1.0	0.9
5	4	Dark limit of civil twilight under a clear sky	1.0	3.4	0.6
6	5	Family living room lights	3.4	50.0	0.4
7	6	Office building hallway/toilet lighting	50.0	80.0	0.4
8	7	Very dark overcast day	80.0	100.0	0.3
9	8	dark overcast day	100.0	320.0	0.3
10	9	Office lighting	320.0	500.0	0.4
11	10	Overcast day typical TV studio lighting	500.0	1000.0	0.4
12	11	Full daylight (not direct sun)	1000.0	25000.0	0.8
13	12	Direct sunlight	25000.0	100000.0	1.0

Fig. 5.20: Predefined classifications of the illumination levels under various conditions

Regarding the acquired battery percentage level, the value of 77% belongs to the “optimal” class, which crossed the determined threshold value of the “sufficient” plan. This interpretation is based on the predefined plans for the utilised mobile device (Huawei Y3II) by the adaptive engineer as can be seen from Figure 5.21.

DB Browser for SQLite - C:\Users\khalil\Desktop\implementation\sql_mig\auis.db

File Edit View Help

New Database Open Database Write Changes Revert Changes

Database Structure Browse Data Edit Pragmas Execute SQL

Table: batteryplan

	id	planName	not_sufficient	sufficient	optimal
	Filter	Filter	Filter	Filter	Filter
1	1	Huawei y3II	10	60	100

Fig. 5.21: Predefined battery plans for Huawei Y3II mobile device

The acquired 30% that indicates the available memory percentage belongs to the “medium” class, which crossed the determined threshold value of the “low plan”. This interpretation is based on the predefined plans for the utilised mobile device (Huawei Y3II) by the adaptive engineer as can be seen from Figure 5.22.

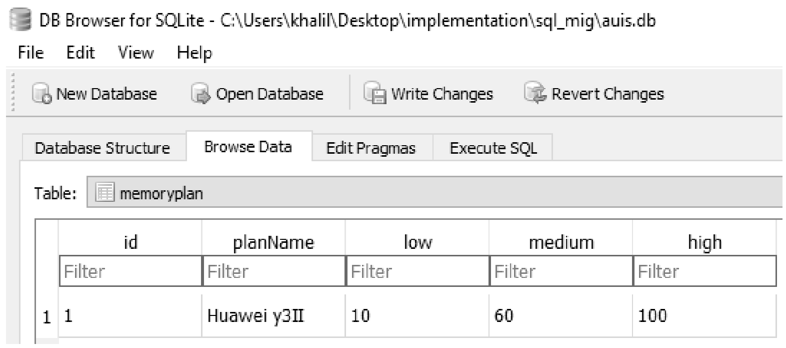


Fig. 5.22: Predefined memory plans for Huawei Y3II mobile device

Once all the information of the determined contextual entities of mobile ERP apps has been acquired and interpreted, it is stored in a SharedPreferences object in order to be used by the adaptive engine's components. The Android SharedPreferences object points to a file that contains key-value pairs, and it provides simple methods to save and retrieve these pairs (Android, 2016a). In addition, some of the stored values in these key-value pairs can be updated at running-time to store the new values of the interpreted dynamic contextual information, which are: the knowledge category of a specific task, the connection state, the acceleration, the sound intensity, the illumination, the battery state, and the memory state. Table 5.2 presents the resulted contextual model of the acquired contextual information in the given example after it has been interpreted by the analyser module.

Contextual parameters	Acquired value
Task id	3
User id	4
Visual acuity	low
Thumb length	short
Hand type	right
Thumb circumference	small
Knowledge category id	1
Connection state id	4
Acceleration id	3
Sound intensity id	1
Illumination id	9
Battery percentage level	optimal
Available memory percentage	medium

Tab. 5.2: Resulted contextual model from the modelling layer which will be used by the adaptive engine's components

5.2.3 Performing the Adaptation Dimensions

As stated earlier, the adaptation processes are classified into three dimensions in this research study in order to realise the determined adaption types (content, presentation, and navigation), and each of these dimensions adapts a specific component of the mobile ERP app whether it is activity, dialog, or a specific widget of a dialog (UI). These dimensions will be explained and demonstrated in the following sub-sections, which utilise the resulted model from the modelling layer to achieve their goals.

5.2.3.1 Activity Selector

In the proposed adaptive system architecture in Chapter 4, the activity selector component of the adaptive engine module aims to invoke the appropriate activity based on the current context of use of the mobile ERP app. This invocation is performed based on mapping the acquired and interpreted information in the resulted contextual model from the modelling layer to the predefined rules in the adaptation models by the adaptive engineer, specifically, in the activity selector model.

As stated earlier in Chapter 4, tasks in the interactive applications aim to define how the end-user can achieve a specific goal. Therefore, achieving any goal in these types of applications requires a successful completion of one or more tasks that serve the achievement of this goal.

In the proposed computational framework, the goals that the end-user attempts to achieve via mobile ERP apps are stored in the "goal" table in the created database, and the tasks that serve the achievement of each one of these goals are stored in the "task" table. For each task in the "task" table, a set of independent activities were identified, and this indicates that each one of these activities is invoked based on a specific context of use to complete its associated task separately from other activities, and this can be seen in the illustrated example in Figure 5.23. In this example, the Goal 1 is achieved by completing Task 1 and Task 2 respectively. Task 1 can be completed by invoking Activity 1.1 in case the context of use was c1, and in case the context of use was c2, the Activity 1.2 will be invoked, and the same illustration for Task 2.

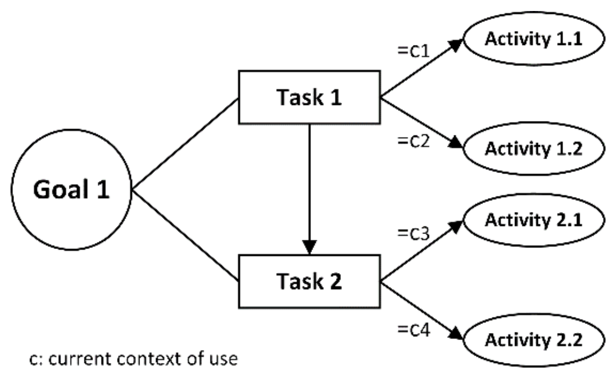


Fig. 5.23: Example of the relation between the identified goals and their associated tasks, and the relation between these tasks and their associated activities

Consequently, each created activity has a unique id in the proposed database schema diagram, and each activity is mapped to a specific task which it serves. As can be seen from Figure 5.24, the "RFQForm", "RFQForm2", and "RFQForm3" activities in the "activity" table serve the "create purchase order" task in the "task" table, which in turn serves the "procure materials" goal in the goal table.

The goal table

id	name
Filter	Filter
1	Root
2	procure materials
3	Create Customers
4	Issue Invoice

The task table

id	name	sequence	Task_id	Goal_id	abstractTask	text
Filter	Filter	Filter	Filter	Filter	Filter	Filter
1	Root	1	NULL	1	1	Root
2	Login	1	1	2	0	Login
3	Create purchase order	2	1	2	0	Create purchase order

The activity table

id	activity_id	Task_id	parent
Filter	Filter	Filter	Filter
1	Login	2	NULL
2	Login2	2	NULL
3	Login3	2	NULL
5	RFQForm	3	NULL
6	RFQForm2	3	NULL
7	RFQForm3	3	NULL
8	RFQ2Main	3	6
9	RFQ2Products	3	6
10	RFQ2Bid	3	6
11	RFQ2Deliveries	3	6

Fig. 5.24: Referential integrity constraints for the activity, task, and goal tables in the proposed relational database schema

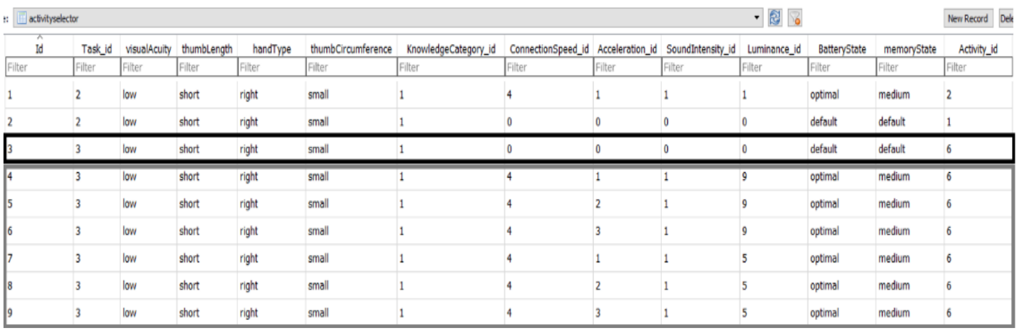
However, the question which arises is, which one of these activities will be invoked to serve the "create purchase order" task? Answering this question is realised by the activity selector component of the adaptation engine module. The role of this component is mapping the information in the resulted contextual model from the modelling layer to the predefined adaptation rules by the adaptive engineer in the "activityselector" table. Figure 5.25 depicts an excerpt from the predefined adaptation rules for selecting an appropriate activity for a specific context of use.

	Id	Task_id	visualAcuity	thumbLength	handType	thumbCircumference	KnowledgeCategory_id	ConnectionSpeed_id	Acceleration_id	SoundIntensity_id	Luminance_id	BatteryState	memoryState	Activity_id
	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter
1	1	2	low	short	right	small	1	4	1	1	1	optimal	medium	2
2	2	2	low	short	right	small	1	0	0	0	0	default	default	1
3	3	3	low	short	right	small	1	0	0	0	0	default	default	6
4	4	3	low	short	right	small	1	4	1	1	9	optimal	medium	6
5	5	3	low	short	right	small	1	4	2	1	9	optimal	medium	6
6	6	3	low	short	right	small	1	4	3	1	9	optimal	medium	6
7	7	3	low	short	right	small	1	4	1	1	5	optimal	medium	6
8	8	3	low	short	right	small	1	4	2	1	5	optimal	medium	6
9	9	3	low	short	right	small	1	4	3	1	5	optimal	medium	6
10	10	3	medium	medium	left	medium	2	0	0	0	0	default	default	6
11	11	3	medium	medium	left	medium	2	4	1	1	9	optimal	medium	6

Fig. 5.25: Excerpt from the predefined adaptation rules for selecting an appropriate activity for a specific context of use

For instance, by mapping the information in the resulted contextual model in Table 5.2 with the predefined adaptation rules in the "activityselector" table, the activity which has an id equal to 6 will be invoked, which is "RFQForm2" in the activity table.

However, identifying adaptation rules that accommodate all the contextual possibilities is a tedious process. Therefore, the developed computational framework enables the adaptive engineer to identify a general rule for an adaptation process, and then it is specialised to different rules, and each one of these rules represents a specific context of use. Furthermore, the user-centred design is considered the core of the used mechanism in identifying the general rules. Therefore, the adaptive engineer starts with identifying a general rule for a specific physiological characteristic of the end-user, and then starts to specialise this rule into different rules to serve the other possibilities of the determined contextual entities. Figure 5.26 depicts this concept for the rule which has an id equal to 3 and its specialised rules.


activityselector

Id	Task_id	visualAcuity	thumbLength	handType	thumbCircumference	KnowledgeCategory_id	ConnectionSpeed_id	Acceleration_id	SoundIntensity_id	Luminance_id	BatteryState	memoryState	Activity_id
1	2	low	short	right	small	1	4	1	1	1	optimal	medium	2
2	2	low	short	right	small	1	0	0	0	0	default	default	1
3	3	low	short	right	small	1	0	0	0	0	default	default	6
4	3	low	short	right	small	1	4	1	1	9	optimal	medium	6
5	3	low	short	right	small	1	4	2	1	9	optimal	medium	6
6	3	low	short	right	small	1	4	3	1	9	optimal	medium	6
7	3	low	short	right	small	1	4	1	1	5	optimal	medium	6
8	3	low	short	right	small	1	4	2	1	5	optimal	medium	6
9	3	low	short	right	small	1	4	3	1	5	optimal	medium	6

General Rule

Specialised rules to serve different contexts of use

Fig. 5.26: Example of the applied concept of the general rule and its specialised rules

Consequently, the ActivitySelector class was developed to handle the resulted contextual model of the current contextual information, and maps it to the predefined adaptation rules in the "activityselector" table to invoke the appropriate activity. Listing 5.12 lists an excerpt from the written code of the developed ActivitySelector class, and Listing 5.13 lists an excerpt from the written code for running the activity selector module.

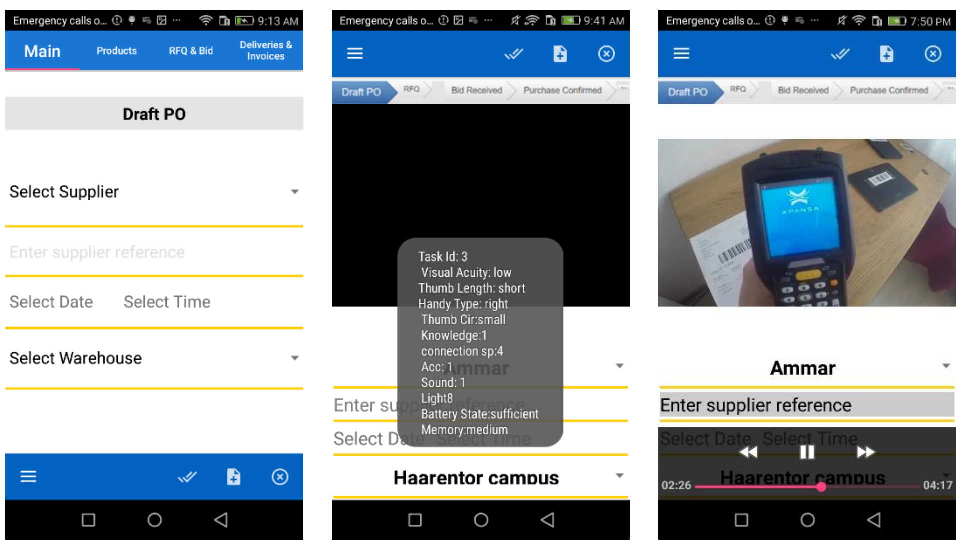
```
..
// Mapping to the specialised rule
c = myDbHelper.query3("select Activity_id from activityselector where
Task_id='"+this.taskId+"' and visualAcuity='"+this.visualAcuity+"' and
thumbLength='"+this.thumbLength+"' and handType='"+this.handType+"' and
thumbCircumference='"+this.thumbCircumference+"' and
KnowledgeCategory_id='"+this.KnowledgeCategory_id+"' and
ConnectionSpeed_id='"+this.ConnectionSpeed_id+"' and
Acceleration_id='"+this.Acceleration_id+"' and
SoundIntensity_id='"+this.SoundIntensity_id+"' and Luminance_id='"+this.Luminance_id+"'
and batteryState='"+this.batteryState+"' and memoryState='"+this.memoryState+"'");
if (c.moveToFirst()) {
    activity_id=c.getInt(0);
}
// This code will be performed in case the specialised mapping was not found (general
rule)
else
{
    c = myDbHelper.query3("select Activity_id from activityselector where
Task_id='"+this.taskId+"' and visualAcuity='"+this.visualAcuity+"' and
thumbLength='"+this.thumbLength+"' and handType='"+this.handType+"' and
thumbCircumference='"+this.thumbCircumference+"' and
KnowledgeCategory_id='"+this.KnowledgeCategory_id+"' and ConnectionSpeed_id='0' and
Acceleration_id='0' and SoundIntensity_id='0' and Luminance_id='0' and
batteryState='default' and memoryState='default'");
    if (c.moveToFirst()) {
        activity_id = c.getInt(0);
    }
}
..
 return activity_name;
..
```

Listing 5.12: Excerpt from the written code of the ActivitySelector class

```
…
//Identify the next task id for the current performed task
Cursor cNextTask = myDbHelper.query2("task","id","sequence",String.valueOf(taskId));
if (cNextTask.moveToFirst()) {
    NextTaskId=Integer.parseInt(cNextTask.getString(0));
}
cNextTask.close();
…
//identify the appropriate activity for the next task id
ActivitySelector activitySelector = new ActivitySelector(Login.this,
getApplicationContext(),
        NextTaskId,
        appContext.getString("visualAcuity","low"),
        appContext.getString("ThumbLength","short"),
        appContext.getString("HandType","right"),
        appContext.getString("ThumbCircumference","small"),
        userLoginKnowledge, connectionState, accId, soundIntensity, lightId, batStatus,
memoryStatus);
String activityName=activitySelector.getActivityName();
Intent intent = new Intent();
String resourcePackageName = getApplicationContext().getPackageName();
intent.setClassName(resourcePackageName,resourcePackageName +
".activities."+activityName);
startActivity(intent);
…
```

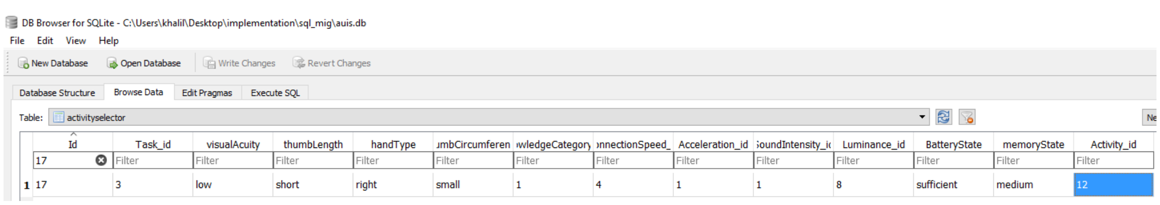
Listing 5.13: Excerpt from the written code for running the activity selector module

As can be seen from Figure 5.27, the "RFQForm2_1video" activity, which has an id equal to 12 was invoked based on the predefined specialised rule in the "activityselector" table in Figure 5.28. This rule aims to provide visual help through running a video tutorial for the end-user who belongs to the novice knowledge category, if the connection speed was high (id=4), battery state was sufficient, and memory state was medium. On the other hand, the "RFQForm2" activity is invoked based on another predefined adaptation rule.



RFQForm2 RFQForm2_1video RFQForm2_1video

Fig. 5.27: Example of selecting an identified activity by the activity selector component based on the acquired and interpreted contextual information



DB Browser for SQLite - C:\Users\khalil\Desktop\implementation\sql_mig\auis.db

Table: activityselector

	Id	Task_id	visualAcuity	thumbLength	handType	ımbCircumferen	ıwledgeCategory	ınnectionSpeed_	Acceleration_id	;oundIntensity_i	Luminance_id	BatteryState	memoryState	Activity_id
1	17	3	low	short	right	small	1	4	1	1	8	sufficient	medium	12

Fig. 5.28: Applied rule by the activity selector component for selecting "RFQForm2_1video" activity

5.2.3.2 Dialog Selector

As stated in Chapter 4, the dialog model aims to describe the syntactic sequence of human-computer interaction through UI components in order to achieve a specific task that serves a specific goal. In the developed computational framework, the dialog represents the layout, which defines the visual structure (syntactic sequence) for a UI of an activity.

The developed computational framework enables the creation of different dialogs for the same activity, to accommodate the constant variance of the context of use, and one of these dialogs will be invoked by the dialog selector component based on the resulted contextual model from the modelling layer as can be seen in Figure 5.29.

Consequently, each created dialog (layout) has a unique id in the "dialog" table in the created proposed database schema diagram, and each dialog is mapped to a specific activity, in which it serves a specific task, which in turn serves the achievement of a specific goal. As can be seen from Figure 5.30, "fragment_rfq2main_default", "fragment_rfq2main_dialog1", and "fragment_rfq2main_dialog2" dialogs in the "dialog" table are identified as dialogs for the "RFQ2Main" activity in the "activity" table, which in turn serves the "Create purchase order" task in the task table, which serves the achievement of the "the procure materials" goal in the "goal" table. In addition, the widgets in each dialog of the listed dialogs are the same with unified ids. For instance, the widgets and their ids in the "fragment_rfq2main_dialog1" dialog are the same in "fragment_rfq2main_dialog2" dialog. But the difference between the two is the visual appearance of the widget in each dialog.

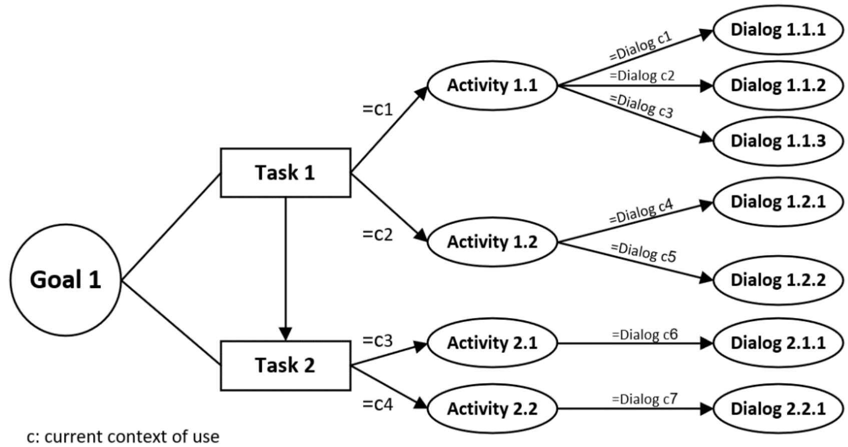
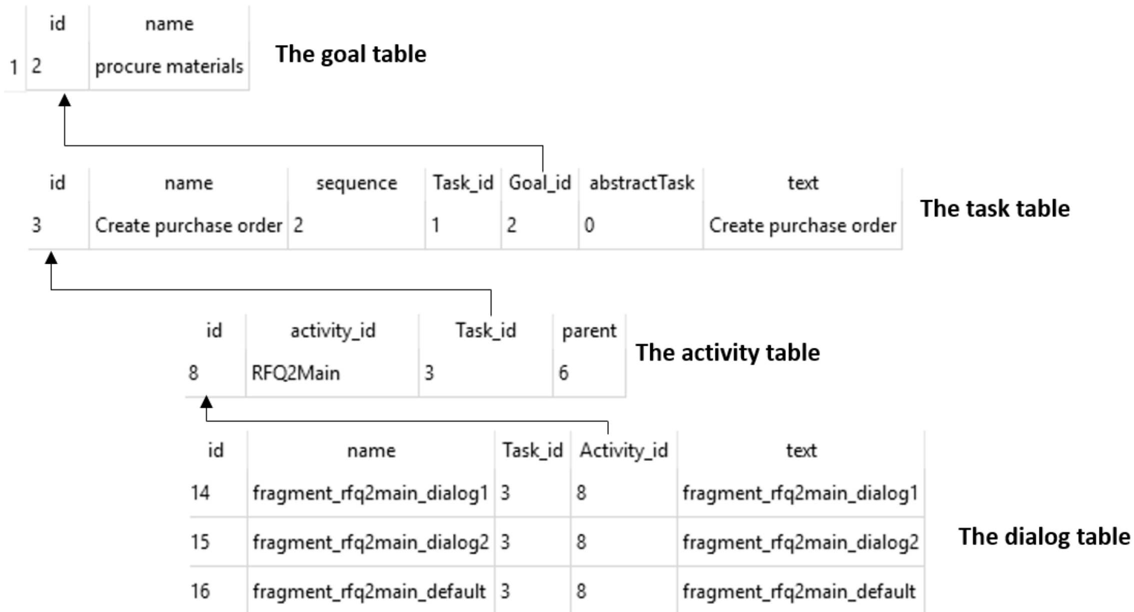


Fig. 5.29: Example of the relation between the identified activities and their associated dialogs, which are invoked based on a specific context of use

However, the question which arises is, which one of these dialogs will be invoked for the "RFQ2Main" activity? Answering this question is realised by the dialog selector component of the adaptation engine module. The role of this component is mapping the information in the resulted contextual model from the modelling layer and the id of the invoked activity for this model to the predefined adaptation rules in the "dialogselector" table. Figure 5.31 depicts an excerpt from the predefined adaptation rules by the adaptive engineer for selecting an appropriate dialog for a specific activity in a specific context of use.



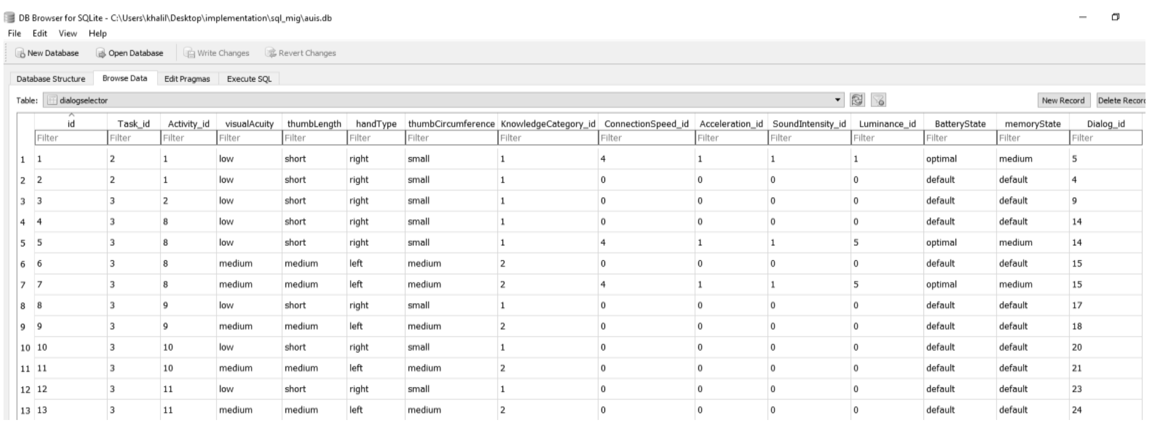
	id	name
1	2	procure materials

id	name	sequence	Task_id	Goal_id	abstractTask	text
3	Create purchase order	2	1	2	0	Create purchase order

id	activity_id	Task_id	parent
8	RFQ2Main	3	6

id	name	Task_id	Activity_id	text
14	fragment_rfq2main_dialog1	3	8	fragment_rfq2main_dialog1
15	fragment_rfq2main_dialog2	3	8	fragment_rfq2main_dialog2
16	fragment_rfq2main_default	3	8	fragment_rfq2main_default

Fig. 5.30: Referential integrity constraints for the dialog, activity, task, and goal tables in the proposed relational database schema



	id	Task_id	Activity_id	visualAcuity	thumbLength	handType	thumbCircumference	KnowledgeCategory_id	ConnectionSpeed_id	Acceleration_id	SoundIntensity_id	Luminance_id	BatteryState	memoryState	Dialog_id
	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter
1	1	2	1	low	short	right	small	1	4	1	1	1	optimal	medium	5
2	2	2	1	low	short	right	small	1	0	0	0	0	default	default	4
3	3	3	2	low	short	right	small	1	0	0	0	0	default	default	9
4	4	3	8	low	short	right	small	1	0	0	0	0	default	default	14
5	5	3	8	low	short	right	small	1	4	1	1	5	optimal	medium	14
6	6	3	8	medium	medium	left	medium	2	0	0	0	0	default	default	15
7	7	3	8	medium	medium	left	medium	2	4	1	1	5	optimal	medium	15
8	8	3	9	low	short	right	small	1	0	0	0	0	default	default	17
9	9	3	9	medium	medium	left	medium	2	0	0	0	0	default	default	18
10	10	3	10	low	short	right	small	1	0	0	0	0	default	default	20
11	11	3	10	medium	medium	left	medium	2	0	0	0	0	default	default	21
12	12	3	11	low	short	right	small	1	0	0	0	0	default	default	23
13	13	3	11	medium	medium	left	medium	2	0	0	0	0	default	default	24

Fig. 5.31: Excerpt from the predefined adaptation rules for selecting an appropriate dialog for a specific activity for a specific context of use

On the same level of the identifying the adaptation rules of the "activityselector" table, the adaptation rules for the dialog table are identified by the adaptive engineer, who starts with identifying a general rule for a specific physiological characteristic of the end-user, and then starts to specialise this rule into different rules to serve different contexts of use.

Consequently, the DialogSelector class was developed to handle the resulted contextual model of the current contextual information and the current performed activity, and maps them to the predefined adaptation rules in the "dialogselector" table to invoke the appropriate dialog. Listing 5.14 lists an excerpt from the written code from this class to invoke the appropriate dialog based on the contextual information in the resulted model and the id of the invoked activity.

```
…
// Mapping to the specialised rule
c = myDbHelper.query3("select Dialog_id from dialogselector where
Task_id='"+this.taskId+"' and Activity_id='"+this.activityId+"' and
visualAcuity='"+this.visualAcuity+"' and thumbLength='"+this.thumbLength+"' and
handType='"+this.handType+"' and thumbCircumference='"+this.thumbCircumference+"' and
KnowledgeCategory_id='"+this.KnowledgeCategory_id+"' and
ConnectionSpeed_id='"+this.ConnectionSpeed_id+"' and
Acceleration_id='"+this.Acceleration_id+"' and
SoundIntensity_id='"+this.SoundIntensity_id+"' and Luminance_id='"+this.Luminance_id+"'
and batteryState='"+this.batteryState+"' and memoryState='"+this.memoryState+"'");
if (c.moveToFirst()) {
    Dialog_id=c.getInt(0);
}
// This code will be performed in case the specialised mapping was not found
else
{
    c = myDbHelper.query3("select Dialog_id from dialogselector where
Task_id='"+this.taskId+"' and Activity_id='"+this.activityId+"' and
visualAcuity='"+this.visualAcuity+"' and thumbLength='"+this.thumbLength+"' and
handType='"+this.handType+"' and thumbCircumference='"+this.thumbCircumference+"' and
KnowledgeCategory_id='"+this.KnowledgeCategory_id+"' and ConnectionSpeed_id='0' and
Acceleration_id='0' and SoundIntensity_id='0' and Luminance_id='0' and
batteryState='default' and memoryState='default'");
    if (c.moveToFirst()) {
        Dialog_id = c.getInt(0);
    }
}
c.close();
c=myDbHelper.query3("select name from dialog where id='"+Dialog_id+"'");
if (c.moveToFirst())
    Dialog_name=c.getString(0);
else
    Dialog_name=this.defaultLayout;
c.close();
myDbHelper.close();
resID = context.getResources().getIdentifier(Dialog_name, "layout",
context.getPackageName());
…
```

Listing 5.14: Excerpt from the written code of the DialogSelector class

```
…
dialogSelector = new DialogSelector(Login.this, getApplicationContext(), NextTaskId,
activityId, visualAcuity, ThumbLength, HandType, ThumbCircumference, userKnowledge,
connectionState, accId, soundIntensity, lightId, batStatus, memoryStatus, defaultLayout);
…
```

Listing 5.15: Excerpt from the written code for running the dialog selector component

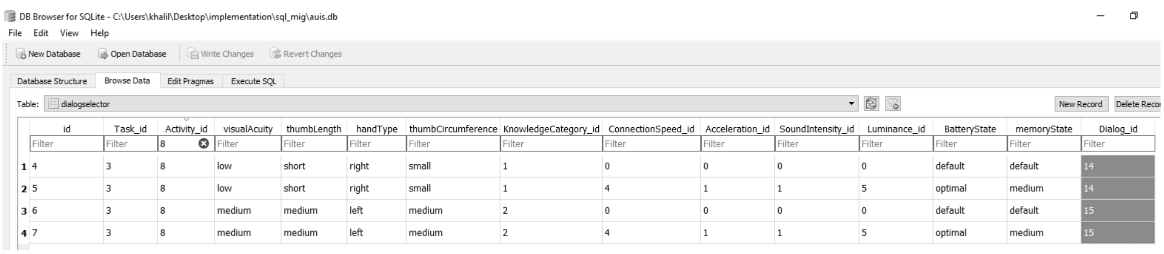
```
…
@Override
protected void onCreate(Bundle savedInstanceState) {
    super.onCreate(savedInstanceState);
    Bundle parameters = getIntent().getExtras();
    if(parameters != null && parameters.containsKey("layout")) {
        dialogResId=parameters.getInt("layout");
        knowledge_id=parameters.getInt("knowledge_id");
        dialogId=parameters.getInt("dialogId");
        selected=parameters.getInt("selected");
        setContentView(parameters.getInt("layout"));
    }
    else {
        selected=0;
        dialogResId=getResources().getIdentifier("rfqform2_dialog1", "layout",
getPackageName());
        setContentView(dialogResId);
    }
…
```

Listing 5.16: Excerpt from the written code for invoking the selected dialog from the dialog selector component in "RFQForm2" activity

For instance, as can be seen from Figure 5.33, the "fragment_rfq2main_dialog1" dialog, which has an id equal to 14 (See Figure 5.30) was invoked for the activity "RFQForm2" based on the predefined general adaptation rule for it in the "dialogselector" table, which has an id equal to 4 as can be seen from Figure 5.32. This invocation was performed after the failure in mapping to a specialised rule that matched the interpreted contextual parameters in Table 5.3. Therefore, the dialog selector component invoked the general rule that matches the acquired information for the end-user parameters (user-centred design), which are: visual acuity= low, thumb length= short, hand type= right, and thumb circumference= small. In the selected dialog for this case (fragment_rfq2main_dialog1), the user-centred design was followed by providing the showcase help pattern, due to the novice category, to which the end-user belongs. In addition, the texts are displayed in this dialog in a large text-size, due to the low visual acuity of the end-user in the resulted contextual model.

Contextual parameters	Acquired value
Knowledge category id	1
Connection state id	4
Acceleration id	3
Sound intensity id	1
Illumination id	7
Battery percentage level	sufficient
Available memory percentage	medium

Tab. 5.3: Contextual parameters that have not a specialised rule in the “dialogselector” table for Case 1



	id	Task_id	Activity_id	visualAcuity	thumbLength	handType	thumbCircumference	KnowledgeCategory_id	ConnectionSpeed_id	Acceleration_id	SoundIntensity_id	Luminance_id	BatteryState	memoryState	Dialog_id
	Filter	Filter	8	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter
1	4	3	8	low	short	right	small	1	0	0	0	0	default	default	14
2	5	3	8	low	short	right	small	1	4	1	1	5	optimal	medium	14
3	6	3	8	medium	medium	left	medium	2	0	0	0	0	default	default	15
4	7	3	8	medium	medium	left	medium	2	4	1	1	5	optimal	medium	15

Fig. 5.32: Applied rule for selecting “fragment_rfq2main_dialog1”, “fragment_rfq2main_dialog2” dialogs by the dialog selector component

In another case of the abovementioned example, the “fragment_rfq2main_dialog2” dialog, which has an id equal to 15 (See Figure 5.30) was invoked for the same activity, which is “RFQForm2”, but in a different context of use as can be seen from Figure 5.34. This invocation was based on the predefined general rule in the “dialogselector” table, which has an id equal to 6 as can be seen from Figure 5.32. This general rule was invoked after the failure in mapping to a specialised rule that matched the interpreted contextual parameters in Table 5.4. Therefore, the dialog selector component invoked the general rule that matches the acquired information for the end-user parameters (user-centred design), which are: visual acuity= medium, thumb length= medium, hand type= left, and thumb circumference= medium. In the selected dialog for this case, the user-centred design was followed by providing simple help notifications, due to the “moderate” category of the determined knowledge categories, to which the end-user belongs. In addition, the texts are displayed in this dialog in a medium text-size, due to the medium visual acuity of the end-user in the resulted model.

Contextual parameters	Acquired value
Knowledge category id	2
Connection state id	4
Acceleration id	2
Sound intensity id	1
Illumination id	8

Battery percentage level	sufficient
Available memory percentage	medium

Tab. 5.4: Contextual parameters that do not have a specialised rule in the “dialogselector” table for Case 2

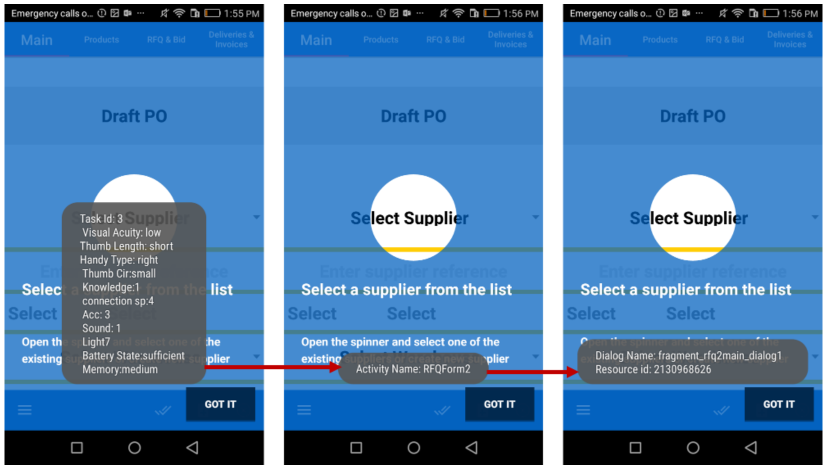


Fig. 5.33: Invoking “fragment_rfq2main_dialog1” dialog for case 1

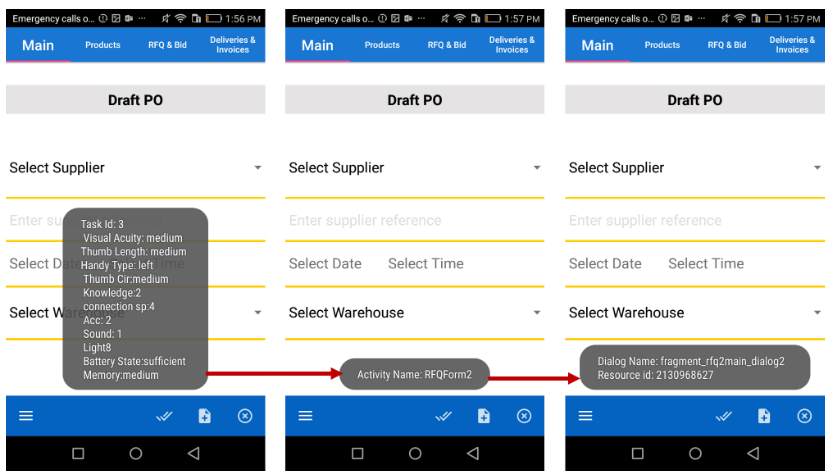


Fig. 5.34: Invoking “fragment_rfq2main_dialog2” dialog for case 2

5.2.3.3 UIs’ Widget Adaptor

The role of this component of the adaptation engine module is to adapt the visual appearance of a particular interaction widget (UI’s component) in an invoked dialog by the dialog selector component, for an invoked activity by the activity selector component. This adaptation dimension is performed at a running time based on the current context of use of the invoked dialog. However, the question which arises is how to access the properties of a particular widget in a running dialog? In order to answer this question, the widgets for each dialog are identified and stored in the “presentation” table with their sequence in this dialog. Figure 5.35 illustrates the referential integrity constraints for the presentation, component (widget), and dialog tables in the proposed relational database schema. Based on these referential integrities, the UIs’ Widget Adaptor can access a particular widget in a particular dialog in order to adapt it.

Table: dialog

id	name	Task_id	Activity_id	text
Filter	Filter	Filter	Filter	Filter
1	root	1	NULL	root
4	login_layout	2	1	login_layout
5	login_layout2	2	1	login_layout2
6	login2_dialog1	2	2	login_dialog1
7	login2_dialog2	2	2	login_dialog2

Table: componenttype

id	type
Filter	Filter
1	RelativeLayout
2	TextView
3	Button
4	LinearLayout
5	ImageView
6	Spinner
7	View
8	EditText

Table: component

id	componentId	ComponentType_id
...	Filter	Filter
1	login_MainRelativeLayout	1
2	login_expansaLogo	5
3	login_SelectUser	6
4	login_OdooURL	8
5	login_UserName	8
6	login_Password	8
7	login_LoginButton	3

Table: presentation

id	Component_id	sequence	Dialog_id
...	Filter	Filter	Filter
1	1	1	4
2	2	2	4
3	3	3	4
4	4	4	4
5	5	5	4
6	6	6	4
7	7	7	4
8	1	1	5

Fig. 5.35: Referential integrity constraints for the presentation, component, and dialog tables in the proposed relational database schema

Adapting a particular widget in the developed computational framework requires answering the following questions:

1. What is the adaptation process that will be performed for this widget?
2. What is the action that will be done after performing the determined adaptation process?
3. What is the rule that will initiate the determined adaptation process?

In the developed computational framework, a set of adaptation processes were identified to modify the properties of the adaptation widget in order to adapt its visualisation and content. Figure 5.36 depicts a set of the identified adaptation processes in the “adaptationprocesses” table by the adaptive engineer.

Table: adaptationprocess

id	adaptationProcess
...	Filter
1	setTextSize
3	test
4	setBackgroundColor
5	setWidth
6	setHeight
7	setTextColor

Fig. 5.36: Set of the identified adaptation processes in the “adaptationprocess” table in the developed computational framework

The actions and their effects are stored in the “ruleaction” table, and these actions utilise the identified adaptation processes in the “adaptationprocesses” table in order to reach their goals. For instance, as can be seen from Figure 5.37, the action which has an id equal to 6 “setHeight for the login_UserName widget” has an adaptation process id equal to 6, which means the "setHeight" adaptation process that will be performed in this action (See Figure 5.36). In addition, this action is specifically assigned to the presentation that has an id equal to 5, and by mapping this value to the "presentation" table in Figure 5.35, the component which has an id equal to 5 and the dialog which has an id equal to 4 will be retrieved. Thus, by mapping these values to the "component" table and the "dialog" table, the "login_UserName" component in the "login_layout" dialog will be determined. Consequently, the height of this widget will be set to the determined value for this action, which is 60dp.

Table: ruleaction

	id	actionName	AdaptationProcess_id	Presentation_id	value
	...	Filter	Filter	Filter	Filter
6	6	setHeight for login_UserName widget	6	5	60
7	7	Return to default height for login_UserName widget	6	5	40
8	8	set Background color for the login_UserName widget	4	5	#fffc00
9	9	Return to default Background color for the login_UserName widget	4	5	#ffffff
10	10	setText size for the login_UserName widget	1	5	30
11	11	return to the default login_UserName text size	1	5	16

Fig. 5.37 Set of the identified actions in the developed computational framework

Each identified action is triggered by a specific adaptation rule, and one or more adaptation rules can trigger a specific action. These rules are identified by the adaptive engineer, and they are stored in the "adaptationrule" table. As can be seen from Figure 5.38, the adaptation rule which has an id equal to 6 triggers the action which has an id equal to 6 in case the identified values for the Connectionspeed_id, Acceleration_id, SoundIntensity, Luminance_id, batteryState, memoryState, KnowldgeCategory_id, and Dialog_id attributes were realised. In addition, the adaptation rule which has an id equal to 7 was identified in case the triggering event that initiates the rule id equal to 6 disappeared, and not finding another adaptation rule that matches the new context of use. Thus, the adapted widget will be returned to its determined default state by triggering the action which has an id equal to 7.

Table: adaptationrule — New Record — Del

	id	Task_id	ConnectionSpeed_id	Acceleration_id	SoundIntensity_id	Luminance_id	batteryState	memoryState	KnowledgeCategory_id	Dialog_id	RuleAction_id
	...	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter
6	6	2	4	5	1	9	sufficient	medium	0	4	6
7	7	2	0	0	0	0	default	default	0	4	7
8	8	2	4	5	1	9	sufficient	medium	0	4	8
9	9	2	0	0	0	0	default	default	0	4	9
10	10	2	4	5	1	9	sufficient	medium	0	4	10
11	11	2	0	0	0	0	default	default	0	4	11

Fig. 5.38: Set of the identified adaptation rules in the adaptation rule

Consequently, the Adaptive class was developed in order to handle the resulted contextual model and the current invoked dialog, and maps them to the predefined adaptation rules in the "adaptationrule" table to perform the matched adaptation process. Listing 5.17 lists an excerpt from the written code of this class, and Listing 5.18 lists the developed code for running the UIs' Widget Adaptor every 5 seconds.

Figure 5.39 demonstrates how the UI widget adaptor adapts particular widgets based on the current context of use of the invoked dialog (acceleration=5).

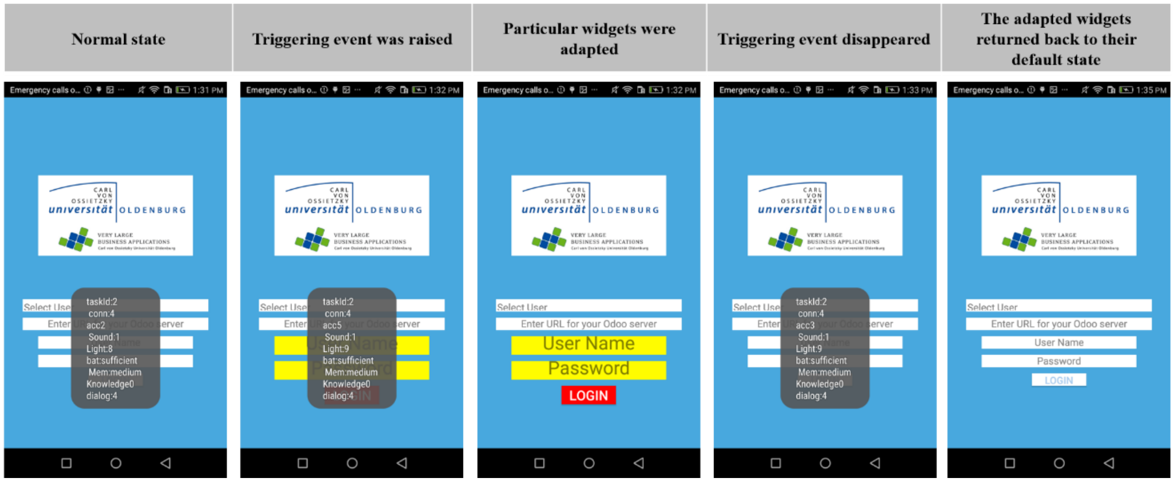


Fig. 5.39: Adapting UI’s widgets based on the current context of use

```
…
c = myDbHelper.query3("select RuleAction_id from adaptationrule where Task_id='" +
this.taskId + "' and ConnectionSpeed_id='" + this.ConnectionSpeed_id + "' and
Acceleration_id='" + this.Acceleration_id + "' and SoundIntensity_id='" +
this.SoundIntensity_id + "' and Luminance_id='" + this.Luminance_id + "' and
batteryState='" + this.batteryState + "' and memoryState='" + this.memoryState + "' and
KnowledgeCategory_id='" + this.KnowledgeCategory_id + "' and Dialog_id='" + this.Dialog_id
+ "'");
if (c.getCount() != 0) {
    if (c.moveToFirst()) {
        do {
            RuleAction_id = c.getInt(0);
            // select presentationId "compoenent" that will be used for adaptation
            c2 = myDbHelper.query3("select * from ruleaction where id='" + RuleAction_id +
"'");
            if (c2.moveToFirst()) {
                presentationId = c2.getInt(3);
                adaptationValue = c2.getString(4);
                //identify component id
                c3 = myDbHelper.query3("select Component_id from presentation where
presentation.id='" + presentationId + "'");
                if (c3.moveToFirst()) componentId = c3.getInt(0);
                c3.close();
                //get the real id for the component
                c4 = myDbHelper.query3("select componentId,ComponentType_id from component
where component.id='" + componentId + "'");
                if (c4.moveToFirst()) {
componentResId = context.getResources().getIdentifier(c4.getString(0), "id",
context.getPackageName());
                    c5 = myDbHelper.query3("select type from componenttype where id='" +
c4.getString(1) + "'");
                    if (c5.moveToFirst()) componentType = c5.getString(0);
                }
                c4.close();
   //identify the adaptation process that will be applied to the identified component
                adaptationProcess_id = c2.getInt(2);
                c6 = myDbHelper.query3("select adaptationProcess from adaptationprocess
where id='" + adaptationProcess_id + "'");
                if (c6.moveToFirst()) {
                    if (c6.getString(0).equals("setTextSize") &&
componentType.equals("EditText")) {
                        TextView txt = (TextView) activity.findViewById(componentResId);
                        txt.setTextSize(Integer.parseInt(adaptationValue));
                    } else if (c6.getString(0).equals("setBackgroundColor") &&
componentType.equals("EditText")) {
                        TextView txt = (TextView) activity.findViewById(componentResId);
                        int colorResID =
context.getResources().getIdentifier(adaptationValue, "color", context.getPackageName());
                        txt.setBackgroundColor(Color.parseColor(adaptationValue));
                    }
…
                }
                c6.close();
            }
            c2.close();
        } while (c.moveToNext());
    }
    c.close();
}
…
```

Listing 5.17: Excerpt from the written code of the developed adaptive class

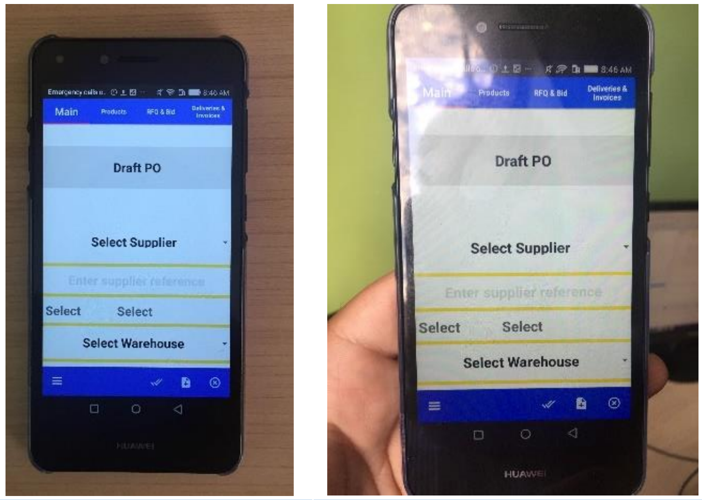
```
handler = new Handler();
handler.post(new Runnable() {
    @Override
    public void run() {

        if (adaptive !=null)
        {
            adaptive=null;
            System.gc();
        }
        adaptive = new
Adaptive(activity,context,taskId,connectionState,accId,soundIntensity,lightId,batStatus,
memoryStatus,knowledge_id,currentDialogId);
        handler.postDelayed(this, 5000);
    }
});
```

Listing 5.18: Developed code for running the UI Widget Adaptor

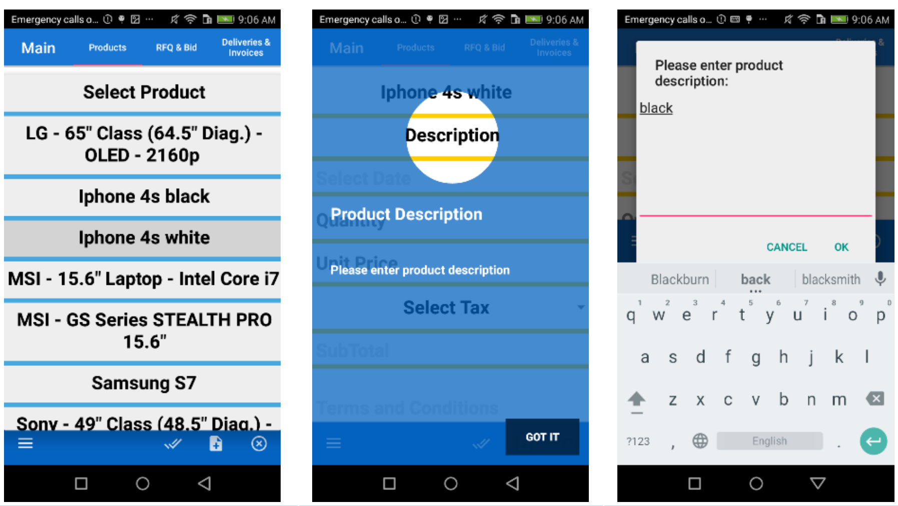
5.2.4 Additional Adaptation Patterns

In addition to the demonstrated adaptation patterns in previous sections, a set of adaptation patterns are presented in the following figures, which were implemented in the developed prototype.



Adapting the screen brightness to the family living room light	Adapting the screen brightness to direct sunlight

Fig. 5.40: Adapting screen brightness based on the ambient light level (Presentation adaptation)



Selecting the desired product from the products spinner	Opens the help showcase for the description edit text automatically	Opens the description dialog automatically

Fig. 5.41: Wizard pattern by automatically open the next UI’s widget (Navigation adaptation)

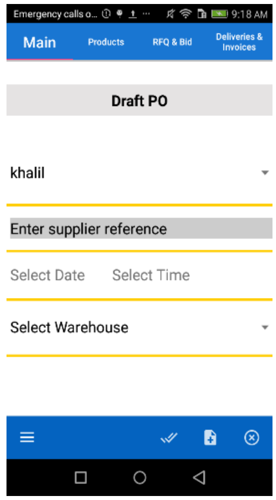


Fig. 5.42: Highlighting the next UI's component for interaction (Navigation and presentation adaptation)

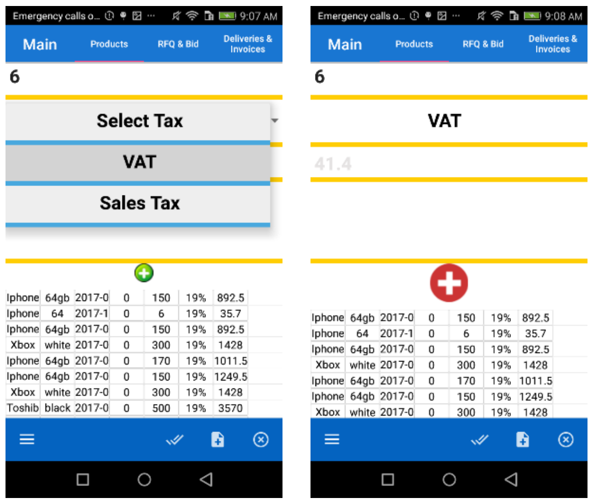


Fig. 5.43: Adapting the presentation of the add button (Predominant done button), once all the required information is inserted (Navigation and presentation adaptation)

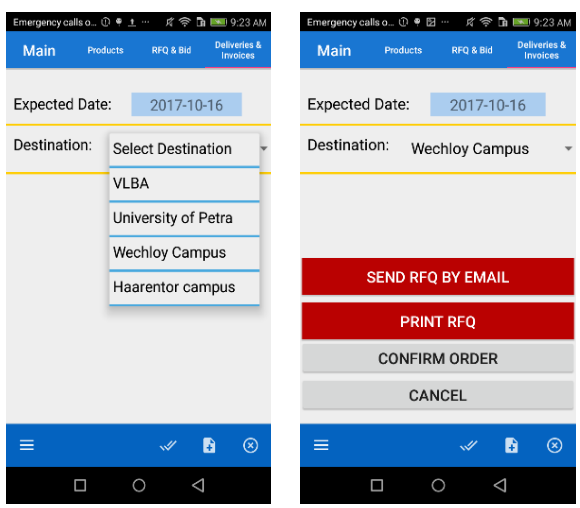


Fig. 5.44: Example of the responsive disclosure pattern, once the desired destination is selected from the destination spinner, a set of main actions buttons will appear (Navigation and presentation adaptation)

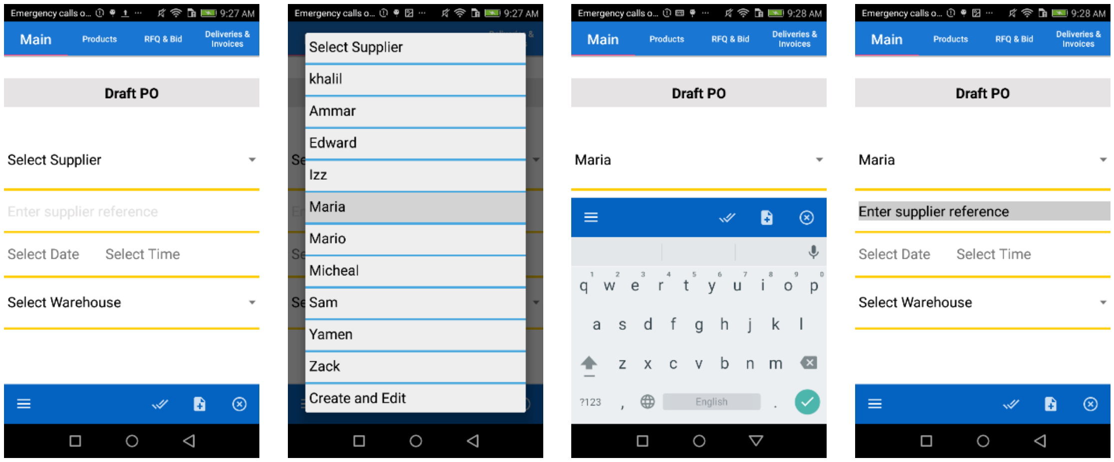


Fig. 5.45: Example of the responsive enabling pattern; the “enter supplier reference” edit text remains disabled until the supplier is selected from the select “supplier spinner” (Navigation and presentation adaptation)

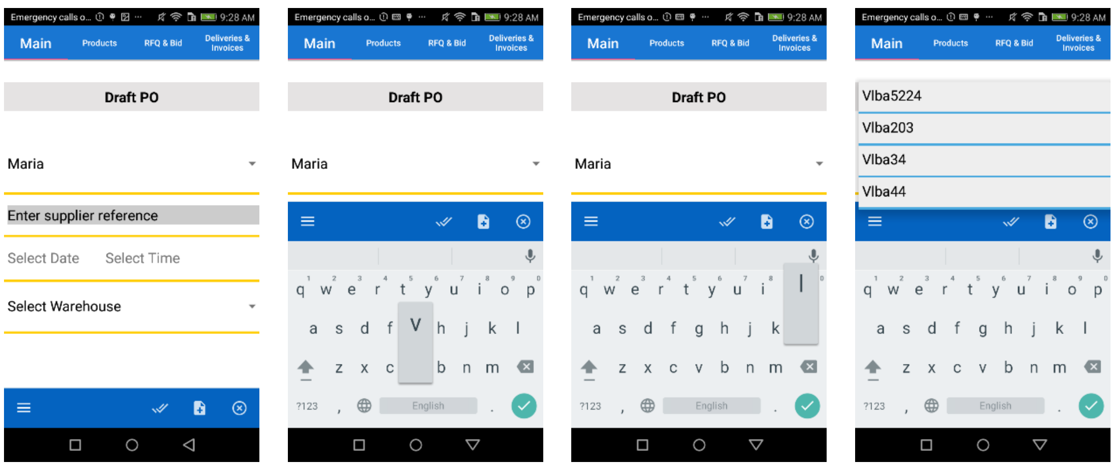


Fig. 5.46: Example of auto complete pattern (Content adaptation)

5.2.5 Knowledge and Adaptation Rules API

The knowledge and adaptation rules API component of the proposed adaptive system architecture aims to assist the adaptive engineer to manipulate (add, update, delete) the information in the knowledge models and the adaptation rules as well. This information is stored in the mobile ERP app server in order to be resynchronised to the mobile ERP app, once it is updated, or migrating it to the new releases of the mobile ERP app. The following figures depict the screenshots of the developed AUIs management module to manipulate the knowledge models and adaptation rules.

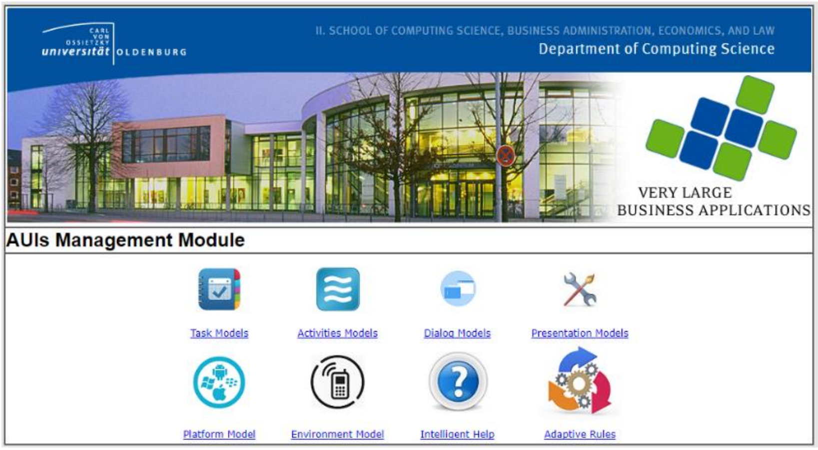


Fig. 5.47: Administration page of the developed AUIs management module

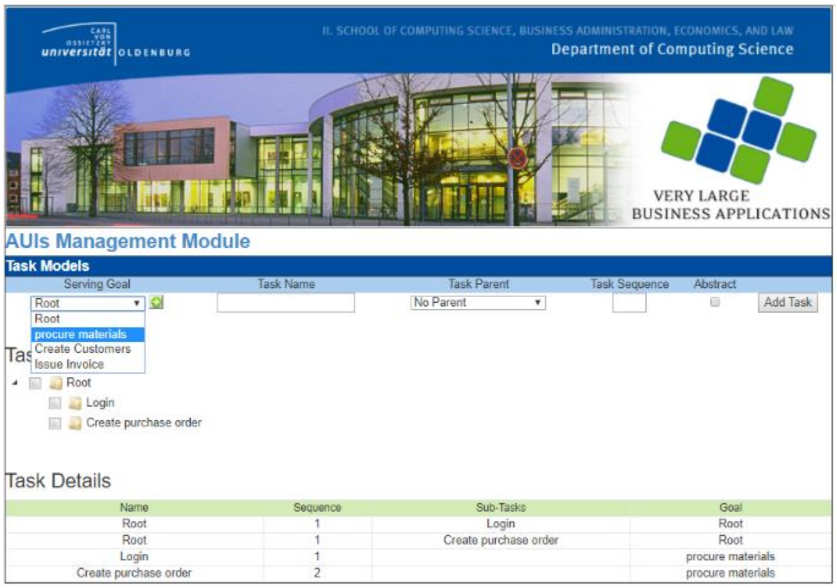


Fig. 5.48: Task model administration page

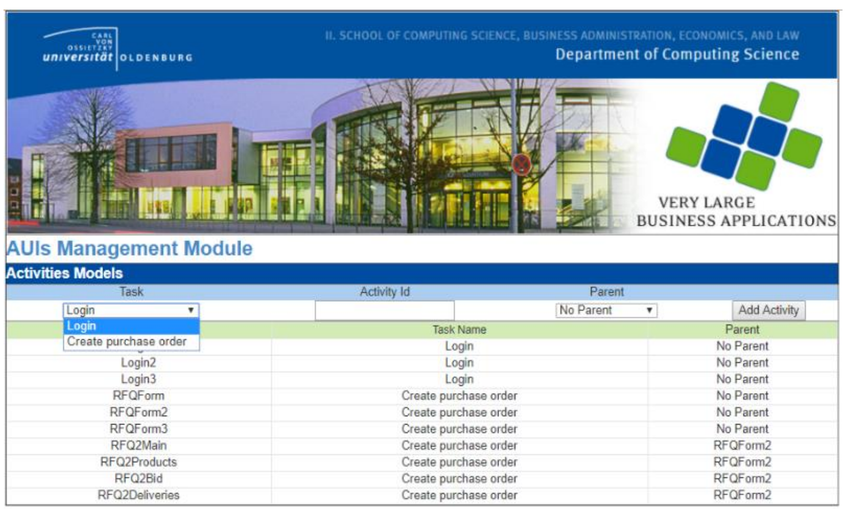


Fig. 5.49: Activity model administration page

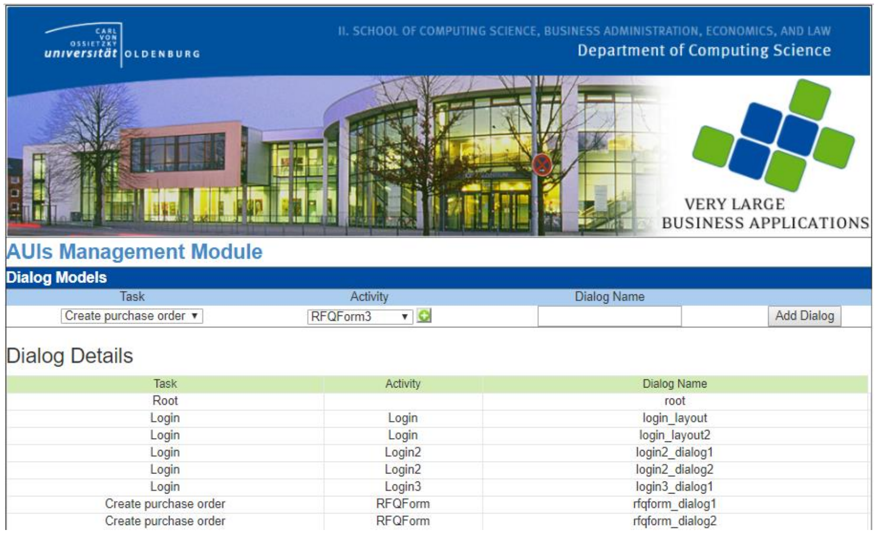


Fig. 5.50: Dialog model administration page

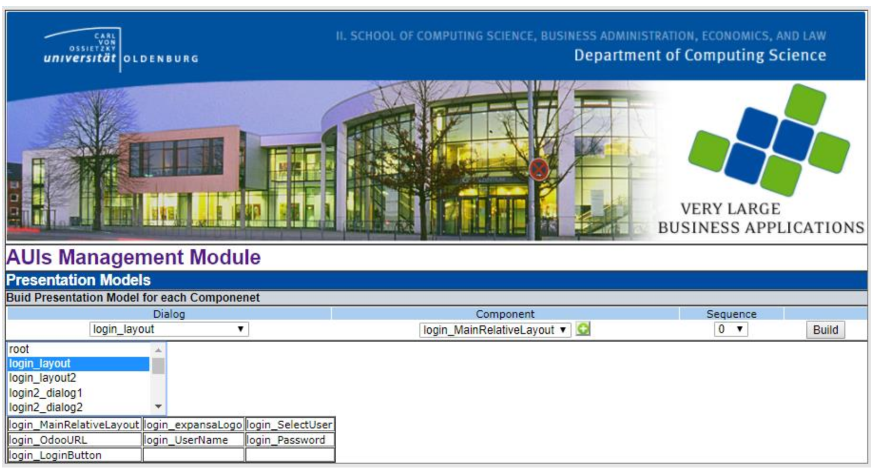


Fig. 5.51: Presentation model administration page

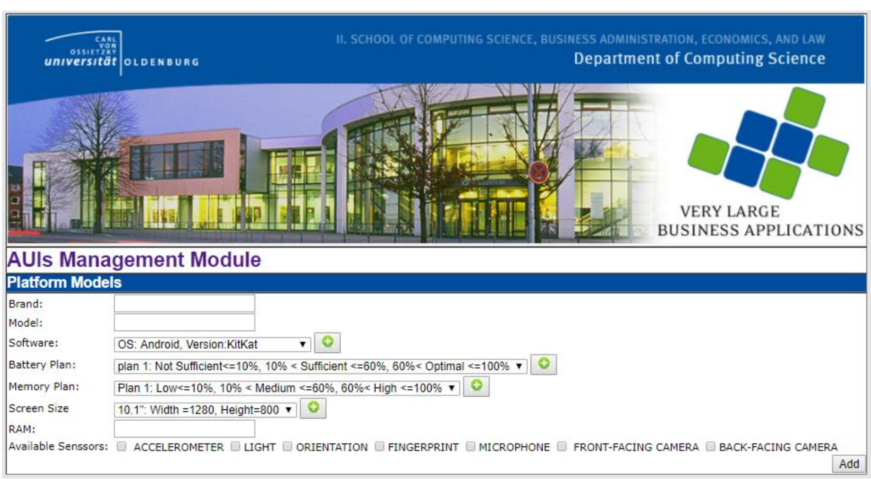


Fig. 5.52: Platform model administration page

Fig. 5.53: Environment model administration page

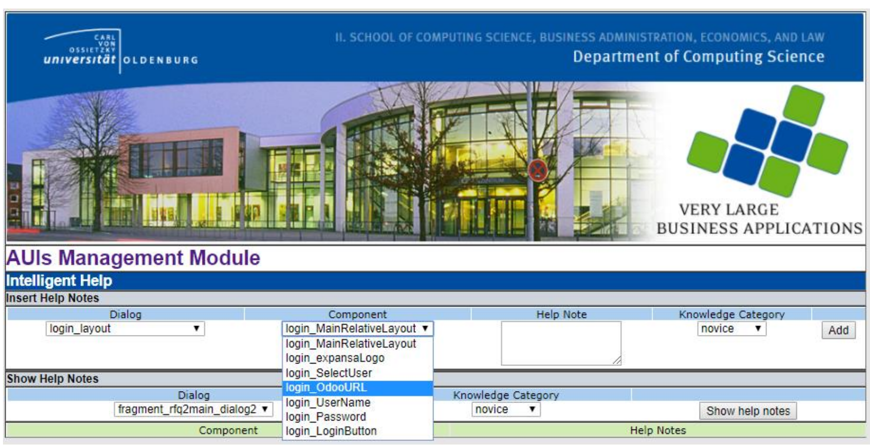


Fig. 5.54: Intelligent help administration page

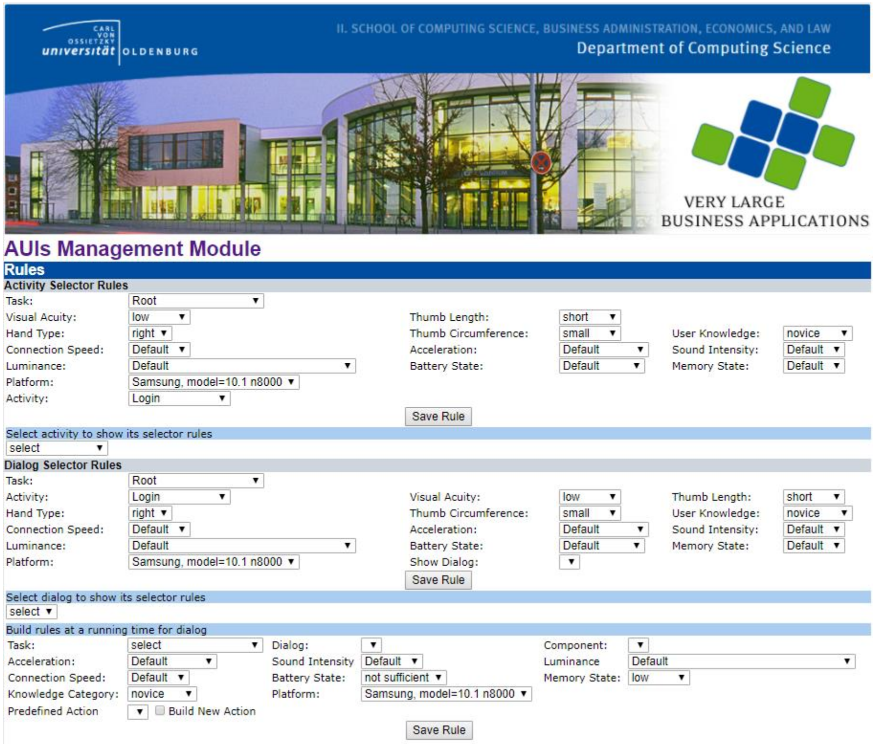


Fig. 5.55: Adaptation models administration page

5.2.6 Database Schema Diagram

In the developed computational framework, two database schemas were created to support the proposed adaptive system architecture in Chapter 4. The first database schema represents the knowledge models layer in the mobile ERP app component, and this schema is depicted in Figure 5.56. Some tables of this schema are synchronised with the updated tables of the knowledge models layer in the mobile ERP apps server, such as creating new adaptation rules by the adaptive engineer, and this is the second database schema which is depicted in Figure 5.57.

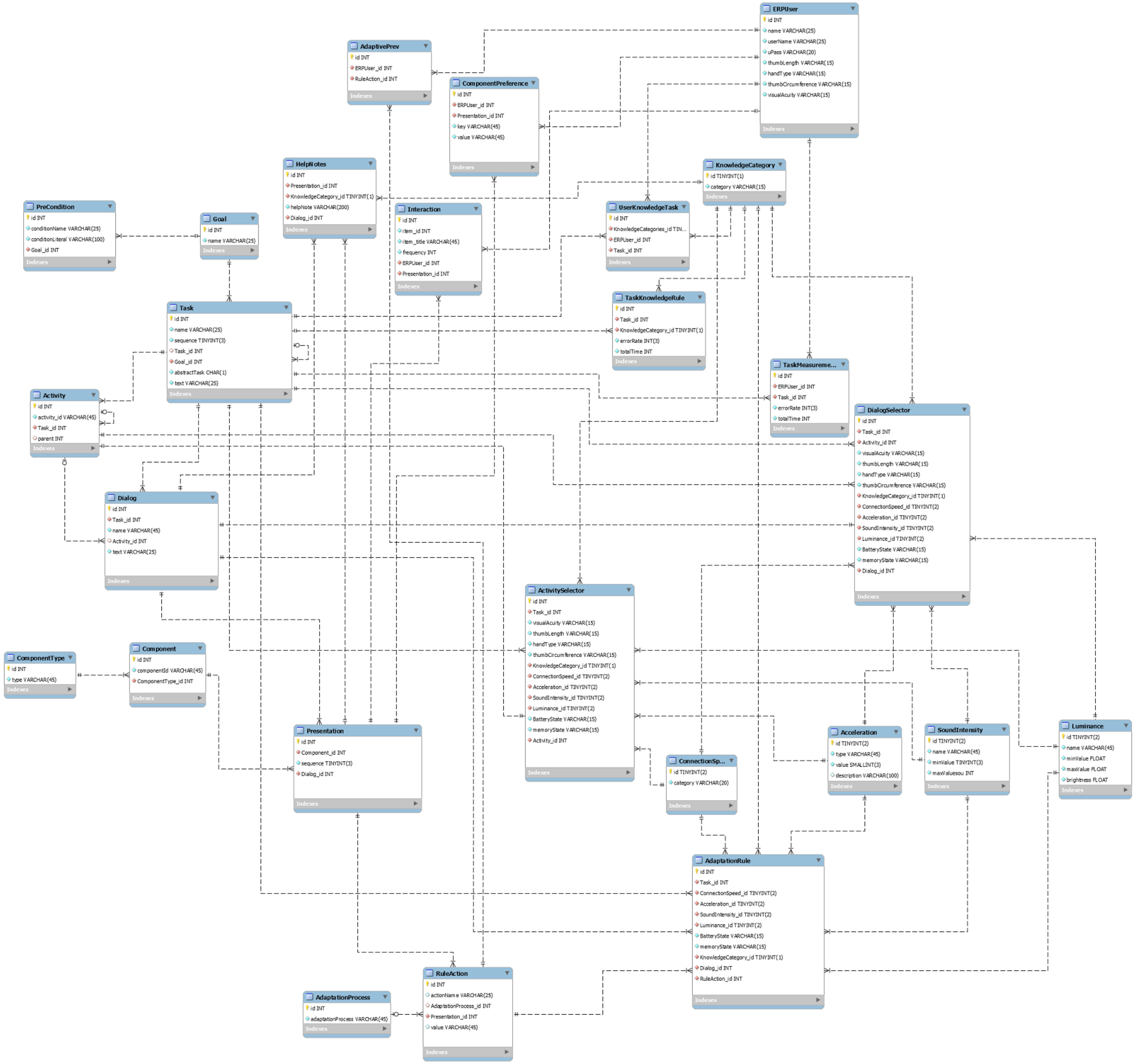


Fig. 5.56: Database schema diagram for the mobile ERP app

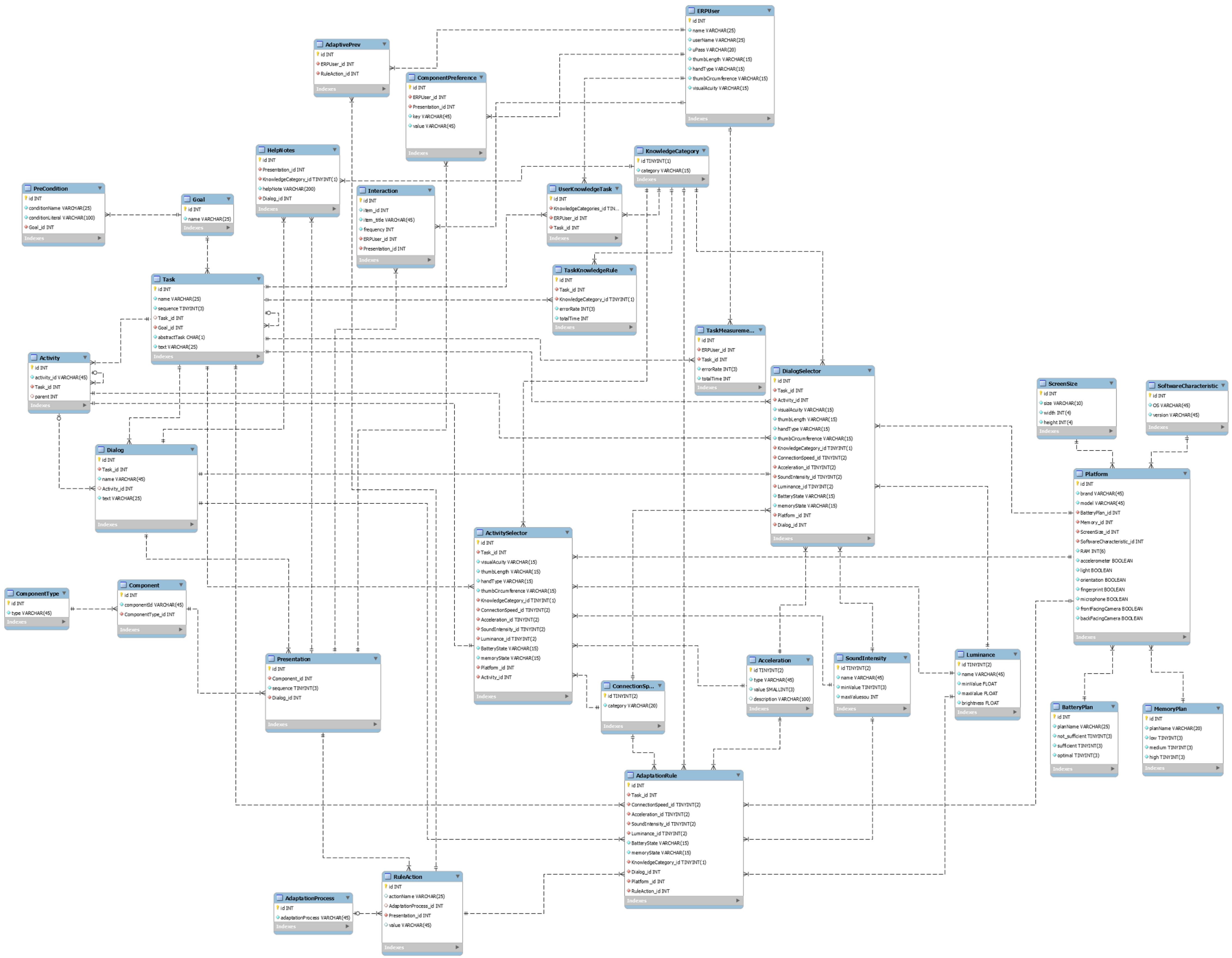


Fig. 5.57: Database schema diagram in the mobile ERP app server

5.3 Summary

This chapter presented a demonstration of how the components of the developed computational framework were utilised and incorporated into the developed prototype of the mERP app.

In addition, the determined dimensions of the adaptation processes in the developed computational framework were discussed and demonstrated, which are:

1. Invoking the appropriate activity based on the current context of use.
2. Invoking the appropriate dialog based on the current context of use for the invoked activity.
3. Adapting the UI’s widgets based on the current context of use.

These dimensions were explained and demonstrated in the adaptive version of the developed prototype by following the determined steps of performing adaptation processes in the proposed adaptive system architecture, which are:

1. Monitoring and acquiring contextual information.
2. Analysing and interpreting the acquired contextual information from the previous step.
3. Triggering the related adaptation rules based on the resulted contextual model from the previous step to perform one or more of the aforementioned dimensions of adaptivity.

In addition, a set of the developed adaptation patterns was presented in this chapter as examples of how to implement the determined adaptation types (content, presentation, and navigation), and their proposed taxonomies in chapter 4.

Furthermore, the knowledge and adaptation rules API were presented in this chapter, which aim to assist the adaptive engineer to manipulate (add, update, delete) the information in the knowledge models and the adaptation rules in the mobile ERP app server as well.

Finally, two database schemas were presented which support the determined adaptation dimensions, processes, and the proposed adaptive system architecture in Chapter 4. The first databases schema represents the knowledge models in the mobile ERP app component. While the second schema represents the knowledge models in the mobile ERP apps server, which are manipulated by the adaptive engineer and synchronised with the knowledge models in the mobile ERP app.

In the next chapter, the results of the conducted comparative evaluation between the adaptive version and the non-adaptive version of the developed prototype will be presented in order to determine whether there is a significant improvement in usability between the two versions.

6 Evaluation

This chapter aims to present the results of the conducted usability evaluation on the developed prototype of the mERP app. Thus, two versions of the developed prototype were compared in this evaluation. The first version is a non-adaptive version that mimics the purchase order and RFQ of the purchases module in the mERP app. Whereas the second version incorporates the developed AUIs computational framework and its components to the first version of the developed prototype.

Consequently, the evaluation process aimed to answer the following research question:

> *RQ.6) What are the usability improvements after incorporating the identified computational framework for the selected mobile ERP app (mERP app)?*

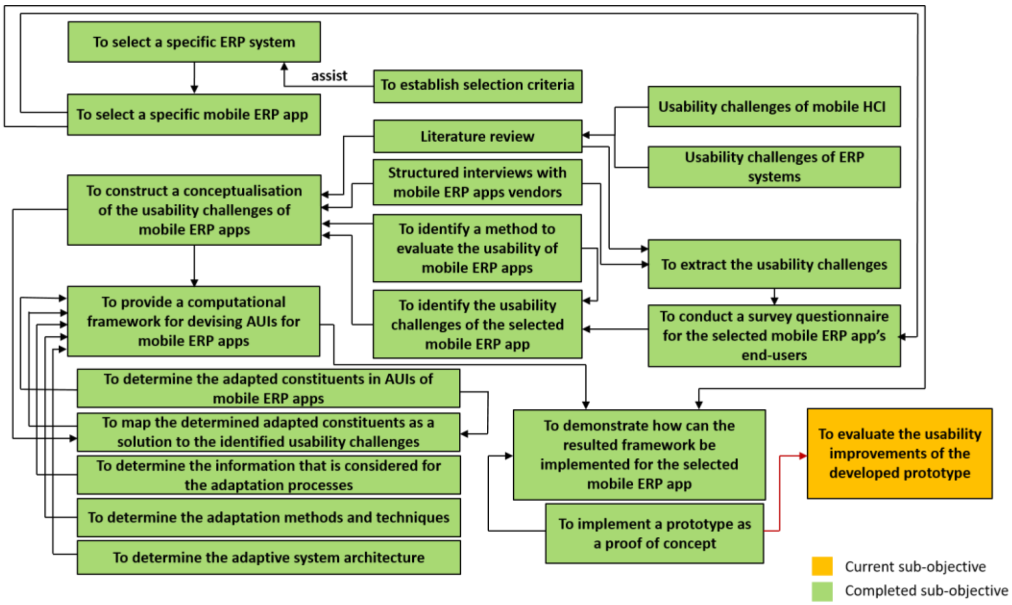


Fig. 6.1: Research objectives status; sub-objectives that will be achieved in Chapter 6

The evaluation process aimed to determine whether the incorporation of the developed AUIs computational framework and its components can improve the usability of the mERP app, in terms of the selected usability attributes of the PACMAD usability model in Chapter 3, which are: efficiency, error rate, memorability, learnability, and satisfaction.

Consequently, this chapter consists of three main sections. The first section provides an overview of the AUIs evaluation methodologies. Then it is followed by the second section, which presents an overview of the followed methodology in the conducted evaluation, which is the empirical evaluation. In addition, each followed phase in this methodology will be demonstrated with the obtained results from this evaluation. Finally, the summary section will be presented.

6.1 AUIs Evaluation Methodologies

In the AUIs research domain, there is no clearly determined methodology for evaluating AUIs (Letsu-Dake & Ntuen, 2010). However, two distinguished evaluation methodologies that can be found in research for evaluating AUIs are: the empirical and layered methodologies (Brusilovsky, Karagiannidis, & Sampson, 2001; Gena, 2006; Weibelzahl, 2005).

In the empirical evaluation methodology, the usability of AUIs is evaluated in a form of controlled experiment (Gena, 2005; Jameson, 2009), by comparing an AUI with a non-AUI in the same domain in order to show the relevance of any achieved performance (Letsu-Dake & Ntuen, 2010).

While in the layered evaluation methodology, the monolithic evaluation process is split down into different components, which can be evaluated independently (Weibelzahl, 2001), such as the proposed layered evaluation framework by (Brusilovsky et al., 2001), who distinguish two layers for the assessment, which are, the interaction assessment layer and the adaptation decision making assessment layer.

Consequently, the empirical evaluation methodology was employed to evaluate the usability of AUIs in the developed prototype to observe any performance improvements. While the layered evaluation methodology was not employed, due to the aim of the conducted evaluation which is not to assess the adaptation decisions in terms of validity and meaningful.

The empirical evaluation methodology is considered the most predominant methodology for evaluating AUIs (Singh, 2011), and this was noted from numerous research works that employed this methodology, such as (van Tonder & Wesson, 2008), (Jameson, 2009), (Letsu-Dake & Ntuen, 2010), and (Singh, 2011). Furthermore, the conventional usability evaluation methods that were explained in Chapter 3 (expert based methods, user testing methods, exploratory methods, and analytical evaluation methods) are usually used in association with the empirical evaluations in order to evaluate the usability of AUIs (Singh, 2011).

6.2 Empirical Evaluations

Empirical evaluations aim to assess the end-user's performance, and attitude towards a specific system, by obtaining subjective end-user's feedback on effectiveness, efficiency, and satisfaction through the conventional usability evaluation methods that were explained in Chapter 3 (Gena, 2005; van Velsen, van der Geest, Klaassen, & Steehouder, 2008; Whiteside, 1988).

Typically, conducting the empirical evaluations is composed of eleven steps, which can be organised into four phases as can be seen from Figure 6.2. This evaluation protocol for empirical evaluations was proposed by (Singh, 2011) based on reviewing the research works that employed the empirical evaluations for assessing AUIs, such as (Findlater & McGrenere, 2010), (Gena, 2005), (Letsu-Dake & Ntuen, 2010), and (Park & Han, 2011). As can be seen from Figure 6.2, this protocol consists of four phases, namely plan, execute, analyse, and conclude. Thus, these phases were followed in the conducted evaluation in this research study, and they will be discussed in the following sub-sections.

6.2.1 Planning Phase

This phase consists of five steps which will be explained in the following sub-sections in terms of how they were followed in the conducted evaluation.

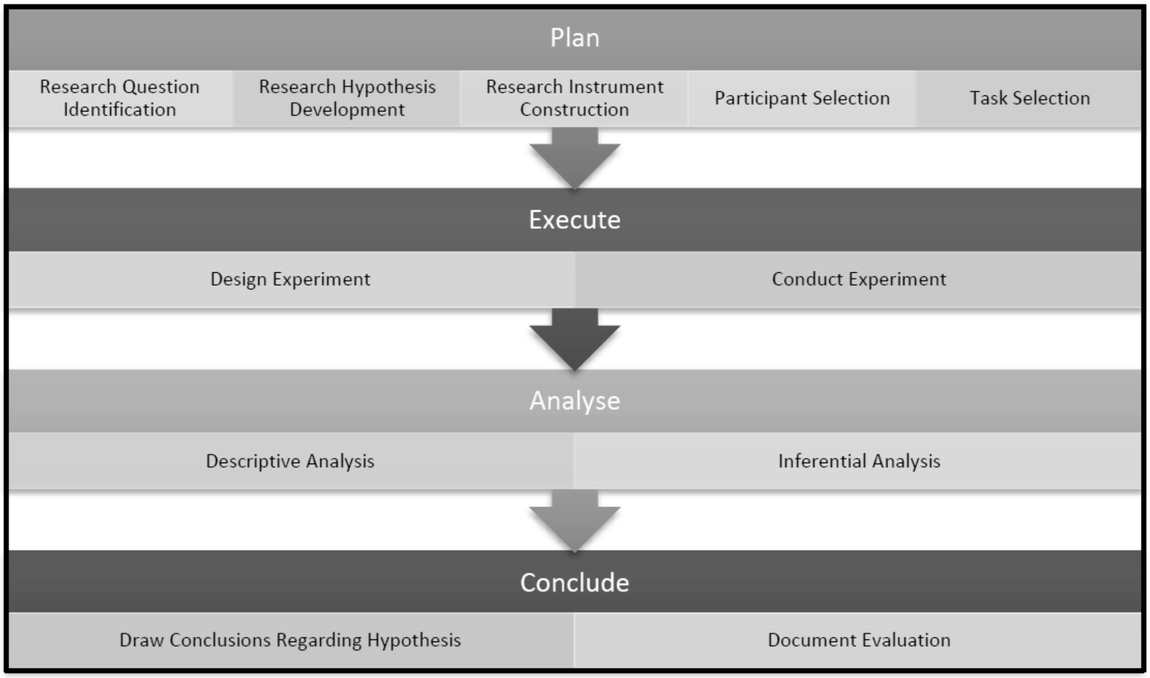


Fig. 6.2: Proposed evaluation protocol for empirical evaluations by (Singh, 2011, p. 136)

6.2.1.1 Research Question Identification

In this step, the main research question that needs to be answered in order to achieve the purpose of the evaluation is identified. In this evaluation, the main objective is to determine whether the developed computational framework and its components can improve the usability of the developed prototype of mERP app or not, and this objective can be achieved by answering the identified research question 6. Therefore, the evaluation was carried out by comparing the adaptive version of the developed prototype of the mERP app with the non-adaptive version of the developed prototype of the mERP app. In addition, the participants of the evaluation were evaluated twice in order to measure learnability and memorability. Furthermore, four different environmental contexts were determined to complete the assigned tasks for them by using both versions of the developed prototype, which are:

1. The end-user is in walking mode.
2. The end-user is distracted by the high ambient sound.
3. The end-user is distracted by the high ambient sound while he/she is walking.
4. The end-user is under a direct sunlight.

6.2.1.2 Research Hypothesis Development

The identified research question in the previous step is formalised into a set of research hypotheses in this step. Based on the results of the evaluation, these hypotheses can either be rejected or fail to be rejected. Afterwards, the independent and dependent variables are identified based on the establishment of the null and alternative hypotheses.

In chapter 3, a set of usability challenges were identified that negatively impacts the usability of the mERP app (Chapter 3). Therefore, to determine whether the proposed computational framework and its components can improve the usability of the developed prototype of the mERP app, the following hypotheses were established:

H_0: Incorporating the developed computational framework for devising AUIs cannot improve the usability of the non-adaptive version of the developed prototype of the mERP app in terms of efficiency, error rate, memorability, learnability, and satisfaction (the selected attributes of the PACMAD usability model).

$H_{0,1}$: Incorporating the developed computational framework for devising AUIs cannot improve the efficiency of the non-adaptive version of the developed prototype of the mERP app, when the end-user uses the app in walking mode, under the distraction of high ambient sound, under the distraction of high ambient sound and walking mode altogether, and under direct sunlight.

$H_{0,2}$: Incorporating the developed computational framework for devising AUIs cannot reduce the rate of errors committed in the non-adaptive version of the developed prototype of the mERP app, when the end-user uses the app in walking mode, under the distraction of high ambient sound, under the distraction of high ambient sound and walking mode altogether, and under direct sunlight.

$H_{0,3}$: Incorporating the developed computational framework for devising AUIs cannot improve the learnability and memorability of the non-adaptive version of the developed prototype of the mERP app, when the end-user uses the app in walking mode, under the distraction of high ambient sound, under the distraction of high ambient sound and walking mode altogether, and under direct sunlight.

$H_{0,4}$: Incorporating the developed computational framework for devising AUIs cannot improve the satisfaction of the non-adaptive version of the developed prototype of the mERP app, when the end-user uses the app in walking mode, under the distraction of high ambient sound, under the distraction of high ambient sound and walking mode altogether, and under direct sunlight.

Consequently, the dependent variables in this evaluation are the adaptive and non-adaptive versions of the developed prototype of the mERP app. In turn, the independent variables are the selected attributes of the PACMAD usability model, which were used to measure the dependent variables in the conducted evaluation.

The aim of the conducted empirical evaluation is to assess the end-user's performance and attitude towards the adaptive version of the developed prototype of the mERP app. As it was stated earlier in Chapter 3, error rate, memorability, learnability, and efficiency (the selected attributes of the PACMAD usability model) are considered objective operational criteria that aim to indicate the end-user performance. While the satisfaction attribute is considered a subjective operational criterion that measures the end-users' subjective perceptions (attitude). Therefore, measuring these abstract usability attributes can be performed by making them more concrete. Therefore, the following metrics were used in the conducted empirical evaluation to evaluate the aforementioned established null hypotheses:

- Efficiency was measured by finding whether there was a significant improvement in the average of: time on tasks, number of committed errors, and the number of UIs' widgets that got focused, between the usage of the non-adaptive version over the two-day evaluation period, and the usage of the adaptive version over the two-day evaluation period for each of the determined environmental contexts of the experiments.

- Error rate was measured by finding whether there was a significant reduction of the average number of errors committed between the usage of the non-adaptive version over the two-day evaluation period and the usage of the adaptive version over the two-day evaluation period for each of the determined environmental contexts of the experiments.
- Memorability and Learnability were measured by finding whether there was a significant difference in the improvement of the efficiency results (the average of: time on tasks, number of errors committed, and the number of UIs' widgets that got focused) between the usage of the non-adaptive version over the two-day evaluation period and the usage of the adaptive version over the two-day evaluation period for each of the determined environmental contexts of the experiments.
- Satisfaction was measured by using the subjective operational criteria that aimed to measure the end-users' subjective perceptions (attitude). Therefore, the subjective metrics were categorised into two categories, and measured by using a 5-point Likert scale, and these categories are:
    - Overall reactions to the application.
    - Attitudes towards the identified usability challenges in the developed construct in Chapter 3.

  Furthermore, the obtained results from the abovementioned categories were used to support the obtained results from the other performance metrics (time on task, errors committed, number of UIs' widgets that got focused).

Consequently, the obtained data from the evaluation of abovementioned metrics supported the measurement of the selected usability attributes of the PACMAD model, and the aforementioned null hypotheses.

6.2.1.3 Research Instruments Construction

In this step, various research instruments were developed in order to be provided to the participants of the evaluation, which are:

1. Informed consent form: this form was handed to the candidate participants in order to be signed before conducting the experiments (Appendix G).
2. Task list: two task lists were handed to the participants in order to complete them by using the non-adaptive version of the developed prototype (Appendix H), and each one of these lists was devoted to each day of the experiments. Each list consists of four RFQs tasks in order to create a purchase order, and each task is devoted to a specific environmental context of the determined contexts for the experiments. The same task lists were provided to the participants of the adaptive version of the developed prototype.
3. Post-test satisfaction questionnaire: the participants who used each version of the developed prototype were invited to complete post-test satisfaction questionnaire after finishing all the determined experiments that were assigned to them over the two-day evaluation period (Appendix I). The utilised questionnaire is an adapted version of the Questionnaire for User Interaction Satisfaction (QUIS), which was proposed by (Chin, Diehl, & Norman, 1988).

In addition to the abovementioned research instruments, the following software and hardware were used in the evaluation:

1. The non-adaptive version of the developed prototype.

2. The adaptive version of the developed prototype.
3. MySQL RDBMS.
4. Huawei Y3II full-screen phone for running both versions of the prototype.
5. Asus X556UQ laptop.

Furthermore, a database was created specifically for the conducted empirical evaluation by using MySQL RDBMS to store the collected measures (amount of time on task, number of errors committed, and the number of UIs' widgets that got focused) for each participant who used a particular version in a specific environmental context over the two-day evaluation period. This data was inserted in the created database by using JSON web services in Android.

6.2.1.4 Participant Selection

Two non-overlapping groups of twenty participants were engaged in the evaluation. The first group consisted of ten participants to use the non-adaptive version of the developed prototype, and these participants were third and fourth year students majoring in Software Engineering, in the Faculty of Information Technology at the University of Petra in Amman, Jordan. The participants for this group were selected based on their fulfilment of the following criteria:

1. Completion of software testing and HCI courses.
2. No previous knowledge of the mERP app.
3. At least three years of prior experience of using mobile apps through smartphones, or mobile full screen phones, or tablet computers.

While the second group consisted of ten participants to use the adaptive version of the developed prototype, and these participants were selected based on their fulfilment of the following criteria:

1. Good experience in the English language.
2. At least three years of prior experience of using mobile apps through smartphones, or mobile full-screen phones, or tablet computers.

The reason behind this heterogeneity in information technology knowledge between the two groups is to find any significant improvements in the usability for the normal end-users (second group) over the well knowledged end-users (first group). Since the latter group's members have more intuitive use of software applications than the second group members, due to the knowledge gained through their prior experience, which enables them to overcome some of the faced difficulties or ambiguities during the usage of any software applications. Accordingly, the values of the determined usability metrics in Section 6.2.1.2 for this group are supposed to be better than the second group's values.

The permission to conduct this evaluation with the selected students of the Faculty of Information Technology, and to use the faculty's facilities (computer labs, Wi-Fi connection, and faculty building) was obtained from the Deanship of this faculty.

6.2.1.5 Task Selection

Task-based are typically used in empirical evaluations of AUIs, and the determined tasks must be representative of the routine tasks that performed by the actual end-users of the system (Singh, 2011). Consequently, two task lists were prepared, and both of these lists were required to be completed by each one of the two versions of the developed prototype. In addition, each task list was devoted to a specific day of the two-day evaluation period in order to observe the learnability and memorability metrics (Appendix H).

The identified tasks in these lists are related to the creation RFQs and purchase orders activities that are frequently used by the mERP end-users (routine tasks), and this is revealed from the conducted survey questionnaire for the mERP App's end-users (Chapter 3). Thus, each task list consists of four RFQs in order to create a specific purchase order, and each one of these tasks was devoted to the determined environmental context of each experiment. For instance, Table 6.1 tabulates the required input data from the end-user in order to successfully complete the RFQ for purchase order 1 in walking mode on the first day of evaluation. This task was performed using both versions of the developed prototype.

RFQ for purchase order 1			
Main information			
Supplier	Izz		
Supplier reference	P40022		
Order date and time	1/6/2017 8:00 AM		
Deliver to company	VLBA		
Products			
Product details	**Product 1**	**Product 2**	**Product 3**
Product name	iPhone 4s white	iPhone 4s black	Xbox 360
Description	64 GB	64 GB	white
Scheduled date	5/6/2017	5/6/2017	5/6/2017
Quantity	5	8	3
Price	150	170	350
Tax type	Sales Tax	Sales Tax	Sales Tax
Terms and conditions	5% discount based on agreement number 1566		
RFQ & Bid			
Bid Valid Until	31/5/2017		
Deliveries & Invoices			
Expected date	5/6/2017		
Destination (warehouse)	VLBA		

Tab. 6.1: Instance of one of the tasks that were used on the first day of the evaluation

6.2.2 Execution Phase

This phase consists of two steps, which are: designing the controlled experiment followed by conducting the evaluation. These steps will be explained in the way they were followed in the conducted evaluation in the following sub-sections.

6.2.2.1 Designing the Experiment

The experimental designs for AUIs regularly include between-subject designs, within-subject designs, or mixed between-within subject designs (Singh, 2011). The between-subject design was used for this evaluation to identify any differences between the two treatment groups in terms of the determined metrics in Section 6.2.1.2. Therefore, the comparative evaluations were conducted between the adaptive version's group and the non-adaptive version's group. These types of evaluations are regularly used to assist the experimental design in determining whether a statistically significant difference exists between the two evaluated systems. In addition, they assist in determining whether the incorporating AUI to the system provides notable improvements in terms of efficiency (Alvarez-Cortes et al., 2007; Singh, 2011).

6.2.2.2 Conducting the Experiment

The empirical evaluation was conducted for each assigned group to each version of the developed prototype over the two-day evaluation period (160 experiments). The aim of determining this period of time between the conducted experiments for each version was to evaluate the learnability and memorability. Figure 6.3 illustrates the chronology of the conducted evaluation's experiments.

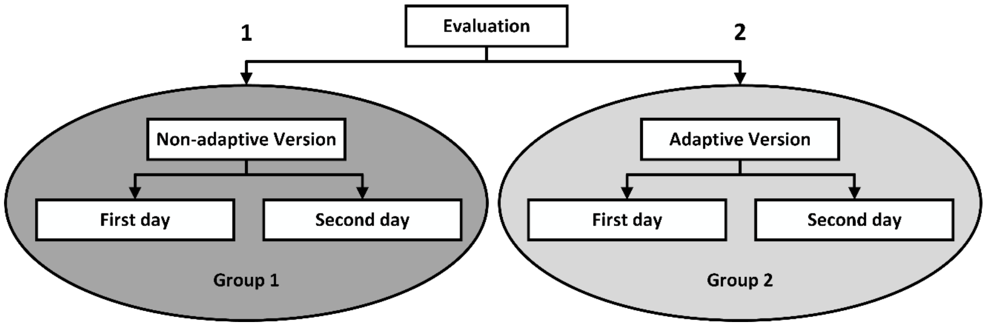


Fig. 6.3: Chronology of the conducted evaluation's experiments

The procedure that was followed with each participant for each day is discussed as follows:

- **First Day**
  1. The participant was informed about the purpose of each experiment, and the way to conduct it.
  2. Once the participant agreed in participating in the experiments, a detailed explanation and illustration were provided of how to create a RFQ by using the purchases module in Odoo ERP system.
  3. The participant was asked to create an RFQ individually by using the Odoo ERP system.
  4. The participant was provided with a consent form to read and sign (Appendix G).
  5. The participant was provided with the prepared task list for the first day of the evaluation (Appendix H), and was asked to complete the determined task for each experiment.
  6. On completion of the four determined experiments for the first day of the evaluation, the date and time for the second day experiments were scheduled with the participant.
- **Second Day**
  1. The participant was reminded of the purpose of each experiment, and the way to conduct it.
  2. The participant was provided with the prepared task list for the second day of the evaluation (Appendix H), and was asked to complete the determined task for each experiment.
  3. On completion of the four determined experiments for the second day of the evaluation, the prepared post-test satisfaction questionnaire was provided to the participant in order to complete (Appendix I).

In addition, the researcher was close to the participant in all experiments in order to overcome any obstacles that might arise, or the emergence of unexpected situations.

6.2.3 Analyses Phase

The obtained data for the determined usability metrics were statistically analysed by using descriptive and inferential statistics.

Descriptive statistics were used to describe the obtained data over the two-day evaluation period, and this usage assisted in performing comparisons of the calculated means of the determined metrics between the non-adaptive version and the adaptive version for each day of the evaluation.

While the non-parametric inferential statistics were used to determine whether there is a statistical significance in the determined usability metrics for each version of the developed prototype over the two-day evaluation (The Wilcoxon Matched-Pairs Test), and between the non-adaptive version and the adaptive version for each day of the evaluation (The Mann-Whitney U Test).

The Wilcoxon Matched-Pairs Test was used as a nonparametric test, due to the small samples size, which are paired and have a non-normally distributed data. This type of test was used to indicate whether a statistically significant difference existed in the usage of the non-adaptive version over the two-day evaluation period. Similarly, it was used for the adaptive version of the developed prototype.

The Mann-Whitney U test was used as a nonparametric test to identify whether a statistically significant difference occurred in the obtained data for the determined metrics between:

1. The first group and the second group on the first day of the evaluation.
2. The first group and the second group on the second day of the evaluation.
3. The average of the first group over the two-day evaluation period and the average of the second group over the two-day evaluation period.

Consequently, the next sub-sections present these comparisons, and the calculated statistical information for each of the determined usability metrics.

6.2.3.1 Time on Tasks

- **Walking Experiments**

In the walking experiments, the means of time on task over the two-day evaluation period were calculated, and Figure 6.4 depicts the comparisons between them. Based on these calculated means, the following results were obtained:

1. The recorded time on tasks on the first day's experiments by using the adaptive version of the developed prototype had a shorter average amount of time by 166.4 seconds than the non-adaptive version of the developed prototype.
2. The recorded time on tasks on the second day's experiments by using the adaptive version of the developed prototype had a shorter average amount of time by 97.6 seconds than the non-adaptive version of the developed prototype.

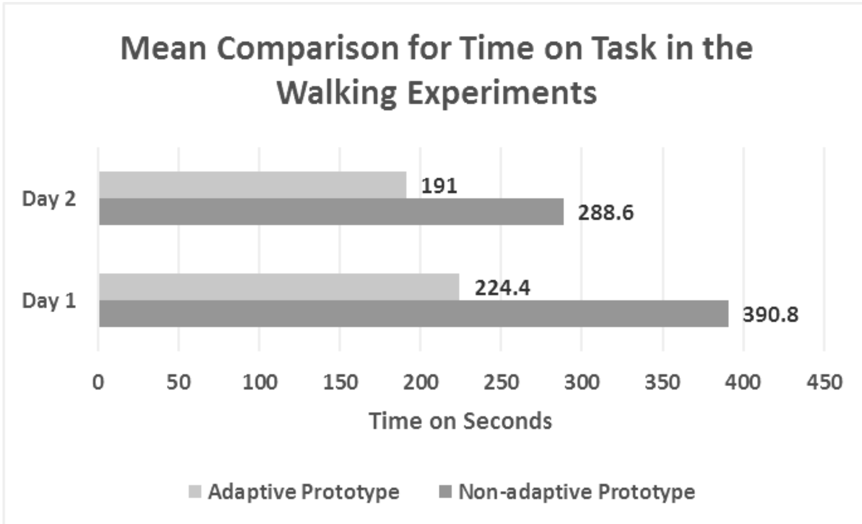


Fig. 6.4: Mean comparison for time on task in the walking experiments (n=20)

The obtained results from the Wilcoxon Matched-Pairs Test revealed that there was a significant improvement in the time on task for the assigned task to the walking experiment by using the non-adaptive version over the two-day evaluation period. Similarly, there was a significant improvement in the time on task for the assigned task to the walking experiment by using the adaptive version over the two-day evaluation period. These results are based on the calculated P-values that had less than the 5% level of significance as can be seen from Table 6.2. In addition, this indicates improvement in the learnability and memorability metrics for each version over the two-day evaluation period.

	Non-adaptive (day 1 and day 2)	Adaptive (day 1 and day2)
P-value	0.005	0.011

Tab. 6.2: P-values from the Wilcoxon Matched-Pairs Test for the time on task in the walking experiments (n=20)

As can be seen from Table 6.3, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version in the first day experiments were 6 and 0.001 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant improvement in the time on task in the walking experiment on the first day of evaluation by using the adaptive version of the developed prototype, which was used by the second group of participants, in comparison to the non-adaptive version, which was used by the first group of participants.

Regarding the second day of the evaluation, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version were 5 and 0.001 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant improvement in the time on task in the walking experiment on the second-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the calculated average amount of time on task for each participant in each group over the two-day evaluation period, the calculated U-value was 3, and the P-value was 0, which is less than the 5% level of significance. This indicates that there was a significant improvement in the time on task in the walking experiments by using the adaptive version of the developed prototype in comparison to the non-adaptive version. In addition, this indicates that the adaptive version supports the improvement of the learnability and memorability metrics more than the non-adaptive version of the developed prototype over the two-day evaluation of this experiment.

	U	P-value
First day	6	0.001
Second day	5	0.001
Average	3	0

Tab. 6.3: Results of Mann-Whitney U Test for the time on task in the walking experiments (n=20)

- **High Ambient Sound Experiments**

In the high ambient sound experiments, the means of time on task over the two-day evaluation period were calculated, and Figure 6.5 depicts the comparisons between them. Based on these calculated means, the following results were obtained:

1. The recorded time on tasks on the first day's experiments by using the adaptive version of the developed prototype scored a shorter average amount of time by 80.3 seconds than the non-adaptive version of the developed prototype.
2. The recorded time on tasks on the second day's experiments by using the adaptive version of the developed prototype scored a shorter average amount of time by 81.6 seconds than the non-adaptive version of the developed prototype.

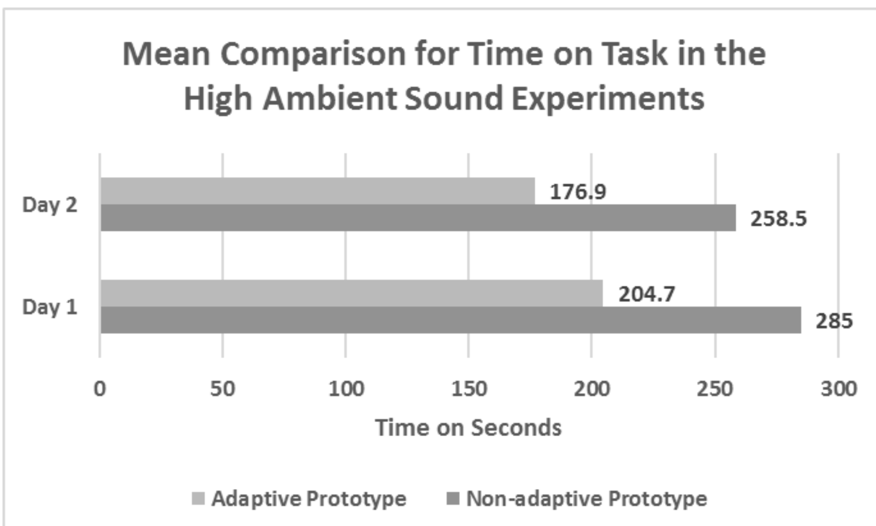


Fig. 6.5: Mean comparison for time on task in the high ambient sound experiments (n=20)

The obtained results from the Wilcoxon Matched-Pairs Test revealed that there was a significant improvement in the time on task for the assigned task to the high ambient sound experiment by using the non-adaptive version over the two-day evaluation period. Similarly, there was a significant improvement in the time on task for the assigned task to the high ambient sound experiment by using the adaptive version over the two-day evaluation period. These results are based on the calculated P-values that were less than the 5% level of significance as can be seen from Table 6.4. In addition, this indicates improvement in the learnability and memorability metrics for each version over the two-day evaluation period.

	Non-adaptive (day 1 and day 2)	Adaptive (day 1 and day2)
P-value	0.009	0.009

Tab. 6.4: P-values from the Wilcoxon Matched-Pairs Test for the time on task in the high ambient sound experiments (n=20)

As can be seen from Table 6.5, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version on the first day experiments were 11.5 and 0.004 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant improvement in the time on task for the assigned task to the high ambient sound experiment on the first-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the second day of the evaluation, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version were 3.5 and 0 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant improvement in the time on task for the assigned task to the high ambient sound experiment on the second-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the calculated average amount of time on task for each participant in each group over the two-day evaluation period, the calculated U-value was 5.5, and the P-value was 0.001, which is less than the 5% level of significance. This indicates that there was a significant improvement in the time on task in the high ambient sound experiments by using the adaptive version of the developed prototype in comparison to the non-adaptive version. In addition, this indicates that the adaptive version supports the improvement of the learnability and memorability metrics more than the non-adaptive version of the developed prototype over the two-day evaluation period of this experiment.

	U	P-value
First day	11.5	0.004
Second day	3.5	0
Average	5.5	0.001

Tab. 6.5: Results of Mann-Whitney U Test for the time on task in the high ambient sound experiments (n=20)

- **Experiments of the High Ambient Sound with Walking**

In the experiments of the high ambient sound while the participants are walking, the means of time on task over the two-day evaluation period were calculated, and Figure 6.6 depicts the comparisons between them. Based on these calculated means, the following results were obtained:

1. The recorded time on tasks on the first day’s experiments by using the adaptive version of the developed prototype had a shorter average amount of time by 167.8 seconds than the non-adaptive version of the developed prototype.
2. The recorded time on tasks on the second day’s experiments by using the adaptive version of the developed prototype had a shorter average amount of time by 150.4 seconds than the non-adaptive version of the developed prototype.

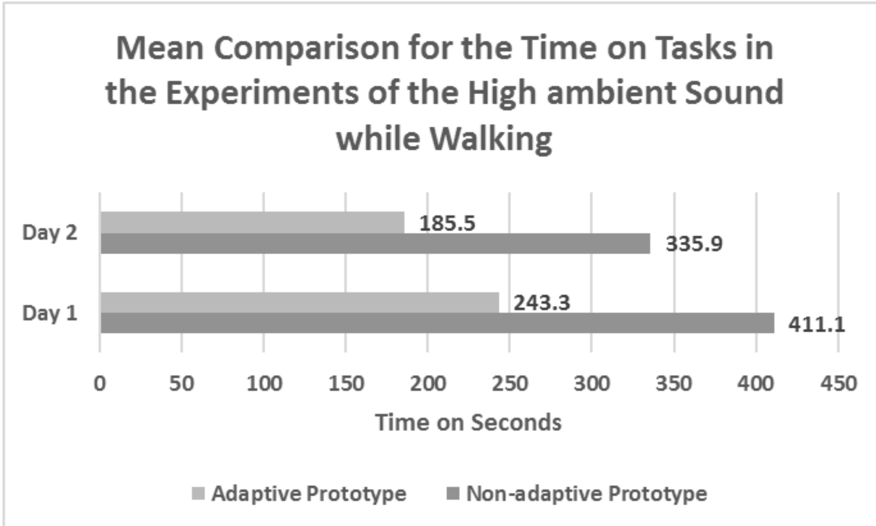


Fig. 6.6: Mean comparison for time on task in the experiments of the high ambient sound with walking (n=20)

The obtained results from the Wilcoxon Matched-Pairs Test revealed that there was a significant improvement in the time on task for the assigned task for the experiment of high ambient sound with walking by using the non-adaptive version over the two-day evaluation period. Similarly, there was a significant improvement in the time on task for the assigned task to the experiment of the high ambient sound with walking by using the adaptive version of the developed prototype over the two-day evaluation period. These results are based on the calculated P-values that were less than the 5% level of significance as can be seen from Table 6.6. In addition, this indicates improvement in the learnability and memorability metrics for each version over the two-day evaluation period.

	Non-adaptive (day 1 and day 2)	Adaptive (day 1 and day2)
P-value	0.005	0.009

Tab. 6.6: P-values from the Wilcoxon Matched-Pairs Test for the time on task in the experiments of high ambient sound with walking (n=20)

As can be seen from Table 6.7, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version in the first day experiments were 4 and 0.001 respectively. This calculated p-value, which is less than the 5% level of significance, indicates that there was a significant improvement in the time on task for the assigned task to the experiment of high ambient sound with walking on the first-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the second day of the evaluation, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version were 8 and 0.001 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant improvement in the time on task for the assigned task for the experiment of high ambient sound with walking on the second-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the calculated average amount of time on task for each participant in each group over the two-day evaluation period, the calculated U-value was 4, and the P-value was 0.001, which is less than the 5% level of significance. This indicates that there was a significant improvement in the time on task in the experiments of high ambient sound with walking by using the adaptive version of the developed prototype in comparison to the non-adaptive version. In addition, this indicates that the adaptive version supports the improvement of the learnability and memorability metrics more than the non-adaptive version of the developed prototype over the two-day evaluation period of this experiment.

	U	P-value
First day	4	0.001
Second day	8	0.001
Average	4	0.001

Tab. 6.7: Results of Mann-Whitney U Test for the time on task in the experiments of high ambient sound with walking (n=20)

- **Direct Sunlight Experiments**

In the direct sunlight experiments, the means of time on task over the two-day evaluation period were calculated, and Figure 6.7 depicts the comparisons between them. Based on these calculated means, the following results were obtained:

1. The recorded time on tasks on the first day's experiments by using the adaptive version of the developed prototype had a shorter average amount of time by 97 seconds than the non-adaptive version of the developed prototype.
2. The recorded time on tasks on the second day's experiments by using the adaptive version of the developed prototype had a shorter average amount of time by 95.4 seconds than the non-adaptive version of the developed prototype.

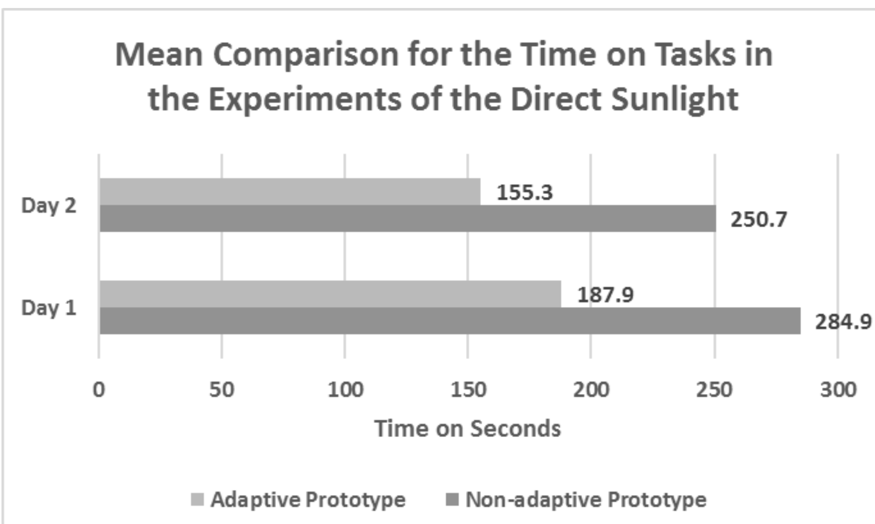


Fig. 6.7: Mean comparison for time on task in the experiments of direct sunlight (n=20)

The obtained results from the Wilcoxon Matched-Pairs Test revealed that there was a significant improvement in the time on task for the assigned task for the direct sunlight experiment for the non-adaptive version over the two-day evaluation period. Similarly, there was a significant improvement in the time on task for the assigned task to the direct sunlight experiment for the adaptive version over the two-day evaluation period. These results are based on the calculated P-values that were less than the 5% level of significance as can be seen from Table 6.8. In addition, this indicates improvement in the learnability and memorability metrics for each version over the two-day evaluation period.

	Non-adaptive (day 1 and day 2)	Adaptive (day 1 and day2)
P-value	0.037	0.005

Tab. 6.8: P-values from the Wilcoxon Matched-Pairs Test for the time on task in the direct sunlight experiments (n=20)

As can be seen from Table 6.9, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version in the first day experiments were 7.5 and 0.001 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant improvement in the time on task for the assigned task to the direct sunlight experiments on the first-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the second day of the evaluation, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version were 6 and 0.001 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant improvement in the task completion times in the direct sunlight experiments on the second-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the calculated average amount of time on task for each participant in each group over the two-day evaluation period, the calculated U-value was 4.5, and the P-value was 0.001, which is less than the 5% level of significance. This indicates that there was a significant improvement in the time on task in the direct sunlight experiments by using the adaptive version of the developed prototype in comparison to the non-adaptive version. In addition, this indicates that the adaptive version supports the improvement of the learnability and memorability metrics more than the non-adaptive version of the developed prototype over the two-day evaluation period of this experiment.

	U	P-value
First day	7.5	0.001
Second day	6	0.001
Average	4.5	0.001

Tab. 6.9: Results of Mann-Whitney U Test for the time on task in the direct sunlight experiments (n=20)

6.2.3.2 Errors Committed

- **Walking Experiments**

In the walking experiments, the means of the number of errors committed over the two-day evaluation period were calculated, and Figure 6.8 depicts the comparisons between them. Based on these calculated means, the following results were obtained:

1. The number of errors committed on the first day’s experiments by using the adaptive version of the developed prototype had a lower error rate by 3.7 errors than the non-adaptive version of the developed prototype.
2. The number of errors committed on the second day’s experiments by using the adaptive version of the developed prototype had a lower error rate by 1.3 errors than the non-adaptive version of the developed prototype.

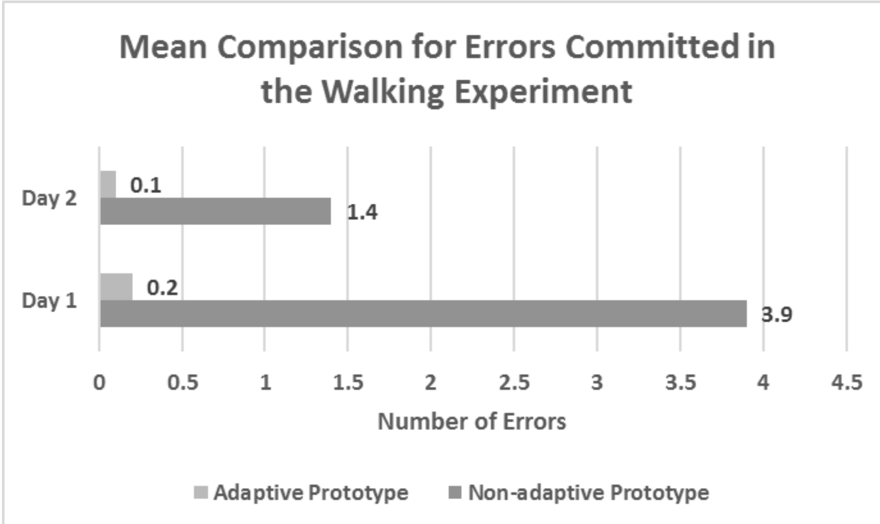


Fig. 6.8: Mean comparison for errors committed in the walking experiments (n=20)

The obtained results from the Wilcoxon Matched-Pairs Test revealed that there was not a significant reduction in the number of errors committed for the assigned task to the walking experiment by using the non-adaptive version over the two-day evaluation period. Similarly, there was not a significant reduction in the number of errors committed for the assigned task to the walking experiment by using the adaptive version over the two-day evaluation period. These results are based on the calculated P-values that were greater than the 5% level of significance as can be seen from Table 6.10.

	Non-adaptive (day 1 and day 2)	Adaptive (day 1 and day2)
P-value	0.127	0.564

Tab. 6.10: P-values from the Wilcoxon Matched-Pairs Test for the errors committed in the walking experiments (n=20)

As can be seen from Table 6.11, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version on the first day experiments were 26 and 0.04 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of errors committed in the walking experiment on the first-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the second day of the evaluation, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version were 28 and 0.04 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of errors committed in the walking experiment on the second-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the calculated average of the number of errors committed by each participant in each group over the two-day evaluation period, the calculated U-value was 21, and the P-value was 0.019, which is less than the 5% level of significance. This indicates that there was a significant reduction in the number of errors committed in the walking experiment by using the adaptive version of the developed prototype in comparison to the non-adaptive version. In addition, this indicates that the adaptive version supports the improvement of the learnability and memorability metrics more than the non-adaptive version of the developed prototype over the two-day evaluation period of this experiment.

	U	P-value
First day	26	0.04
Second day	28	0.04
Average	21	0.019

Tab. 6.11: Results of Mann-Whitney U Test for the errors committed in the walking experiments (n=20)

- **High Ambient Sound Experiments**

In the high ambient sound experiments, the means of the number of errors committed over the two-day evaluation period were calculated, and Figure 6.9 depicts the comparisons between them. Based on these calculated means, the following results were obtained:

1. The number of the errors committed on the first day's experiments by using the adaptive version of the developed prototype had a lower error rate by 1.8 errors than the non-adaptive version of the developed prototype.
2. The number of the errors committed on the second day's experiments by using the adaptive version of the developed prototype had a lower error rate by 0.8 errors than the non-adaptive version of the developed prototype.

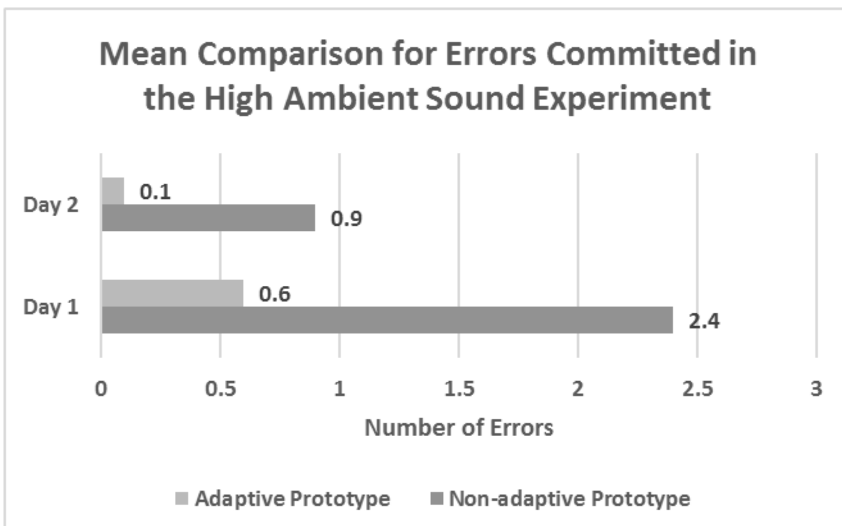


Fig. 6.9: Mean comparison for errors committed in the high ambient sound experiments (n=20)

The obtained results from the Wilcoxon Matched-Pairs Test revealed that there was a significant reduction in the number of errors committed for the assigned task to the high ambient sound experiments by using the non-adaptive version over the two-day evaluation period. This result is based on the calculated P-value that was less than the 5% level of significance as can be seen from Table 6.12. In addition, this indicates improvement in the learnability and memorability metrics for this version over the two-day evaluation period. On the contrary, there was not a significant reduction in the number of errors committed for the assigned task to the high ambient sound experiments by using the adaptive version over the two-day evaluation period. This result is based on the calculated P-value that was greater than the 5% level of significance as can be seen from Table 6.12.

	Non-adaptive (day 1 and day 2)	Adaptive (day 1 and day2)
P-value	0.027	0.053

Tab. 6.12: P-values from the Wilcoxon Matched-Pairs Test for the errors committed in the high ambient sound experiments (n=20)

As can be seen from Table 6.13, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version in the first day experiments were 12.5 and 0.004 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of errors committed in the high ambient sound experiments on the first-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the second day of the evaluation, the calculated U-value and P-value from the Wilcoxon Mann-Whitney U Test for the non-adaptive version and the adaptive version were 23.5 and 0.018 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of errors committed in the high ambient sound experiments on the second-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the calculated average of the number of errors committed by each participant in each group over the two-day evaluation period, the calculated U-value was 10.5, and the P-value was 0.002, which is less than the 5% level of significance. This indicates that there was a significant reduction in the number of errors committed in the high ambient sound experiments by using the adaptive version of the developed prototype in comparison to the non-adaptive version. In addition, this indicates that the adaptive version supports the improvement of the learnability and memorability metrics more than the non-adaptive version of the developed prototype over the two-day evaluation period of this experiment.

	U	P-value
First day	12.5	0.004
Second day	23.5	0.018
Average	10.5	0.002

Tab. 6.13: Results of Mann-Whitney U Test for the errors committed in the high ambient sound experiments (n=20)

- **Experiments of the High Ambient Sound with Walking**

  In the experiments of high ambient sound while the participants are walking, the means of the number of errors committed over the two-day evaluation period were calculated, and Figure 6.10 depicts the comparisons between them. Based on these calculated means, the following results were obtained:

  1. The number of the errors committed on the first day’s experiments by using the adaptive version of the developed prototype had a lower error rate by 3.7 errors than the non-adaptive version of the developed prototype.
  2. The number of the errors committed on the second day’s experiments by using the adaptive version of the developed prototype had a lower error rate by 3.3 errors than the non-adaptive version of the developed prototype.

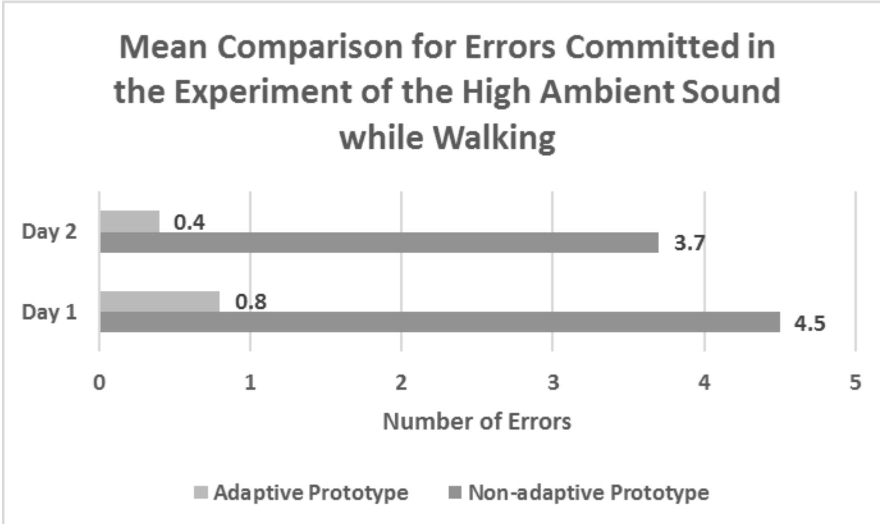


Fig. 6.10: Mean comparison for errors committed in the experiments of the high ambient sound with walking (n=20)

The obtained results from the Wilcoxon Matched-Pairs Test revealed that there was not a significant reduction in the number of errors committed for the assigned task for the experiments of the high ambient sound while the participant is walking by using the non-adaptive version over the two-day evaluation period. Similarly, there was not a significant reduction in the number of errors committed for the assigned task to the experiments of the high ambient sound while the participant is walking by using the adaptive version over the two-day evaluation period. These results are based on the calculated P-values that were greater than the 5% level of significance as can be seen from Table 6.14.

	Non-adaptive (day 1 and day 2)	Adaptive (day 1 and day2)
P-value	0.717	0.102

Tab. 6.14: P-values from the Wilcoxon Matched-Pairs Test for the errors committed in the experiments of the high ambient sound with walking (n=20)

As can be seen from Table 6.15, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version on the first day experiments were 11 and 0.003 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of errors committed in the experiments of the high ambient sound while the participant is walking on the first-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the second day of the evaluation, the calculated U-value and P-value from the Wilcoxon Mann-Whitney U Test for the non-adaptive version and the adaptive version were 11 and 0.002 respectively. The calculated p-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of errors committed in the experiments of the high ambient sound while the participant is walking on the second-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the calculated average for the number of errors committed by each participant in each group over the two-day evaluation period, the calculated U-value was 7, and the P-value was 0.001, which is less than the 5% level of significance. This indicates that there was a significant reduction in the number of errors committed in the experiments of the high ambient sound while the participant is walking by using the adaptive version of the developed prototype in comparison to the non-adaptive version. In addition, this indicates that the adaptive version supports the improvement of the learnability and memorability metrics more than the non-adaptive version of the developed prototype over the two-day evaluation period of this experiment.

	U	P-value
First day	11	0.003
Second day	11	0.002
Average	7	0.001

Tab. 6.15: Results of Mann-Whitney U Test for the errors committed in the experiments of the high ambient sound with walking (n=20)

- **Direct Sunlight Experiments**

  In the direct sunlight experiments, the means of the number of errors committed over the two-day evaluation period were calculated, and Figure 6.11 depicts the comparisons between them. Based on these calculated means, the following results were obtained:

  1. The number of the errors committed on the first day's experiments by using the adaptive version of the developed prototype had a lower error rate by 2.5 errors than the non-adaptive version of the developed prototype.
  2. The number of the errors committed on the second day's experiments by using the adaptive version of the developed prototype had a lower error rate by 0.6 errors than the non-adaptive version of the developed prototype.

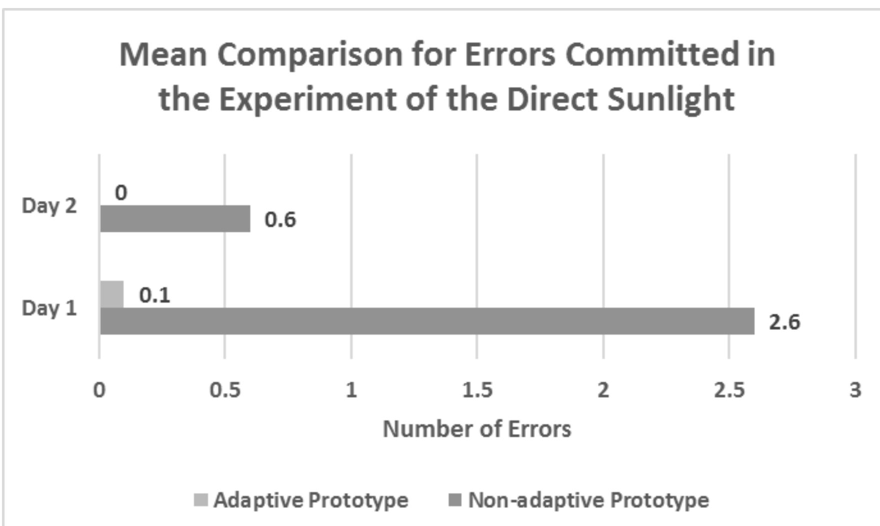


Fig. 6.11: Mean comparison for errors committed in the direct sunlight experiments (n=20)

The obtained results from the Wilcoxon Matched-Pairs Test revealed that there was a significant reduction in the number of errors committed for the assigned task to the direct sunlight experiments by using the non-adaptive version over the two-day evaluation period. This result is based on the calculated P-value that was less than the 5% level of significance as can be seen from Table 6.16. In addition, this indicates improvement in the learnability and memorability metrics for this task over the two-day evaluation period. On contrary, there was not a significant reduction in the number of errors committed for the assigned task to the direct sunlight experiments by using the adaptive version over the two-day evaluation period. This result is based on the calculated P-value that was greater than the 5% level of significance as can be seen from Table 6.16.

	Non-adaptive (day 1 and day 2)	Adaptive (day 1 and day2)
P-value	0.041	0.317

Tab. 6.16: P-values from the Wilcoxon Matched-Pairs Test for the errors committed in the direct sunlight experiments (n=20)

As can be seen from Table 6.17, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version in the first day experiments were 12.50 and 0.002 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of errors committed in the direct sunlight experiments on the first-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the second day of the evaluation, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version were 20 and 0.004 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of errors committed in the direct sunlight experiments on the second-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the calculated average for the number of errors committed by each participant in each group over the two-day evaluation period, the calculated U-value was 6.5, and the P-value was 0, which is less than the 5% level of significance. This indicates that there was a significant reduction in the number of errors committed in the direct sunlight experiments by using the adaptive version of the developed prototype in comparison to the non-adaptive version. In addition, this indicates that the adaptive version supports the improvement of the learnability and memorability metrics more than the non-adaptive version of the developed prototype over the two-day evaluation period of this experiment.

	U	P-value
First day	12.50	0.002
Second day	20	0.004
Average	6.5	0

Tab. 6.17: Results of Mann-Whitney U Test for the errors committed in the direct sunlight experiments (n=20)

6.2.3.3 Rate of UI’s Widgets that Got Focused

- **Walking Experiments**

In the walking experiments, the means of the number of the UI’s widgets that got focused over the two-day evaluation period were recorded, and Figure 6.12 depicts the comparisons between them. Based on these calculated means, the following results were obtained:

1. The number of the UI’s widgets that got focused on the first day’s experiments by using the adaptive version of the developed prototype had a lower rate of UI’s focused widgets by 9.1 widgets than the non-adaptive version of the developed prototype.
2. The number of the UI’s widgets that got focused on the second day’s experiments by using the adaptive version of the developed prototype had a lower rate of the UI’s focused widgets by 2.5 widgets than the non-adaptive version of the developed prototype.

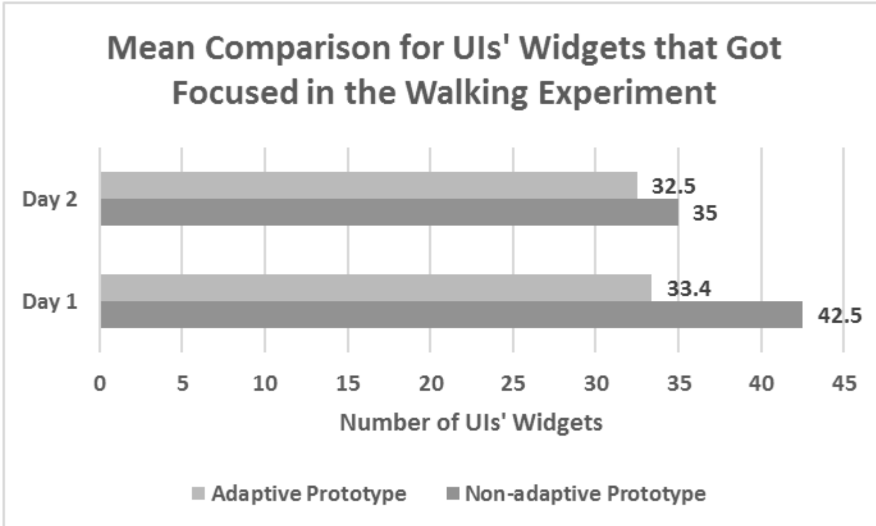


Fig. 6.12: Mean comparison for the UIs’ widgets that got focused in the walking experiments (n=20)

The obtained results from the Wilcoxon Matched-Pairs Test revealed that there was a significant reduction in the number of the UI’s widgets that got focused from the participants for the assigned task to the walking experiments by using the non-adaptive version over the two-day evaluation period. This result is based on the calculated P-value that was less than the 5% level of significance as can be seen from Table 6.18. In addition, this indicates improvement in the learnability and memorability metrics for this version over the two-day evaluation period. On the contrary, there was not a significant reduction in the number of UI’s widgets that got focused from the participants for the assigned task to the walking experiments by using the adaptive version over the two-day evaluation period. This result is based on the calculated P-value that was greater than the 5% level of significance as can be seen from Table 6.18.

	Non-adaptive (day 1 and day 2)	Adaptive (day 1 and day2)
P-value	0.028	0.131

Tab. 6.18: P-values from the Wilcoxon Matched-Pairs Test for the number of the UI’s widgets that got focused in the walking experiments (n=20)

As can be seen from Table 6.19, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version on the first day experiments were 20.50 and 0.024 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of UI’s widgets that got focused from the participants in the walking experiments on the first-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the second day of the evaluation, the calculated U-value and P-value from the Wilcoxon Mann-Whitney U Test for the non-adaptive version and the adaptive version were 23 and 0.025 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of UI’s widgets that got focused from the participants in the walking experiments on the second-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the calculated average of the number of UI’s widgets that got focused by each participant in each group over the two-day evaluation period, the calculated U-value was 17.5, and the P-value was 0.013, which is less than the 5% level of significance. This indicates that there was a significant reduction in the number of UI's widgets that got focused from the participants in the walking experiments by using the adaptive version of the developed prototype in comparison to the non-adaptive version. In addition, this indicates that the adaptive version supports the improvement of the learnability and memorability metrics more than the non-adaptive version of the developed prototype over the two-day evaluation period of this experiment.

	U	P-value
First day	20.50	0.024
Second day	23	0.025
Average	17.5	0.013

Tab. 6.19: Results of Mann-Whitney U Test for the number of UI's widgets that got focused in the walking experiments (n=20)

- **High Ambient Sound Experiments**

In the high ambient sound experiments, the means of the number of the UI's widgets that got focused over the two-day evaluation period were recorded, and Figure 6.13 depicts the comparisons between them. Based on these calculated means, the following results were obtained:

1. The number of the UI's widgets that got focused on the first day's experiments by using the adaptive version of the developed prototype had a lower rate of UI's focused widgets by 2.7 widgets than the non-adaptive version of the developed prototype.
2. The number of the UI's widgets that got focused on the second day's experiments by using the adaptive version of the developed prototype had a lower rate of UI's focused widgets by 2.5 widgets than the non-adaptive version of the developed prototype.

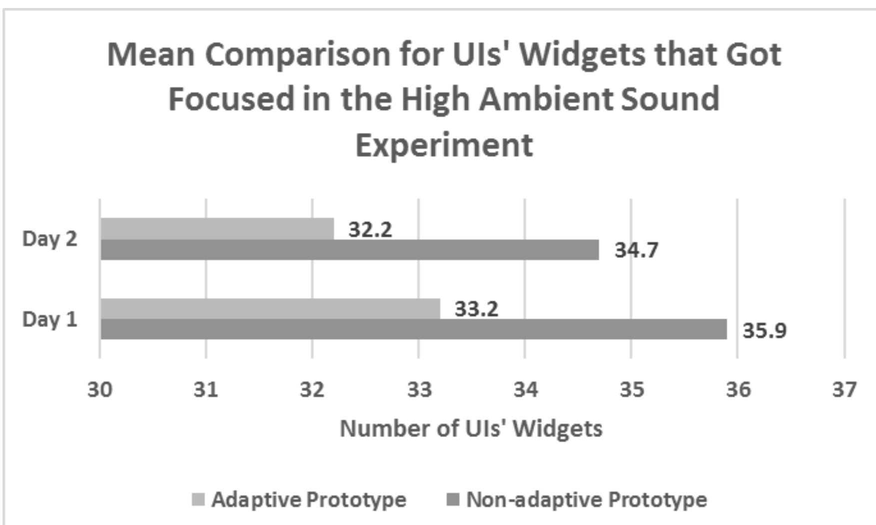


Fig. 6.13: Mean comparison for the UIs' widgets that got focused in the high ambient sound experiments (n=20)

The obtained results from the Wilcoxon Matched-Pairs Test revealed that there was not a significant reduction in the number of UI's widgets that got focused from the participants for the assigned task to the high ambient sound experiments by using the non-adaptive version over the two-day evaluation period. This result is based on the calculated P-value that was greater than the 5% level of significance as can be seen from Table 6.20. On the contrary, there was a significant reduction in the number of UI's widgets that got focused from the participants for the assigned task to the high ambient sound experiments by using the adaptive version over the two-day evaluation period. This result is based on the calculated P-value that was less than the 5% level of significance as can be seen from Table 6.20. In addition, this indicates improvement in the learnability and memorability metrics for this version over the two-day evaluation period.

	Non-adaptive (day 1 and day 2)	Adaptive (day 1 and day2)
P-value	0.360	0.026

Tab. 6.20: P-values from the Wilcoxon Matched-Pairs Test for the number of the UI's widgets that got focused in the high ambient sound experiments (n=20)

As can be seen from Table 6.21, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version in the first day experiments were 23 and 0.038 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of UI's widgets that got focused from the participants in the high ambient sound experiments on the first-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the second day of the evaluation, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version were 17.5 and 0.006 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of UI's widgets that got focused from the participants in the high ambient sound experiments on the second-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the calculated average of the number of UI's widgets that got focused by each participant in each group over the two-day evaluation period, the calculated U-value was 15, and the P-value was 0.007, which is less than the 5% level of significance. This indicates that there was a significant reduction in the number of UI's widgets that got focused from the participants in the high ambient sound experiments by using the adaptive version of the developed prototype in comparison to the non-adaptive version. In addition, this indicates that the adaptive version supports the improvement of the learnability and memorability metrics more than the non-adaptive version of the developed prototype over the two-day evaluation period of this experiment.

	U	**P-value**
First day	23	0.038
Second day	17.50	0.006
Average	15	0.007

Tab. 6.21: Results of Mann-Whitney U Test for the number of UI's widgets that got focused in the high ambient sound experiments (n=20)

- **Experiments of the High Ambient Sound with Walking**

In the experiments of high ambient sound while the participants are walking, the means of the number of UI's widgets that got focused over the two-day evaluation period were recorded, and Figure 6.14 depicts the comparisons between them. Based on these calculated means, the following results were obtained:

1. The number of the UI's widgets that got focused on the first day's experiments by using the adaptive version of the developed prototype had a lower rate of the UI's focused widgets by 5.3 widgets than the non-adaptive version of the developed prototype.

2. The number of the UI's widgets that got focused on the second day's experiments by using the adaptive version of the developed prototype had a lower rate of the UI's focused widgets by 2.1 widgets than the non-adaptive version of the developed prototype.

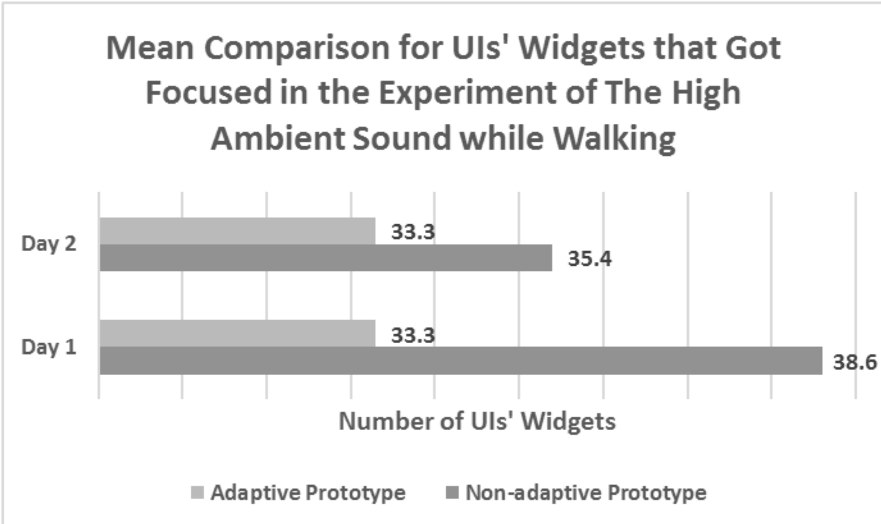


Fig. 6.14: Mean comparison for the UIs' widgets that got focused in the experiments of the high ambient sound with walking (n=20)

The obtained results from the Wilcoxon Matched-Pairs Test revealed that there was not a significant reduction in the number of the UI's widgets that got focused from the participants for the assigned task to the experiments of high ambient sound with walking by using the non-adaptive version over the two-day evaluation period. Similarly, there was not a significant reduction in the number of UI's widgets that got focused from the participants for the assigned task to the experiments of the high ambient sound with walking by using the adaptive version over the two-day evaluation period. These results are based on the calculated P-values that were greater than the 5% level of significance as can be seen from Table 6.22.

	Non-adaptive (day 1 and day 2)	**Adaptive (day 1 and day2)**
P-value	0.258	1

Tab. 6.22: P-values from the Wilcoxon Matched-Pairs Test for the number of the UI's widgets that got focused in the experiments of the high ambient sound with walking (n=20)

As can be seen from Table 6.23, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version in the first day experiments were 21 and 0.026 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of UI's widgets that got focused from the participants in the experiments of the high ambient sound with walking on the first-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the second day of the evaluation, the calculated U-value and P-value from the Wilcoxon Mann-Whitney U Test for the non-adaptive version and the adaptive version were 17 and 0.012 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of UI's widgets that got focused from the participants in the experiments of the high ambient sound with walking on the second-day of evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the calculated average of the number of UI's widgets that got focused by each participant in each group over the two-day evaluation period, the calculated U-value was 10, and the P-value was 0.002, which is less than the 5% level of significance. This indicates that there was a significant reduction in the number of UI's widgets that got focused from the participants in the experiments of the high ambient sound with walking by using the adaptive version of the developed prototype in comparison to the non-adaptive version. In addition, this indicates that the adaptive version supports the improvement of the learnability and memorability metrics more than the non-adaptive version of the developed prototype over the two-day evaluation period of this experiment.

	U	P-value
First day	21	0.026
Second day	17	0.012
Average	10	0.002

Tab. 6.23: Results of Mann-Whitney U Test for the number of UI's widgets that got focused in the experiments of the high ambient sound with walking (n=20)

- **Direct Sunlight Experiments**

In the direct sunlight experiments, the means of the number of UI's widgets that got focused over the two-day evaluation period were recorded, and Figure 6.15 depicts the comparisons between them. Based on these calculated means, the following results were obtained:

1. The number of the UI's widgets that got focused on the first day's experiments by using the adaptive version of the developed prototype had a lower rate of UI's focused widgets by 2.8 widgets than the non-adaptive version of the developed prototype.
2. The number of the UI's widgets that got focused on the second day's experiments by using the adaptive version of the developed prototype had a lower rate of UI's focused widgets by 2 widgets than the non-adaptive version of the developed prototype.

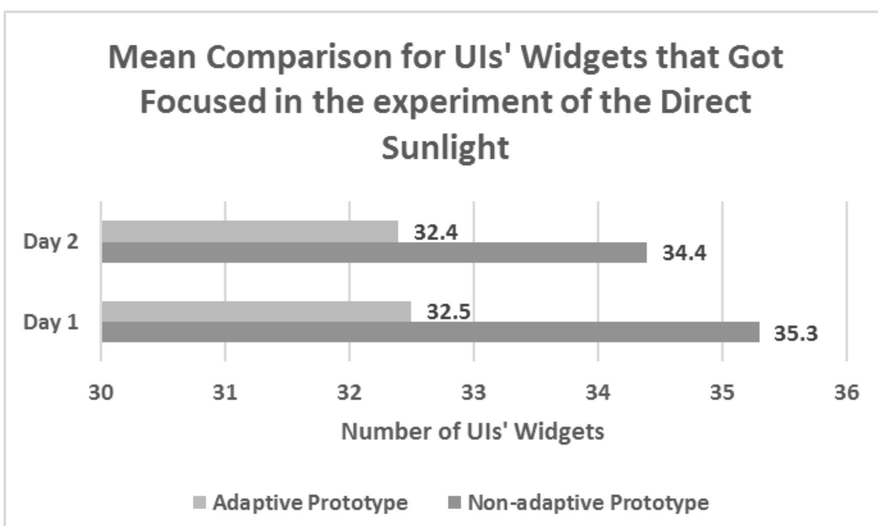


Fig. 6.15: Mean comparison for the UIs' widgets that got focused in the direct sunlight experiments (n=20)

The obtained results from the Wilcoxon Matched-Pairs Test revealed that there was not a significant reduction in the number of UI’s widgets that got focused from the participants for the assigned task to the direct sunlight experiments by using the non-adaptive version over the two-day evaluation period. Similarly, there was not a significant reduction in the number of UI’s widgets that got focused from the participants for the assigned task to the direct sunlight experiments by using the adaptive version over the two-day evaluation period. These results are based on the calculated P-values that were greater than the 5% level of significance as can be seen from Table 6.24.

	Non-adaptive (day 1 and day 2)	**Adaptive (day 1 and day2)**
P-value	0.203	0.705

Tab. 6.24: P-values from the Wilcoxon Matched-Pairs Test for the number of the UI’s widgets that got focused in the direct sunlight experiments (n=20)

As can be seen from Table 6.25, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version on the first day experiments were 17.5 and 0.008 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of UI’s widgets that got focused from the participants in the direct sunlight experiments on the first-day evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the second day of the evaluation, the calculated U-value and P-value from the Mann-Whitney U Test for the non-adaptive version and the adaptive version were 9 and 0.001 respectively. This calculated P-value, which is less than the 5% level of significance, indicates that there was a significant reduction in the number of UI’s widgets that got focused from the participants in the direct sunlight experiments on the second-day evaluation by using the adaptive version of the developed prototype, in comparison to the non-adaptive version.

Regarding the calculated average of the number of UI’s widgets that got focused by each participant in each group over the two-day evaluation period, the calculated U-value was 8, and the P-value was 0.001, which is less than the 5% level of significance. This indicates that there was a significant reduction in the number of UI’s widgets that got focused from the participants in the direct sunlight experiments by using the adaptive version of the developed prototype in comparison to the non-adaptive version. In addition, this indicates that the adaptive version supports the improvement of the learnability and memorability metrics more than the non-adaptive version of the developed prototype over the two-day evaluation period of this experiment.

	U	**P-value**
First day	17.5	0.008
Second day	9	0.001
Average	8	0.001

Tab. 6.25: Results of Mann-Whitney U Test for the number of UI’s widgets that got focused in the direct sunlight experiments (n=20)

6.2.3.4 Satisfaction Metrics

The aim of the satisfaction metrics is to measure the participants’ subjective perceptions towards each of the two versions of the developed prototype (Appendix I). Therefore, each participant from each group was provided with a post-test satisfaction questionnaire to complete after finishing all the determined experiments over the two-day evaluation period. In this questionnaire, the identified subjective metrics were categorised into two categories, namely:

1. Overall reactions to the application.
2. Attitudes towards the identified usability challenges in the developed construct in Chapter 3.

A Cronbach alpha test was applied on participants' responses for each group to assess the reliability or internal consistency of the scales used for each category in this questionnaire.

Regarding the "Overall reactions to the application" category, the calculated α values for each group of the participants are tabulated in Table 6.26. Based on these values, the scale that was used for this category was accepted as reliable (α >= 0.6).

Group	Cronbach's α value
1	0.895
2	0.943

Tab. 6.26: Calculated α values for the responses of each group of participants regarding the "Overall reactions to the application" category (n=20)

Figure 6.16 illustrates the comparisons between the calculated means for the responses of each group's participants for each item in this category.

Furthermore, the Mann-Whitney U Test was applied on participants' responses for each item in this category from the first group, and the participants from the second group. The calculated results from this test revealed that there were significant improvements in overall reactions to the adaptive version of the developed prototype as can be seen from Table 6.27.

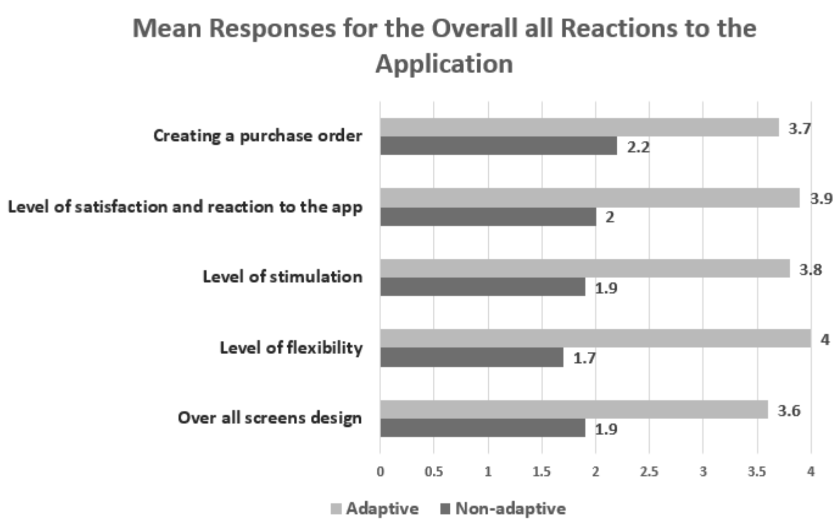


Fig. 6.16: Comparison of overall reactions between the adaptive and non-adaptive versions of the developed prototype (n=20)

Item	U	P-value
Creating a purchase order	11.5	0.003
Level of satisfaction and reaction to the app	7	0.001
Level of stimulation	10	0.002
Level of flexibility	2	0
Over all screens design	11	0.002

Tab. 6.27: Results from the Mann-Whitney U Test for each item in the "Overall reactions to the application" category (n=20)

Regarding the “Attitudes towards the identified usability challenges in the developed construct” category, the calculated α values from Cronbach alpha test for each group of the participants are tabulated in Table 6.28. Based on these values, the scale that was used for this category was accepted as reliable (α >= 0.6).

Group	Cronbach’s α value
1	0.605
2	0.875

Tab. 6.28: Calculated α values for the responses of each group of participants regarding the “Attitudes towards the identified usability challenges in the developed construct” category (n=20)

Figure 6.17 illustrates the comparisons between the calculated means for the responses of each group’s participants for each item in this category.

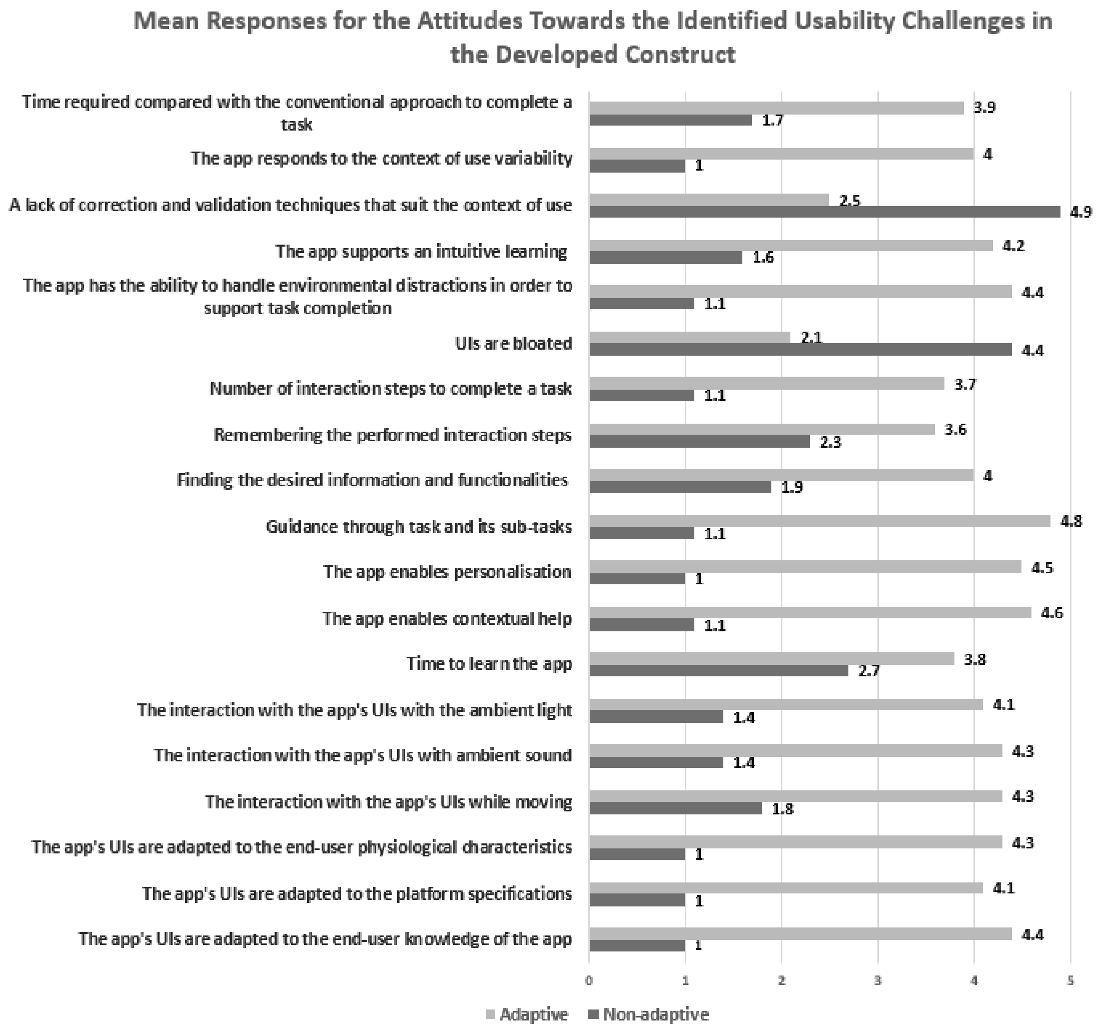


Fig. 6.17: Comparison of attitudes towards the identified usability challenges in the developed construct between the adaptive and non-adaptive versions of the developed prototype (n=20)

Furthermore, the Mann-Whitney U Test was applied on the participants’ responses for each item in this category from the first group, and the participants from the second group. The calculated results from this test revealed that there were significant improvements in the attitudes towards the identified usability challenges in the developed construct by using the adaptive version of the developed prototype as can be seen from Table 6.29.

Item	U	P-value
Time required compared with the conventional approach to complete a task	0	0
The app responds to the context of use variability	0	0
A lack of correction and validation techniques that suit the context of use	12	0.001
The app supports intuitive learning	1	0
The app has the ability to handle environmental distractions in order to support task completion	0	0
UIs are bloated	3	0
Number of interaction steps to complete a task	0	0
Remembering the performed interaction steps	18	0.011
Finding the desired information and functionalities	2	0
Guidance through task and its sub-tasks	0	0
The app enables personalisation	0	0
The app enables contextual help	0	0
Time to learn the app	24	0.035
The interaction with the app's UIs with the ambient light	0	0
The interaction with the app's UIs with ambient sound	0	0
The interaction with the app's UIs while moving	0	0
The app's UIs are adapted to the end-user physiological characteristics	0	0
The app's UIs are adapted to the platform specifications	0	0
The app's UIs are adapted to the end-user knowledge of the app	0	0

Tab. 6.29: Results from the Mann-Whitney U Test for each item in the "Attitudes towards the identified usability challenges in the developed construct" category (n=20)

6.2.4 Hypotheses Testing

In sub-section 6.2.1.2, four hypotheses were established to determine whether the incorporating of the developed computational framework could improve the usability of the non-adaptive version of the developed prototype of the mERP app in terms of efficiency, error rate, memorability, learnability, and satisfaction (the determined metrics) for the determined four contextual experiments. Therefore, this sub-section aims to evaluate these hypotheses by utilising the obtained results from the analyses phase of the followed evaluation protocol for empirical evaluations.

6.2.4.1 Efficiency

Table 6.30 presents the statistical significance results from the Mann Whitney U Test for the average of: time on tasks, errors committed, and the rate of UI's widgets that got focused; which were determined to measure the efficiency.

		Time on tasks	**Errors committed**	**Rate of UI's widgets that got focused**
Walking experiments	**First day**	✓ (See Table 6.3)	✓ (See Table 6.11)	✓ (See Table 6.19)
	Second day	✓ (See Table 6.3)	✓ (See Table 6.11)	✓ (See Table 6.19)
High ambient sound experiments	**First day**	✓ (See Table 6.5)	✓ (See Table 6.13)	✓ (See Table 6.21)
	Second day	✓ (See Table 6.5)	✓ (See Table 6.13)	✓ (See Table 6.21)
High ambient sound while walking experiments	**First day**	✓ (See Table 6.7)	✓ (See Table 6.15)	✓ (See Table 6.23)
	Second day	✓ (See Table 6.7)	✓ (See Table 6.15)	✓ (See Table 6.23)

Direct sunlight experiments	**First day**	✓ (See Table 6.9)	✓ (See Table 6.17)	✓ (See Table 6.25)
	Second day	✓ (See Table 6.9)	✓ (See Table 6.17)	✓ (See Table 6.25)

Tab. 6.30: Statistical significance results for efficiency metrics ticked with "✓" symbol (Mann Whitney U Test)

Based on the results in Table 6.30, the null hypothesis for efficiency ($H_{0,1}$) was rejected. Consequently, incorporating the developed computational framework for devising AUIs can improve the efficiency of the non-adaptive version of the developed prototype of the mERP app, when the end-user uses the app in walking mode, under the distraction of high ambient sound, under the distraction of high ambient sound and walking mode altogether, and under direct sunlight.

6.2.4.2 Errors Rate

Table 6.31 presents the statistical significance results from the Mann Whitney U Test for average number of errors committed, which was determined to measure the error rate.

		Errors committed
Walking experiments	**First day**	✓ (See Table 6.11)
	Second day	✓ (See Table 6.11)
High ambient sound experiments	**First day**	✓ (See Table 6.13)
	Second day	✓ (See Table 6.13)
High ambient sound while walking experiments	**First day**	✓ (See Table 6.15)
	Second day	✓ (See Table 6.15)
Direct sunlight experiments	**First day**	✓ (See Table 6.17)
	Second day	✓ (See Table 6.17)

Tab. 6.31: Statistical significance results for the average error numbers committed ticked with "✓" symbol (Mann Whitney U Test)

Based on the results in Table 6.31, the null hypothesis for error rate ($H_{0,2}$) was rejected. Consequently, incorporating the developed computational framework for devising AUIs can reduce the rate of errors committed in the non-adaptive version of the developed prototype of the mERP app, when the end-user uses the app in walking mode, under the distraction of high ambient sound, under the distraction of high ambient sound and walking mode altogether, and under direct sunlight.

6.2.4.3 Memorability and Learnability

The null hypothesis for memorability and learnability ($H_{0,3}$) was rejected, due to the significant difference in the improvement of the efficiency results as can be seen from Table 6.30. Consequently, incorporating the developed computational framework for devising AUIs can improve the learnability and memorability of the non-adaptive version of the developed prototype of the mERP app, when the end-user uses the app in walking mode, under the distraction of high ambient sound, under the distraction of high ambient sound and walking mode altogether, and under direct sunlight.

6.2.4.4 Satisfaction

Table 6.32 presents the statistical significance results from the Mann Whitney U Test for the determined subjective metrics in the post-test satisfaction questionnaire over the two-day evaluation period.

Category	Significance
Overall reactions to the application	✓ (See Table 6.27)
Attitudes towards the identified usability challenges in the developed construct	✓ (See Table 6.29)

Tab. 6.32: Statistical significance results for the determined subjective metrics over the two-day evaluation period ticked with "✓" symbol (Mann Whitney U Test)

Based on the results in Table 6.32, the null hypothesis for satisfaction ($H_{0,4}$) was rejected. Consequently, incorporating the developed computational framework for devising AUIs can improve the satisfaction of the non-adaptive version of the developed prototype of the mERP app, when the end-user uses the app in walking mode, under the distraction of high ambient sound, under the distraction of high ambient sound and walking mode altogether, and under direct sunlight.

6.2.4.5 Overall Usability

Table 6.33 presents the hypotheses testing for the selected attributes of the PACMAD usability model, which represent the overall usability. Based on these results, the null hypothesis for the overall usability (H_0) was rejected. Consequently, incorporating the developed computational framework for devising AUIs can improve the overall usability of the non-adaptive version of the developed prototype of the mERP app.

Efficiency	Error rate	Memorability	Learnability	Satisfaction
✓	✓	✓	✓	✓

Tab. 6.33: Testing results for the determined hypotheses of the selected attributes of the PACMAD usability model

6.3 Summary

In this chapter, an overview of the AUIs evaluation methodologies was presented, and the empirical evaluation methodology was selected to achieve the main goal of this chapter, which is determining whether any significant improvements in the usability of the developed prototype of the mERP app can be achieved by incorporating the developed computational framework for devising AUIs to it.

Four different environmental contexts were determined to complete the assigned tasks for them by using both versions of the developed prototype (walking, high ambient sound, high ambient sound with walking, under direct sunlight).

Consequently, a set of hypotheses were established in order to formalise the identified research question regarding the main objective of this chapter. These hypotheses were evaluated by measuring the determined usability metrics that aimed to indicate:

1. The participants' performance through measuring the efficiency, error rate, learnability, and memorability (objectives measures).
2. The participants' subjective perceptions through measuring the satisfaction (subjective measures).

A total of 160 experiments were conducted for the determined groups of participants in the determined environmental contexts to measure their performance. In addition, the developed post-test satisfaction questionnaire was handed for the participants to fill out in order to measure their satisfaction.

The collected data from the conducted empirical evaluation was analysed by using the descriptive and inferential statistics, and the obtained results have rejected all the established hypotheses. Consequently, incorporating the developed computational framework for devising AUIs can improve the overall usability of the non-adaptive version of the developed prototype of the mERP app.

7 Conclusion and Outlook

This chapter summarises the obtained results throughout this dissertation by answering the research questions, which were identified, to determine the extent to which these results have contributed to the improvement of the usability of mobile ERP apps (the main research objective). In addition, an outlook on future research directions which can be derived from this research will be presented.

The first section of this chapter summarises the conducted research studies and the major contributions derived from these studies. The last section of this chapter presents a discussion on the potential future research directions in the usability of mobile ERP apps and designing AUIs for such apps.

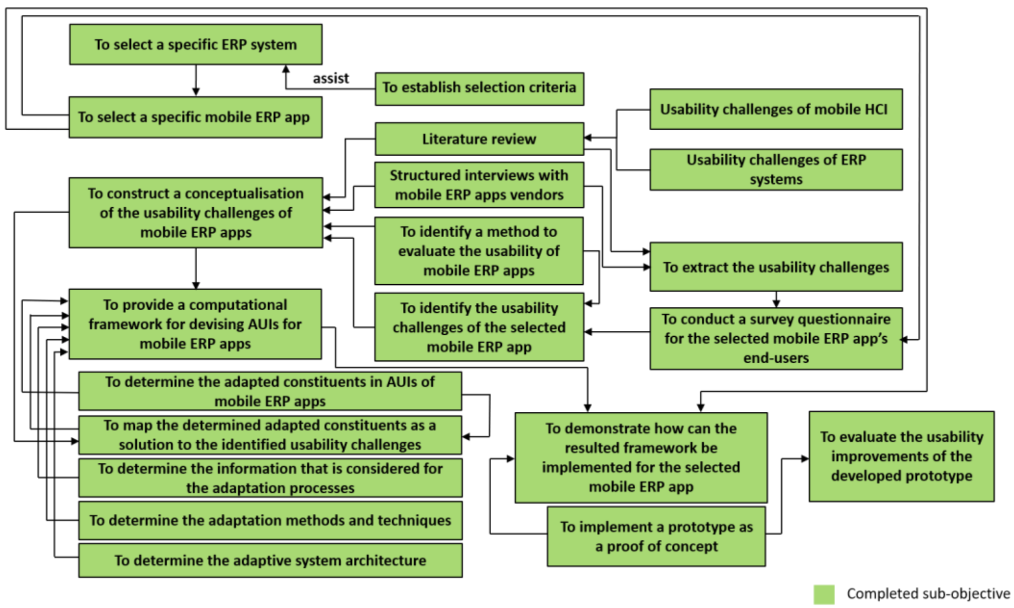


Fig. 7.1: Completed sub-objectives in this research study

7.1 Research Summary

The conducted research in this study demonstrates all the related aspects of the usability of mobile ERP apps in the foundations and methodologies of the IS knowledge base, and shows how these aspects can be applied to achieve the main research objective. Furthermore, some of these aspects were developed and adapted to result in the following artefacts:

1. Firstly, the conceptual framework for devising AUIs that aims to guide the developers of the mobile ERP apps through its components in solving the following problems:

    - Developing high usable applications by incorporating AUIs in them.
    - Increasing the developer's awareness regarding the potential usability challenges of mobile ERP apps.
    - Evaluating the usability of mobile ERP apps.

2. Secondly, the developed construct of the conceptualisation of the usability challenges of mobile ERP apps.

3. Thirdly, the developed computational framework for devising AUIs for mobile ERP apps to address the identified usability challenges in the developed construct.
4. Fourthly, the developed heuristic evaluation checklist to evaluate the usability of mobile ERP apps.
5. Finally, the developed selection model that assists the researchers in their selection process of an appropriate ERP system in order to be researched by following the design science research paradigm in the domain of the mobile ERP research domain.

The abovementioned artefacts have been discussed in detail throughout the presented chapters in this dissertation. Therefore, they are only listed in this section without going back into their details.

Furthermore, a prototypical implementation of the developed computational framework was demonstrated as a proof of concept. The evaluation of this prototype has revealed that significant improvements have been achieved in the usability, after the incorporation of the developed computational framework and its components.

Finally, this research study has successfully met its main objective.

7.2 Future Research Directions

This section attempts to propose some future research in the usability of mobile ERP apps and designing AUIs for mobile ERP apps.

Donahue stated that "*every dollar spent on usability offers a return of $30.25. That's a nice return-on-investment*" (Donahue, 2001, p. 33). As stated earlier, research on mobile ERP apps is still in the budding stage, and in particular, research on the usability of such apps. Therefore, the resulted artifacts from this research study can inspire other researchers to enrich this domain with further research. The following are some of the proposed future research topics based on the resulted artefacts:

1. Enriching the developed construct for the usability challenges of mobile ERP apps with further challenges.
2. Enriching the developed heuristic evaluation checklist with further heuristics.
3. Extending the applied contextual parameters in the developed computational framework by modelling further information regarding the modelled contextual entities in this research study.
4. Enriching the proposed adaptation taxonomies with further methods, techniques, and mobile HCI patterns.

At the programming level, it is recommended to develop an AUIs IDE to assist the mobile ERP developers in creating AUIs. This IDE should include toolsets, such as visual designer, code editor, debugger, class designer, and database schema designer.

At the level of mobile devices, the wearable devices rapidly penetrate different aspects of our daily life, such as Apple watches and Google Glass. Therefore, further research efforts are required to facilitate ERP systems' business processes and functions through utilising these types of devices. Furthermore, AUIs are tightly coupled with these types of devices since they are used in variable contexts of use.

Research on the “smart city” concept aims to synthesis the resulted ideas from the researchers in this domain to demonstrate how information and communications technologies (ICT) might improve cities in terms of functioning, efficiency, and competitiveness. In addition to providing new approaches for addressing problems of poverty, social deprivation, and poor environment (Batty et al., 2012; Harrison et al., 2010). Based on the stated benefits of mobile ERP apps in Chapter 3, the mobile ERP model is one of the ICT applications that can support the “smart city” concept, and in particular, in the business dimension. Therefore, further research efforts are required to utilise these types of apps to realise the “smart city” concept.

References

Abdinnour-Helm, S., Lengnick-Hall, M. L., & Lengnick-Hall, C. A. (2003). Pre-implementation attitudes and organizational readiness for implementing an enterprise resource planning system. *European journal of operational research*, *146*(2), 258–273.

Adipat, B., & Zhang, D. (2005). Interface design for mobile applications.

Ahmad, A. R., Basir, O. A., & Hassanein, K. (2004). Adaptive User Interfaces for Intelligent E-Learning: Issues and Trends. In *ICEB* (pp. 925–934).

Ahmed, S., & Ashraf, G. (2007). Model-based user interface engineering with design patterns. *Journal of Systems and Software*, *80*(8), 1408–1422.

Akiki, P. (2014). Engineering Adaptive Model-Driven User Interfaces for Enterprise Applications (PhD thesis ,The Open University). The Open University.

Akiki, P. A., Bandara, A. K., & Yu, Y. (2015). Adaptive model-driven user interface development systems. *ACM Computing Surveys*, *47*(1), In-press.

Al Bar, A., Mohamed, E., Akhtar, M., & Abuhashish, F. (2011). A preliminary review of implementing Enterprise Mobile Application in ERP environment, *11*(4), 77–82.

Albashrawi, M., & Motiwalla, L. (2016). Adoption of Mobile ERP in Traditional-ERP Organizations: The Effect of Computer Self-Efficacy.

Alvarez-Cortes, V., Zayas-Perez, B. E., Zarate-Silva, V. H., & Uresti, J. A. R. (2007). Current trends in adaptive user interfaces: Challenges and applications. In *Electronics, Robotics and Automotive Mechanics Conference (CERMA 2007)* (pp. 312–317).

Amid, A., Moalagh, M., & Ravasan, A. Z. (2012). Identification and classification of ERP critical failure factors in Iranian industries. *Information Systems*, *37*(3), 227–237.

Ammon News mobile app. (2017). Ammon News Website. Retrieved from http://en.ammonnews.net/

Android. (2016a). Saving Key-Value Sets | Android Developers. Retrieved from https://developer.android.com/training/basics/data-storage/shared-preferences.html

Android. (2016b). Sensors Overview | Android Developers. Retrieved from https://developer.android.com/guide/topics/sensors/sensors_overview.html

Android. (2017a). Activities | Android Developers. Retrieved from https://developer.android.com/guide/components/activities/index.html

Android. (2017b). Environment Sensors | Android Developers. Retrieved from https://developer.android.com/guide/topics/sensors/sensors_environment.html

Android. (2017c). Layouts | Android Developers. Retrieved from https://developer.android.com/guide/topics/ui/declaring-layout.html

Android. (2017d). UI Overview | Android Developers. Retrieved from https://developer.android.com/guide/topics/ui/overview.html

Arcaini, P., Riccobene, E., & Scandurra, P. (2015). Modeling and analyzing MAPE-K feedback loops for self-adaptation. In *Proceedings of the 10th International Symposium on Software Engineering for Adaptive and Self-Managing Systems* (pp. 13–23).

Asif, M., & Krogstie, J. (2012). Taxonomy of personalization in mobile services. In *Proceedings of the 10th IADIS International Conference e-Society*.

Baharuddin, R., Singh, D., & Razali, R. (2013). Usability dimensions for mobile applications—A review. *Res. J. Appl. Sci. Eng. Technol*, *5*, 2225–2231.

Baltrunas, L., Kaminskas, M., Ludwig, B., Moling, O., Ricci, F., Aydin, A.,. . . Schwaiger, R. (2011). Incarmusic: Context-aware music recommendations in a car. In *International Conference on Electronic Commerce and Web Technologies* (pp. 89–100).

Barnard, L., Yi, J. S., Jacko, J. A., & Sears, A. (2007). Capturing the effects of context on human performance in mobile computing systems. *Personal and Ubiquitous Computing*, *11*(2), 81–96.

Batty, M., Axhausen, K. W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M.,. . . Portugali, Y. (2012). Smart cities of the future. *The European Physical Journal Special Topics*, *214*(1), 481–518.

Bauer, J., Kutsche, R.-D., & Ehrmanntraut, R. (2003). Identification and modeling of contexts for different information scenarios in air traffic. *Technische Universität Berlin, Diplomarbeit*.

Benyon, D. (1996). Domains Models for User Interface Design. In *Critical issues in user interface systems engineering* (pp. 3–19). Springer.

Benyon, D., Innocent, P., & Murray, D. (1987). *System adaptivity and the modelling of stereotypes*: National Physical Laboratory, Division of Information Technology and Computing Teddington.

Benyon, D., & Murray, D. (1993a). Adaptive systems: From intelligent tutoring to autonomous agents. *Knowledge-Based Systems*, *6*(4), 197–219.

Benyon, D., & Murray, D. (1993b). Applying user modeling to human-computer interaction design. *Artificial Intelligence Review*, *7*(3-4), 199–225.

Bevan, N., Kirakowski, J., & Maissel, J. (Eds.) 1992. *What is Usability? Proceedings of the 4th International Conference on HCI, Stuttgart 1991*: Elsevier. Retrieved from http://www.nigelbevan.com/papers/whatis92.pdf

B'far, R. (2005). *Mobile computing principles: Designing and developing mobile applications with UML and XML*. New York: Cambridge University Press.

Bickmore, T. W., & Schilit, B. N. (1997). Digestor: device-independent access to the World Wide Web. *Computer Networks and ISDN Systems*, *29*(8), 1075–1082.

Bodendorf, F. (1990). Benutzermodellierung mit Hilfe Neuronaler Netze. In *GI—20. Jahrestagung II* (pp. 349–358). Springer.

Boudreau, M.-C. (2003). Learning to use ERP technology: A causal model. In *System Sciences, 2003. Proceedings of the 36th Annual Hawaii International Conference on* (p. 10).

Bowman, D. A., Gabbard, J. L., & Hix, D. (2002). A survey of usability evaluation in virtual environments: classification and comparison of methods. *Presence: Teleoperators and Virtual Environments*, *11*(4), 404–424.

Bra, P. de, Aerts, A., Berden, B., Lange, B. de, Rousseau, B., Santic, T.,. . . Stash, N. (2003). AHA! The adaptive hypermedia architecture. In *Proceedings of the fourteenth ACM conference on Hypertext and hypermedia* (pp. 81–84).

Brajnik, G., Guida, G., & Tasso, C. (1990). User modeling in expert man-machine interfaces: A case study in intelligent information retrieval. *IEEE Transactions on Systems, Man, and Cybernetics*, *20*(1), 166–185.

Britsios, J. (2013). Why usability is important to you. Retrieved from http://www.webnauts.net/usability.html

Browne, D., Totterdell, P., & Norman, M. (. (1990). *Adaptive user interfaces*: Academic Press.

Brusilovsky, P. (1996). Methods and techniques of adaptive hypermedia. *User modeling and user-adapted interaction*, *6*(2-3), 87–129.

Brusilovsky, P., & Cooper, D. W. (2001). Domain, task, and user models for an adaptive hypermedia performance support system. In K. Hammond, Y. Gil, & D. Leake (Eds.), *Bridging the gap: Technology, service and you* (p. 23). New York, New York, USA: ACM Press. https://doi.org/10.1145/502716.502724

Brusilovsky, P., Karagiannidis, C., & Sampson, D. (2001). The benefits of layered evaluation of adaptive applications and services. In *Empirical Evaluation of Adaptive Systems. Proceedings of workshop at the Eighth International Conference on User Modeling, UM2001* (pp. 1–8).

Budiu, R. (2015). Mobile User Experience: Limitations and Strengths. Retrieved from https://www.nngroup.com/articles/mobile-ux/

Budiu, R., & Nielsen, J. (2008). *Usability of Mobile Websites: 85 Design Guidelines for Improving Access to Web-Based Content and Services Through Mobile Devices.*

Bunt, A., Conati, C., & McGrenere, J. (2004). What role can adaptive support play in an adaptable system? In *Proceedings of the 9th international conference on Intelligent user interfaces* (pp. 117–124).

Butler, H. M. (2001). Implementing Content Negotiation using CC/PP and WAP UAProf. Retrieved from http://www.hpl.hp.com/techreports/2001/HPL-2001-190.pdf

Butler, K. A. (1996). Usability engineering turns 10. *interactions*, *3*(1), 58–75.

Căilean, D. A., & Sharifi, K. (2013). Mobile ERP: A literature review on the concept of Mobile ERP systems (Master's Thesis in Informatics). Jönköping University, Jönköping University, Sweden.

Casas, R., Mar'in, R. B., Robinet, A., Delgado, A. R., Yarza, A. R., Mcginn, J.,. . . Grout, V. (2008). User modelling in ambient intelligence for elderly and disabled people. In *International Conference on Computers for Handicapped Persons* (pp. 114–122).

Castellina, N. (2014). Mobile ERP: Taking ERP ROI into Your Own Hands: Aberdeen Group.

Castillejo, E. (2015). DYNAMIC USER INTERFACE ADAPTATION ENGINE THROUGH SEMANTIC MODELLING AND REASONING IN MOBILE DEVICES (Doctoral). UNIVERSIDAD DE DEUSTO, Spain.

Charland, A., & Leroux, B. (2011). Mobile application development: web vs. native. *Communications of the ACM*, *54*(5), 49–53.

Charlton, C. (2014). BYOD and the growing demand for mobile ERP. Retrieved from http://www.manmonthly.com.au/features/byod-and-the-growing-demand-for-mobile-erp/

Chen, C. C., Law, C. C. H., & Yang, S. C. (2009). Managing ERP implementation failure: a project management perspective. *Engineering Management, IEEE Transactions on*, *56*(1), 157–170.

Chen, G., & Kotz, D. (2000). *A survey of context-aware mobile computing research.*

Chen, H., Finin, T., & Joshi, A. (2005). *Using OWL in a pervasive computing broker.*

Chen, H., Perich, F., Finin, T., & Joshi, A. (2004). Soupa: Standard ontology for ubiquitous and pervasive applications. In *Mobile and Ubiquitous Systems: Networking and Services, 2004. MOBIQUITOUS 2004. The First Annual International Conference on* (pp. 258–267).

Chen, I. J. (2001). Planning for ERP systems: analysis and future trend. *Business process management journal*, *7*(5), 374–386.

Chin, J. P., Diehl, V. A., & Norman, K. L. (1988). Development of an instrument measuring user satisfaction of the human-computer interface. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 213–218).

Chou, S.-W., & Chang, Y.-C. (2008). The implementation factors that influence the ERP (enterprise resource planning) benefits. *Decision support systems*, *46*(1), 149–157.

Columbus, L. (2013). Roundup of Cloud Computing & Enterprise Software Market Estimates and Forecasts, 2013. Retrieved from http://onforb.es/1VF1xsT

Cortes, V. A., Zirate, V. H., Uresti, J. A. R., & Zayas, B. E. (2009). *Current Challenges and Applications for Adaptive User Interfaces*: InTech.

Cote, J. A. (1990). AIDA: Ein an den Benutzer angepaBtes Graphisch-Interaktives System. *Darmstadter Dissertation D, 17*.

Coursaris, C., & Kim, D. (2006). A qualitative review of empirical mobile usability studies. *AMCIS 2006 Proceedings*, 352.

Crowther, M. S., Keller, C. C., & Waddoups, G. L. (2004). Improving the quality and effectiveness of computer-mediated instruction through usability evaluations. *British Journal of Educational Technology*, *35*(3), 289–303.

Cynthia Lee. (2014). Gartner Says Traditional Development Practices Will Fail for Mobile Apps. Retrieved from http://www.gartner.com/newsroom/id/2823619

Da Silva, P. P. (2000). User interface declarative models and development environments: A survey. In *International Workshop on Design, Specification, and Verification of Interactive Systems* (pp. 207–226).

Dabkowski, A., & Jankowska, A. M. (Eds.) 2003. *Comprehensive framework for mobile ERP system*. *Proc. 14th Int. Workshop on Database and Expert Systems Applications,Prague 2003*. Washington DC: IEEE Computer Society.

Dahlén, C., & Elfsson, J. (1999). An Analysis of the current and future ERP market. *Industrial Economics and Management, The Royal Institut of Technology, Schweden*.

Davenport, T. H. (1998). Putting the enterprise into the enterprise system. *Harvard business review*, *76*(4).

Deloitte Consulting. (1998). *ERP's SECOND WAVE: Maximizing the Value of ERP-Enabled Processes*. Retrieved from Deloitte Consulting website: http://www.ctiforum.com/technology/CRM/wp01/download/erp2w.pdf

Delsart, Y., & van Nieuwenhuysen, C. (2011). *OpenERP Evaluation with SAP as Reference*: Tiny Sprl.

Dey, A. K. (2001). Understanding and Using Context. *Personal and Ubiquitous Computing*, *5*(1), 4–7. https://doi.org/10.1007/s007790170019

Dieterich, H., Malinowski, U., Kühme, T., & Schneider-Hufschmidt, M. (1993). State of the art in adaptive user interfaces. *Human factors in information technology*, *10*, 13.

Dix, A., Finlay, J., D. Abowd, G., & Beale, R. (2004). *Human–Computer Interaction* (Third edition): Pearson.

Donahue, G. M. (2001). Usability and the bottom line. *IEEE Software*, *18*(1), 31–37.

Dospinescu, O., Fotache, D., Munteanu, B. A., & Hurbean, L. (2008). Mobile enterprise resource planning: new technology horizons. *Communications of the IBIMA*, *1*(11), 91–97.

Dringus, L. P., & Cohen, M. S. (2005). An adaptable usability heuristic checklist for online courses. In *Frontiers in Education, 2005. FIE'05. Proceedings 35th Annual Conference* (T2H-6).

Duan, J., Faker, P., Fesak, A., & Stuart, T. (2013). Benefits and drawbacks of cloud-based versus traditional ERP systems. *Proceedings of the 2012-13 Course on Advanced Resource Planning*.

Dunlop, M., & Brewster, S. (2002). The challenge of mobile devices for human computer interaction. *Personal and Ubiquitous Computing*, *6*(4), 235–236.

Epicor Software Corporation. (2014). ERP and Mobile, Social, and Cloud – New Global Research Findings Revealed. Retrieved from http://www.epicor.com/Company/Pages/whats-next.aspx

Feng, J., & Liu, Y. (2015). Intelligent Context-Aware and Adaptive Interface for Mobile LBS. *Computational intelligence and neuroscience*.

Findlater, L., & McGrenere, J. (2010). Beyond performance: Feature awareness in personalized interfaces. *International Journal of Human-Computer Studies*, *68*(3), 121–137.

Fischer, G. (2001). User modeling in human-computer interaction. *User modeling and user-adapted interaction*, *11*(1-2), 65–86.

Folmer, E., & Bosch, J. (2004). Architecting for usability: a survey. *Journal of Systems and Software*, *70*(1), 61–78.

Fonseca, José Manuel Cantera. (2010). Model-Based UI XG Final Report. Retrieved from http://www.w3.org/2005/Incubator/model-based-ui/XGR-mbui-20100504/

Gajos, K., & Weld, D. S. (2004). SUPPLE: automatically generating user interfaces. In *Proceedings of the 9th international conference on Intelligent user interfaces* (pp. 93–100).

Gajos, K. Z., Czerwinski, M., Tan, D. S., & Weld, D. S. (2006). Exploring the design space for adaptive graphical user interfaces. In *Proceedings of the working conference on Advanced visual interfaces* (pp. 201–208).

Gartner. (2013). Enterprise Application Software, Worldwide, 2011-2016, 4Q12 Update Published: 31 January 2013. Retrieved from http://gtnr.it/22w3VY9

Gauch, S., Chaffee, J., & Pretschner, A. (2003). Ontology-based personalized search and browsing. *Web Intelligence and Agent Systems: An international Journal*, *1*(3, 4), 219–234.

Gelogo, Y. E., & Kim, H.-K. (2014). Mobile Integrated Enterprise Resource Planning System Architecture. *International Journal of Control and Automation*, *7*(3/14), 379–388. https://doi.org/10.14257/ijca.2014.7.3.36

Gena, C. (2005). Methods and techniques for the evaluation of user-adaptive systems. *The Knowledge Engineering Review*, *20*(1), 1–37.

Gena, C. (2006). A user-centered approach for adaptive systems evaluation. In *5th Workshop on User-Centred Design and Evaluation of Adaptive Systems* (pp. 20–23).

Ghédira, C., Maret, P., Fayn, J., & Rubel, P. (2002). Adaptive user interface customization through browsing knowledge capitalization. *International journal of medical informatics*, *68*(1), 219–228.

Golemati, M., Katifori, A., Vassilakis, C., Lepouras, G., & Halatsis, C. (2007). Creating an ontology for the user profile: Method and applications. In *Proceedings of the first RCIS conference* (pp. 407–412).

Grabski, S. V., Leech, S. A., & Schmidt, P. J. (2011). A review of ERP research: A future agenda for accounting information systems. *Journal of information systems*, *25*(1), 37–78.

Gregor, P., Newell, A. F., & Zajicek, M. (2002). Designing for dynamic diversity: interfaces for older people. In *Proceedings of the fifth international ACM conference on Assistive technologies* (pp. 151–156).

Gu, T., Pung, H. K., & Zhang, D. Q. (2004a). A middleware for building context-aware mobile services. In *Vehicular Technology Conference, 2004. VTC 2004-Spring. 2004 IEEE 59th* (Vol. 5, pp. 2656–2660).

Gu, T., Pung, H. K., & Zhang, D. Q. (2004b). Toward an OSGi-based infrastructure for context-aware applications. *IEEE Pervasive Computing*, *3*(4), 66–74.

Guermah, H., Fissaa, T., Hafiddi, H., Nassar, M., & Kriouile, A. (2014). An Ontology Oriented Architecture for Context Aware Services Adaptation. *arXiv preprint arXiv:1404.3280*.

Gullà, F., Cavalieri, L., Ceccacci, S., Germani, M., & Bevilacqua, R. (2015). Method to Design Adaptable and Adaptive User Interfaces. In *HCI International 2015-Posters' Extended Abstracts* (pp. 19–24). Springer.

Gupta, M., & Kohli, A. (2006). Enterprise resource planning systems and its implications for operations function. *Technovation*, *26*(5), 687–696.

Haas, M. W., & Hettinger, L. J. (2001). Current Research in Adaptive Interfaces. *The International Journal of Aviation Psychology*, *11*(2), 119–121. https://doi.org/10.1207/S15327108IJAP1102_01

Haddara, M. (2014). ERP Selection: The SMART Way. *Procedia Technology*, *16*, 394–403.

Hailu, A., & Rahman, S. (2012). Evaluation of key success factors influencing ERP implementation success. In *Services (SERVICES), 2012 IEEE Eighth World Congress on* (pp. 88–91).

Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., & Williams, P. (2010). Foundations for smarter cities. *IBM Journal of Research and Development*, *54*(4), 1–16.

Harrison, R., Flood, D., & Duce, D. (2013). Usability of mobile applications: Literature review and rationale for a new usability model. *Journal of Interaction Science*, *1*(1), 1–16.

Hatala, M., & Wakkary, R. (2005). Ontology-based user modeling in an augmented audio reality system for museums. *User modeling and user-adapted interaction*, *15*(3-4), 339–380.

Heckmann, D., Schwartz, T., Brandherm, B., Schmitz, M., & Wilamowitz-Moellendorff, M. von (2005). Gumo-the general user model ontology. In *International Conference on User Modeling* (pp. 428–432).

Held, A., Buchholz, S., & Schill, A. (2002). Modeling of context information for pervasive computing applications. *Proceedings of SCI*, 167–180.

Henricksen, K., Indulska, J., & Rakotonirainy, A. (2002). Modeling context information in pervasive computing systems. In *International Conference on Pervasive Computing* (pp. 167–180).

Herzog, T. (2006). A comparison of open source ERP systems.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research: MIS Quarterly, *28*(1), 75–105.

Hoehle, H., & Venkatesh, V. (2015). Mobile application usability: conceptualization and instrument development. *MIS quarterly*, *39*(2), 435–472.

Hollingsed, T., & Novick, D. G. (2007). Usability inspection methods after 15 years of research and practice. In *Proceedings of the 25th annual ACM international conference on Design of communication* (pp. 249–255).

Holzinger, A., & Errath, M. (2007). Mobile computer Web-application design in medicine: some research based guidelines. *Universal Access in the Information Society*, *6*(1), 31–41.

Holzinger, A., Searle, G., & Wernbacher, M. (2011). The effect of previous exposure to technology on acceptance and its importance in usability and accessibility engineering. *Universal Access in the Information Society*, *10*(3), 245–260.

Hoober, S., & Berkman, E. (2011). *Designing Mobile Interfaces: Patterns for Interaction Design*: O'Reilly Media, Inc.

Höök, K. (2000). Steps to take before intelligent user interfaces become real. *Interacting with computers*, *12*(4), 409–426.

Huy, N., & van Thanh, D. (2012). Selecting the right mobile app paradigms. In *Service-Oriented Computing and Applications (SOCA), 2012 5th IEEE International Conference on* (pp. 1–6).

IDC Research, I. (2015). Smartphone OS Market Share, 2015 Q2. Retrieved from http://www.idc.com/prodserv/smartphone-os-market-share.jsp

Ioppolo & Associates. (2016). Odoo & ERP Consulting Australia Web Site. Retrieved from http://odoo.com.au/modules/

Ismail, M. N., Ibrahim, R., & Md Fudzee, Mohd Farhan. (2013). A survey on content adaptation systems towards energy consumption awareness. *Advances in Multimedia*, *2013*, 3.

ISO. (1998). Ergonomic requirements for office work with visual display terminals (VDTs): Part 11 : Guidance on usability,International Standards Organisation (ISO). (First edition).

Jameson, A. (2001). Modelling both the Context and the User. *Personal and Ubiquitous Computing*, *5*(1), 29–33.

Jameson, A. (2009). Adaptive interfaces and agents. *Human-Computer Interaction: Design Issues, Solutions, and Applications*, *105*, 105–130.

Jankowska, A. M., & Kurbel, K. (2005). Service-Oriented Architecture Supporting Mobile Access to an ERP System. In *Wirtschaftsinformatik* (pp. 371–390).

Järvinen, P. (2007). Action research is similar to design science. *Quality & Quantity*, *41*(1), 37–54.

Ji, Y. G., Park, J. H., Lee, C., & Yun, M. H. (2006). A usability checklist for the usability evaluation of mobile phone user interface. *International Journal of Human-Computer Interaction*, *20*(3), 207–231.

Jobe, W. (2013). Native Apps Vs. Mobile Web Apps. *iJIM*, *7*(4), 27–32.

Juristo, N., Moreno, A. M., & Sanchez-Segura, M.-I. (2007a). Guidelines for eliciting usability functionalities. *IEEE Transactions on Software Engineering*, *33*(11).

Juristo, N., Moreno, A. M., & Sanchez-Segura, M.-I. (2007b). Analysing the impact of usability on software design. *Journal of Systems and Software*, *80*(9), 1506–1516.

Kass, R., & Finin, T. (1988). Modeling the user in natural language systems. *Computational Linguistics*, *14*(3), 5–22.

Keeble, R. J., Macredie, R. D., & Williams, D. S. (2000). User Environments and Individuals: Experience with Adaptive Interface Agents. *Cognition, Technology & Work*, *2*(1), 16–26.

Keller, G., & Teufel, T. (1998). *SAP R/3 process oriented implementation*: Addison-Wesley Longman Publishing Co., Inc.

Kezmah, B., & Rozman, I. (2002). Web services in ERP solutions: a managerial perspective. In *International Symposium on Metainformatics* (pp. 177–179).

Kim, J. H., Aulck, L., Bartha, M. C., Harper, C. A., & Johnson, P. W. (2014). Differences in typing forces, muscle activity, comfort, and typing performance among virtual, notebook, and desktop keyboards. *Applied ergonomics*, *45*(6), 1406–1413.

Klaus, H., Rosemann, M., & Gable, G. G. (2000). What is ERP? *Information systems frontiers*, *2*(2), 141–162.

Knutov, E. (2012). Generic Adaptation Framework: for unifying adaptive web-based systems (PhD). Eindhoven University of Technology (TU/e), Eindhoven NL.

Knutov, E., Bra, P. de, & Pechenizkiy, M. (2009). AH 12 years later: a comprehensive survey of adaptive hypermedia methods and techniques. *New Review of Hypermedia and Multimedia*, *15*(1), 5–38.

Kobsa, A. (1993). User modeling: Recent work, prospects and hazards. *Human factors in information technology*, *10*, 111.

Koch, C., Slater, D., & Baatz, E. (1999). the ABCs of ERP. *CIO magazine*, *22*.

Kok, A. J. (1991). A review and synthesis of user modelling in intelligent systems. *The Knowledge Engineering Review*, *6*(01), 21–47.

Krebs, R., Momm, C., & Kounev, S. (2012). Architectural Concerns in Multi-tenant SaaS Applications. *CLOSER*, *12*, 426–431.

Krogsaeter, M., & Thomas, C. G. (1994). Adaptivity: System-initiated individualization. *Adaptive user support: Ergonomic design of manually and automatically adaptable software*, 67.

Krogstie, J., Lyytinen, K., Opdahl, A. L., Pernici, B., Siau, K., & Smolander, K. (2004). Research areas and challenges for mobile information systems. *International Journal of Mobile Communications*, *2*(3), 220–234.

Kurbel, K., Dabkowski, A., & Jankowska, A. M. (2003). A multi-tier architecture for mobile enterprise resource planning. In *Wirtschaftsinformatik 2003/Band I* (pp. 75–93). Springer.

Lambeck, C., Muller, R., Fohrholz, C., & Leyh, C. (Eds.) 2014. *(Re-)Evaluating User Interface Aspects in ERP Systems -- An Empirical User Study*. *System Sciences (HICSS), 2014 47th Hawaii International Conference on*: IEEE.

Laudon, K. C., & Laudon, J. P. (2014). *Management information systems: Managing the digital firm* (Thirteenth edition, Global edition). Global edition: Pearson.

Lauesen, S. (2005). *User interface design: a software engineering perspective*: Pearson Education.

Lea, B.-R., Gupta, M. C., & Yu, W.-B. (2005). A prototype multi-agent ERP system: an integrated architecture and a conceptual framework. *Technovation*, *25*(4), 433–441.

Lee, Y. E., & Benbasat, I. (2003). Interface design for mobile commerce. *Communications of the ACM*, *46*(12), 48–52.

Lemlouma, T., & Layaida, N. (2004). Context-aware adaptation for mobile devices. In *Mobile Data Management, 2004. Proceedings. 2004 IEEE International Conference on* (pp. 106–111).

Leon, A. (2008a). *Enterprise resource planning* (Second): McGraw-Hill Education.

Leon, A. (2008b). *ERP demystified* (Second Edition): Tata McGraw-Hill Education.

Leon, A. (2014). *Enterprise resource planning* (Third): McGraw-Hill Education.

Letsu-Dake, E., & Ntuen, C. A. (2009). A conceptual model for designing adaptive human-computer interfaces using the living systems theory. *Systems Research and Behavioral Science*, *26*(1), 15–27.

Letsu-Dake, E., & Ntuen, C. A. (2010). A case study of experimental evaluation of adaptive interfaces. *International Journal of Industrial Ergonomics*, *40*(1), 34–40.

Lien, C.-T., & Chan, H.-L. (2007). A selection model for ERP system by applying fuzzy AHP approach. *International Journal of the computer, the internet and management*, *15*(3), 58–72.

Lim, A., Azlianor, A., Suhaizan, S., & Massila, K. (2008). Architecture of Mobile Web Application for Generating Dynamic Route Map. *Architecture of Mobile Web Application for Generating Dynamic Route Map*, 107–111.

Lionbridge. (2012). Mobile Web Apps vs. Mobile Native Apps: How to Make the Right Choice. Retrieved from http://www.lionbridge.com/files/2012/11/Lionbridge-WP_MobileApps2.pdf

Looije, R., Te Brake, G. M., & Neerincx, M. A. (2007). Usability engineering for mobile maps. In *Proceedings of the 4th international conference on mobile technology, applications, and systems and the 1st international symposium on Computer human interaction in mobile technology* (pp. 532–539).

Louis Columbus. (2014). Gartner's ERP Market Share Update Shows The Future Of Cloud ERP Is Now. Retrieved from http://onforb.es/1URfi36

Magal, S. R., & Word, J. (2011). *Integrated business processes with ERP systems*: Wiley Publishing.

Marnewick, C., & Labuschagne, L. (2005). A conceptual model for enterprise resource planning (ERP). *Information management & computer security*, *13*(2), 144–155.

Mason, M. V., & Thomas, R. C. (1984). Experimental adaptive interface. *Information Technology Research Development Applications*, *3*(3), 162–167.

Mayhew, D. J. (1999). The usability engineering lifecycle. In *CHI'99 Extended Abstracts on Human Factors in Computing Systems* (pp. 147–148).

McAvoy, L., Chen, L., & Donnelly, M. (2012). An Ontology Based Context Management System for Smart Environments. In *Proceedings of the International Conference on Mobile Ubiquitous Computing, Systems, Services and Technologies (UBICOMM 2012)* (pp. 18–23).

McDonald, P. M., & Aron, D. (2012). Executive Summary: Amplifying the Enterprise: The 2012 CIO Agenda. Retrieved from https://www.gartner.com/doc/1901815/executive-summary-amplifying-enterprise-cio

Menkhaus, G., & Fischmeister, S. (2003). Dialog model clustering for user interface adaptation. In *International Conference on Web Engineering* (pp. 194–203).

Menkhaus, G., & Pree, W. (2002). A hybrid approach to adaptive user interface generation. *CIT. Journal of computing and information technology*, *10*(3), 171–179.

Mitrovic, N., Royo, J. A., & Mena, E. (2005). Adaptive user interfaces based on mobile agents: Monitoring the behavior of users in a wireless environment. In *I Symposium on Ubiquitous Computing and Ambient Intelligence, Spain.*

Monk, E., & Wagner, B. (2012). *Concepts in Enterprise Resource Planning,* (Fouth Edition): Cengage Learning.

Moore, S. (2015). Gartner Says Demand for Enterprise Mobile Apps Will Outstrip Available Development Capacity Five to One. Retrieved from http://www.gartner.com/newsroom/id/3076817

Motiwalla, L., & Thompson, J. (2012). *Enterprise systems for management* (2nd). Boston: Prentice Hall.

Motti, V. G., & Vanderdonckt, J. (2013). A computational framework for context-aware adaptation of user interfaces. In *IEEE 7th International Conference on Research Challenges in Information Science (RCIS)* (pp. 1–12).

Nayebi, F., Desharnais, J.-M., & Abran, A. (2012). The state of the art of mobile application usability evaluation. In *CCECE* (pp. 1–4).

Neil, T. (2014). *Mobile design pattern gallery: UI patterns for smartphone apps / Theresa Neil* (Second edition): O'Reilly Media, Inc.

Nielsen, J. (1993). *Usability engineering* ([Updated ed.]). San Francisco, Calif.: Morgan Kaufmann Publishers.

Nielsen, J. (1995). Severity Ratings for Usability Problems: Article by Jakob Nielsen. Retrieved from https://www.nngroup.com/articles/how-to-rate-the-severity-of-usability-problems/

Nielsen, J. (2003). *Usability 101: Introduction to usability.*

Nielsen, J., & Budiu, R. (2013). *Mobile usability*. *Voices that matter*. Berkeley, CA: New Riders.

Nielsen, J., & Mack, R. L. (1994). *Usability inspection methods*. New York: Wiley.

Nielsen, J., & Molich, R. (1990). Heuristic evaluation of user interfaces. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 249–256).

Nilsson, M., Hjelm, J., & Ohto, H. (2000). Composite capabilities/preference profiles: Requirements and architecture. *W3C Working Draft*, *21*, 2–28.

Norcio, A. F., & Stanley, J. (1989). Adaptive human-computer interfaces: A literature survey and perspective. *IEEE Transactions on Systems, Man, and Cybernetics*, *19*(2), 399–408.

Nosrati, M., Karimi, R., & Hasanvand, H. A. (2012). Mobile computing: principles, devices and operating systems. *World Applied Programming*, *2*(7), 399–408.

Ntawanga, F. F., Calitz, A. P., & Barnard, L. (2015). A Context-Aware Model to Improve Usability of Information Display on Smartphone Apps for Emerging Users. *The African Journal of Information Systems*, *7*(4), 3.

Odoo. (2012). OpenERP as a multitenant three-tiers architecture. Retrieved from http://bit.ly/1ZOhZH3

Odoo. (2016a). Odoo Nightly builds. Retrieved from https://nightly.odoo.com/

Odoo. (2016b). Odoo Web Site. Retrieved from https://www.odoo.com/

Ohigashi, Y., & Omori, T. (2006). Modeling of autonomous problem solving process by dynamic construction of task models in multiple tasks environment. *Neural networks*, *19*(8), 1169–1180.

Omar, K. (2015). Towards Improving the Usability of Mobile ERP: A Model for Devising Adaptive Mobile UIs to Improve the Usability of Mobile ERP. In Douglas W. Cunningham, Petra Hofstedt, Klaus Meer (Ed.), *45. Jahrestagung der Gesellschaft für Informatik INFORMATIK 2015: Informatik, Energie und Umwelt* (pp. 1783–1794). Gesellschaft für Informatik e.V. (GI).

Omar, K., & Marx Gómez, J. (2015). Usability challenges for mobile ERP systems. Retrieved from ERP Management, http://bit.ly/1UaTCVC

Omar, K., & Marx Gómez, J. (2016a). *A conceptual framework for Devising Adaptive User Interfaces for Mobile ERP: In Eureka International Virtual Meeting Eureka 2016 y OPTISAD 2016.*

Omar, K., & Marx Gómez, J. (2016b). *A selection model of ERP system in mobile ERP design science research: Case study: mobile ERP usability, In the proceedings of 13th ACS/IEEE International Conference on Computer Systems and Applications AICCSA 2016, Agadir, Morocco*: IEEE.

Omar, K., & Marx Gómez (2017a). An Adaptive System Architecture for Devising Adaptive User Interfaces for Mobile ERP Apps. In G. Issa, A. Al-Maqousi, N. El-khalili, & M. Abu-Arqoub (Eds.), *In proceedings of the 2nd International Conference on the Applications of Information Technology in Developing Renewable Energy Processes and Systems (IT-DREPS 2017)* (pp. 80–85). IEEE.

Omar, K., & Marx Gómez. (2017b). An investigation of the proliferation of mobile ERP apps and their usability. In *proceedings of the 8th International Conference on Information and Communication Systems (ICICS)* (352–357). IEEE.

Omar, K., Rapp, B., & Marx Gómez, J. (2016). Heuristic evaluation checklist for mobile ERP user interfaces. In *proceedings of the 7th International Conference on Information and Communication Systems (ICICS)* (pp. 180–185). IEEE.

OpenDDR Project. (2017). OpenDDRdotORG/OpenDDR-Resources. Retrieved from https://github.com/OpenDDRdotORG/OpenDDR-Resources

Oppermann, R. (1994). *Adaptive user support: ergonomic design of manually and automatically adaptable software*: CRC Press.

Pang, C., Dharmasthira, Y., Eschinger, C., F. Brant, K., & Motoyoshi, K. (2014). *Market Share Analysis: ERP Software, Worldwide, 2013*. Retrieved from Gartner, Inc. website: http://gtnr.it/1WMGI0j

Panorama Consulting Solutions. (2015). 2015 ERP REPORT: A Panorama Consulting Solutions Research Report. Retrieved from http://bit.ly/2iu7u16

Park, J., & Han, S. H. (2011). Complementary menus: Combining adaptable and adaptive approaches for menu interface. *International Journal of Industrial Ergonomics*, *41*(3), 305–316.

Parks, N. E. (2012). Testing & quantifying ERP usability. In *Proceedings of the 1st Annual conference on Research in information technology* (pp. 31–36).

Paterno, F. (2013). User Interface Design Adaptation. *The Encyclopedia of Human-Computer Interaction, 2nd Ed*.

Paternò, F. (2004). ConcurTaskTrees: an engineered notation for task models. *The handbook of task analysis for human-computer interaction*, 483–503.

Paternò, F., Mancini, C., & Meniconi, S. (1997). ConcurTaskTrees: A diagrammatic notation for specifying task models. In *Human-Computer Interaction INTERACT'97* (pp. 362–369).

Pattnaik, P. K., & Mall, R. (2015). *Fundamentals of Mobile Computing*: PHI Learning Pvt. Ltd.

Pavin, R. D. P., & Klein, A. Z. (2015). ORGANIZATIONAL CONSEQUENCES OF THE ADOPTION OF MOBILE ERP SYSTEMS: CASE STUDIES IN BRAZIL. *JISTEM-Journal of Information Systems and Technology Management*, *12*(2), 219–232.

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of management information systems*, *24*(3), 45–77.

Pereira, F. (2005). A triple user characterization model for video adaptation and quality of experience evaluatio. In *2005 IEEE 7th Workshop on Multimedia Signal Processing* (pp. 1–4).

Persad, U., Langdon, P., & Clarkson, J. (2007). Characterising user capabilities to support inclusive design evaluation. *Universal Access in the Information Society*, *6*(2), 119–135.

Pierotti, D. (1995). Heuristic evaluation-a system checklist. *Xerox Corporation*.

Pinckaers, F., & Gardiner, G. (2009). *Open Erp for Retail and Industrial Management*. *Open Source and Management*: Open Object Press. Retrieved from https://books.google.de/books?id=hQ6fPgAACAAJ

Pinckaers, F. (2016). The Odoo story. Retrieved from http://bit.ly/25V7itf

Pohl, W. (1999). Logic-Based Representation and Reasoning for User Modeling Shell Systems (Ph.D.).

Pombinho, P., Carmo, M. B., & Afonso, A. P. (2015). Adaptive mobile visualization-the chameleon framework. *Computer Science and Information Systems*, *12*(2), 445–464.

Poulcheria, B., & Costas, V. (2011). A Software Architecture for Provision of Context-Aware Web-based m-Commerce Applications. In *Computer and Information Technology (CIT), 2011 IEEE 11th International Conference on* (pp. 344–349).

Poulcheria, B., & Costas, V. (2012). A context management architecture for m-commerce applications. *Open Computer Science*, *2*(2), 87–117.

Poulovassilis, A., Papamarkos, G., & Wood, P. T. (2006). Event-condition-action rule languages for the semantic web. In *International Conference on Extending Database Technology* (pp. 855–864).

Puerta, A. R. (1997). A model-based interface development environment. *IEEE Software*, *14*(4), 40–47.

Ragowsky, A., & Gefen, D. (2008). What makes the competitive contribution of ERP strategic. *ACM SIGMIS Database*, *39*(2), 33–49.

Rajesh K. (2011). Advantages & Disadvantages of ERP (Enterprise Resource Planning) Systems. Retrieved from http://www.excitingip.com/2010/advantages-disadvantages-of-erp-enterprise-resource-planning-systems/

Raluca, B. (2013). Mobile: Native Apps, Web Apps, and Hybrid Apps. Retrieved from https://www.nngroup.com/articles/mobile-native-apps/

Ramachandran, K. (2009). Adaptive user interfaces for health care applications. *IBM developerWorks*.

Rashid, M. A., Hossain, L., & Patrick, J. D. (2002). *The evolution of ERP systems: A historical perspective.*

Razmerita, L., Angehrn, A., & Maedche, A. (2003). Ontology-based user modeling for knowledge management systems. In *International Conference on User Modeling* (pp. 213–217).

Reichenbacher, T. (2004). *Mobile cartography: adaptive visualisation of geographic information on mobile devices*: Verlag Dr. Hut München.

Rich, E. (1979). Building and exploiting user models. In *Proceedings of the 6th international joint conference on Artificial intelligence-Volume 2* (pp. 720–722).

Rimini-Street. (2014). Mobility Solutions for ERP. Retrieved from http://www.riministreet.com/Documents/Collateral/Rimini-Street-White-Paper-Mobility-Solutions-for-ERP.pdf

Rusu, C., Roncagliolo, S., Rusu, V., & Collazos, C. (2011). A methodology to establish usability heuristics. In *Proc. 4th International Conferences on Advances in Computer-Human Interactions (ACHI 2011), IARIA* (pp. 59–62).

Saini, S. L., Saini, D. K., Yousif, J. H., & Khandage, S. V. (2011). Cloud computing and enterprise resource planning systems. In *Proceedings of the world Congress on Engineering* (Vol. 1, pp. 6–8).

Satyanarayanan, M. (1996). Fundamental challenges in mobile computing. In *Proceedings of the fifteenth annual ACM symposium on Principles of distributed computing* (pp. 1–7).

Schilit, B., Adams, N., & Want, R. (1994). Context-aware computing applications. In *Mobile Computing Systems and Applications, 1994. WMCSA 1994. First Workshop on* (pp. 85–90).

Schilit, B. N., & Theimer, M. M. (1994). Disseminating active map information to mobile hosts. *IEEE network*, *8*(5), 22–32.

Schlungbaum, E. (1996). *Model-based user interface software tools-current state of declarative models.*

Schmidt, A., Aidoo, K. A., Takaluoma, A., Tuomela, U., van Laerhoven, K., & van de Velde, W. (1999). Advanced interaction in context. In *International Symposium on Handheld and Ubiquitous Computing* (pp. 89–101).

Scholtz, B., Cilliers, C., & Calitz, A. (2010). Qualitative techniques for evaluating enterprise resource planning (ERP) user interfaces. In *Proceedings of the 2010 Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists* (pp. 284–293).

Schryen, G. (2015). Writing qualitative IS literature reviews-Guidelines for synthesis, interpretation and guidance of research. *Communications of the AIS*, *37*(Art 12), 286–325.

Schwab, T. (1989). Methoden zur Dialog-und Benutzermodellierung in adaptiven Computer systemen.

Scientiamobile. (2016). WURFL - Mobile Device Database by ScientiaMobile. Retrieved from http://wurfl.sourceforge.net/

Shneiderman, B. (1997). Direct manipulation for comprehensible, predictable and controllable user interfaces. In *Proceedings of the 2nd international conference on Intelligent user interfaces* (pp. 33–39).

Shneiderman, B., & Plaisant, C. (2004). *Designing the user interface: Strategies for effective human-computer interaction* (4th ed.). Boston: Pearson/Addison Wesley.

Simon, H. A. (1996). *The sciences of the artificial (3rd ed.)* (3rd ed.). *3*. Cambridge, MA: MIT Press.

Singh, A., & Wesson, J. (Eds.) 2009. *Evaluation criteria for assessing the usability of ERP systems*. *Proc. of the 2009 annual research conference of the South African Institute of Computer Scientists and Information Technologists*. South Africa: ACM.

Singh, A., & Wesson, J. (2011). The Design of Adaptive Interfaces for Enterprise Resource Planning Systems. In *ICEIS (4)* (pp. 281–286).

Singh, A. (2011). Designing Adaptive User Interfaces for Enterprise Resource Planning Systems for Small Enterprises (Philosophiae Doctor). Nelson Mandela Metropolitan University, South Africa.

Singla, A. R. (2008). Impact of ERP systems on small and mid sized public sector enterprises. *Journal of Theoretical and Applied Information Technology*, *4*(2), 119–131.

Skillen, K.-L., Chen, L., Nugent, C. D., Donnelly, M. P., Burns, W., & Solheim, I. (2012). Ontological user profile modeling for context-aware application personalization. In *International Conference on Ubiquitous Computing and Ambient Intelligence* (pp. 261–268).

Stephanidis, C., Karagiannidis, C., & Koumpis, A. (1997). Decision making in intelligent user interfaces. In *Proceedings of the 2nd international conference on Intelligent user interfaces* (pp. 195–202).

Stieglitz, S., & Brockmann, T. (2012). Increasing organizational performance by transforming into a mobile enterprise. *MIS Quarterly Executive*. (11), 189–204.

Svanæs, D., Alsos, O. A., & Dahl, Y. (2010). Usability testing of mobile ICT for clinical settings: Methodological and practical challenges. *International journal of medical informatics*, *79*(4), e24-e34.

T O'Connor, J., & Dodd, S. C. (2000). Achieving integration on capital projects with enterprise resource planning systems. *Automation in construction*, *9*(5), 515–524.

Tarkoma, S., & Kangasharju, J. (2009). *Mobile middleware: architecture, patterns and practice*: Wiley.

Thiagarajan, N., Aggarwal, G., Nicoara, A., Boneh, D., & Singh, J. P. (2012). Who killed my battery? analyzing mobile browser energy consumption. In *Proceedings of the 21st international conference on World Wide Web* (pp. 41–50).

Tidwell, J. (2011). *Designing interfaces* (Second Edn): O'Reilly Media, Inc.

Topi, H., Lucas, W. T., & Babaian, T. (2005). Identifying Usability Issues with an ERP Implementation. In *ICEIS* (pp. 128–133).

Tran, V., Vanderdonckt, J., Kolp, M., & Faulkner, S. (2009). Generating user interface from task, user and domain models. In *Advances in Human-oriented and Personalized Mechanisms, Technologies, and Services, 2009. CENTRIC'09. Second International Conference on* (pp. 19–26).

Trefis Team. (2014). Key Trends Impacting ERP Software Revenues For SAP In 2014. Retrieved from https://www.forbes.com/sites/greatspeculations/2014/01/06/key-trends-impacting-erp-software-revenues-for-sap-in-2014/#463fc92640bc

Tsandilas, T., & Schraefel, M. C. (2004). Usable adaptive hypermedia systems. *New Review of Hypermedia and Multimedia*, *10*(1), 5–29.

Tselios, N., Avouris, N., & Komis, V. (2008). The effective combination of hybrid usability methods in evaluating educational applications of ICT: Issues and challenges. *Education and Information Technologies*, *13*(1), 55–76.

Tsiaousis, A. S., & Giaglis, G. M. (2010). An empirical assessment of environmental factors that influence the usability of a mobile website. In *Mobile Business and 2010 Ninth Global Mobility Roundtable (ICMB-GMR), 2010 Ninth International Conference on* (pp. 161–167).

U.S. Department of Health and Human Services. (2017). Usability.gov improving the User Experience. Retrieved from https://guidelines.usability.gov/

Uther, M. (2002). Mobile Internet Usability: What Can'Mobile Learning'Learn From the Past? In *WMTE* (pp. 174–176).

Uwizeyemungu, S., & Raymond, L. (2005). Essential characteristics of an ERP system: conceptualization and operationalization. *Journal of Information and Organizational Sciences*, *29*(2), 69–81.

van den Bergh, J., & Coninx, K. (2004). Model-based design of context-sensitive interactive applications: a discussion of notations. In *Proceedings of the 3rd annual conference on Task models and diagrams* (pp. 43–50).

van Tonder, B., & Wesson, J. (2008). Using adaptive interfaces to improve mobile map-based visualisation. In *Proceedings of the 2008 annual research conference of the South African Institute of Computer Scientists and Information Technologists on IT research in developing countries: riding the wave of technology* (pp. 257–266).

van Velsen, L., van der Geest, T., Klaassen, R., & Steehouder, M. (2008). User-centered evaluation of adaptive and adaptable systems: a literature review. *The Knowledge Engineering Review*, *23*(3), 261–281.

van Vossel, E., & Pinckaers, F. (2011). *Integrate your Logistic Processes with OpenERP: Efficient Warehouse Management with Sales and Purchases Integration* (First edition): Open Object Press.

Vasilyeva, E., Pechenizkiy, M., & Puuronen, S. (2005). Towards the framework of adaptive user interfaces for eHealth. In *Computer-Based Medical Systems, 2005. Proceedings. 18th IEEE Symposium on* (pp. 139–144).

Vázquez-Ramírez, R., Marín-Vega, H., & Alor-Hernández, G. (2013). Overview of UI Patterns on Mobile Platform for Educational Applications. *Research in Computing Science*, *65*, 95–102.

Verville, J., & Halingten, A. (2003). A six-stage model of the buying process for ERP software. *Industrial Marketing Management*, *32*(7), 585–594.

Vieira, V., Caldas, L. R., & Salgado, A. C. (2011). Towards an ubiquitous and context sensitive public transportation system. In *Ubi-Media Computing (U-Media), 2011 4th International Conference on* (pp. 174–179).

W3C. (2003). UAProfIndex - W3C Wiki. Retrieved from https://www.w3.org/wiki/UAProfIndex

W3C. (2004). Composite Capability/Preference Profiles (CC/PP): Structure and Vocabularies 1.0. Retrieved from https://www.w3.org/TR/2004/REC-CCPP-struct-vocab-20040115/

W3C. (2017). World Wide Web Consortium (W3C). Retrieved from https://www.w3.org/

Wahlster, W., & Kobsa, A. (1989). User models in dialog systems. In *User models in dialog systems* (pp. 4–34). Springer.

WAPFORUM. (2017). User Agent Profile (UAProf). Retrieved from http://www.wapforum.org

Ward, A., Jones, A., & Hopper, A. (1997). A new location technique for the active office. *IEEE Personal Communications*, *4*(5), 42–47.

Wei, C.-C., Chien, C.-F., & Wang, M.-J. J. (2005). An AHP-based approach to ERP system selection. *International journal of production economics*, *96*(1), 47–62.

Weibelzahl, S. (2001). Evaluation of adaptive systems. *User Modeling 2001*, 292–294.

Weibelzahl, S. (2005). Problems and pitfalls in the evaluation of adaptive systems. *Adaptable and adaptive hypermedia systems*, *11*, 285–299.

Weiser, M. (1991). The computer for the 21st century. *Scientific american*, *265*(3), 94–104.

Whiteside, J. (1988). Usability engineering: Our experience and evolution. *Handbook of Humam-Computer Interaction*, 791–817.

Wikipedia. (2017). Lux - Wikipedia. Retrieved from https://en.wikipedia.org/w/index.php?oldid=794206155

Willis, T. H., & Willis-Brown, A. H. (2002). Extending the value of ERP. *Industrial Management & Data Systems*, *102*(1), 35–38. https://doi.org/10.1108/02635570210414640

Yamabe, T., Takagi, A., & Nakajima, T. (2005). Citron: A context information acquisition framework for personal devices. In *11th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA'05)* (pp. 489–495).

Yáñez Gómez, R., Cascado Caballero, D., & Sevillano, J.-L. (2014). Heuristic Evaluation on Mobile Interfaces: A New Checklist. *The Scientific World Journal*, *2014*.

Yeh, J.-Y. (2006). Evaluating ERP performance from user perspective. In *Services Computing, 2006. APSCC'06. IEEE Asia-Pacific Conference on* (pp. 311–314).

Zarikas, V. (2007). Modeling decisions under uncertainty in adaptive user interfaces. *Universal Access in the Information Society*, *6*(1), 87–101. https://doi.org/10.1007/s10209-007-0072-1

Zhang, D. (2007). Web content adaptation for mobile handheld devices. *Communications of the ACM*, *50*(2), 75–79.

Zhang, D., & Adipat, B. (2005). Challenges, methodologies, and issues in the usability testing of mobile applications. *International Journal of Human-Computer Interaction*, *18*(18.3), 293–308.

Zheng, M., Ormandjieva, O., & Fan, H. (2015). Designing Context Sensitive Mobile User Interface. In *Proceedings of the International Conference on Software Engineering Research and Practice (SERP)* (p. 152).

Zimmerman, J. B. (1999). Mobile Computing: Characteristics, Business benefits, and the mobile framework. *University of Maryland European Division-Bowie State*, *10*, 12.

Appendix A

The consent form for the structured interviews' survey with Mobile ERP vendors.

Consent Form

A questionnaire to investigate the proliferation of Mobile ERP apps and their usability
Name of Researcher: Khalil Omar

Please tick as appropriate	**Yes**	**No**
Have you read the General Information Sheet (Participant Information) for the above study?		
Have you had the opportunity to ask questions and discuss this study?		
Have you received satisfactory answers to all of your questions?		
Do you understand that you will not be referred to by name in any report concerning the study?		
Have you received enough information about this study?		
Do you understand that your participation is voluntary, and you are free to withdraw at any time, without giving any reason, and without any penalty?		
Do you agree to taking part in the above study?		

Participant Name:…………………………………………………………

Signature:………………………………………………………………….

Date:………………………………………………………………………..

Appendix B

General instructions for the structured interviews' survey with mobile ERP vendors.

General Instructions

- **Purpose:**

  This questionnaire attempts to gather insights and thoughts from mobile ERP's salespersons, customer service representatives, and developers in the business, and to determine in which business sector mobile ERP spreads.

  The data that will be gathered in this questionnaire is for research purposes only.

- **Range of Participants:**

  A globally wide range of mobile ERP's salespersons.

- **Confidentiality and Anonymity:**

  All information provided in this questionnaire is strictly private and confidential. Furthermore, all individuals or their responses are completely anonymous.

- **Voluntary Participation:**

  Your participation in this questionnaire is voluntary. If you do not want to participate, please don't submit the questionnaire to the researcher. Moreover, you do not have to answer any question that makes you uncomfortable.

- **This questionnaire consists of 5 sections:**

  1. Section I: Demographic Data.
  2. Section II: Adopting Mobile ERP in Business Sectors and Enterprise Sizes (Questions 1 and 2).
  3. Section III: Motivations and Reasons behind Adopting a Mobile ERP (Question 3).
  4. Section IV: Mobile ERP Modules (Questions 4 -7).
  5. Section V: Mobile OSes and Devices (Questions 8 and 9.
  6. Section VI: General (Question 10).

  The above sections consist of total 10 questions.

- **Please answer these questions to the best of your knowledge.**
- **If you have any questions, comments or concerns about this questionnaire, please contact the researcher.**
- **Thank you for your participation in completing this questionnaire.**

Appendix C

A questionnaire to investigate the proliferation of Mobile ERP apps and their usability.

Section I: Demographic Details						
Fields that have been marked with * in this section are strictly private and confidential.						
* Company Name:						
* Name:						
* Email:						
Age:	○ 20 or less	○ 21-30	○ 31-40	○ 41-50	○ 51-60	○ 61+
Gender:	◉ Male ○ Female					
Country:						
Position:						
Date:						

Section II: Adopting Mobile ERP in Business Sectors and Enterprise Sizes	
1. For each sector of the below business categories, please determine the degree of mobile ERP adoption for this sector?	
Financial and Public Services	
Banking	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Business	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Defence & Security	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Finance	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Healthcare	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Higher Education & Research	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Insurance	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Public Sector	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Other	……………………………………..
Government	

Government	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Other	……………………………………..
Manufacturing	
Aerospace & Defence	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Automotive	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Chemicals	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Consumer Products	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Electricity	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Engineering & Construction	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Pharmaceuticals	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
High Technology	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Industrial Machinery & Components	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Life Sciences	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Manufacturing	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Mill Products	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Mining & Quarrying	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Oil, Gas and Water	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Other	……………………………………..
Non-Profit Organisations	
Non-Profit Organisations	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Other	……………………………………..

Services	
Agriculture	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Community	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Media	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Trade (Retail, Wholesale distribution)	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Telecommunications	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Personal	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Postal Services	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Professional Services	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Service Provider	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Social	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Travel & Transportations	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Life Sciences	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Logistics Service Providers	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Utilities	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Other	……………………………………..

2. For each of the following enterprise sizes, please determine the degree of interest in the adoption of mobile ERP?	
Micro (<10 employees)	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Small (10-49 employees)	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Medium (50-249 employees)	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all

Large (250 or more)	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all

Section III: Motivations Reasons behind Adopting Mobile ERP
3. The following are the reasons that motivate enterprises to start adopting mobile ERP. Can you determine the level of your agreement with each reason?
Better business intelligence
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree
Cost reduction
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree
Deeper business relationships
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree
Expanded real-time visibility into all business activities
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree
Improved competitiveness
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree
Improved quality of service
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree
Increased productivity
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree
More accurate data capture
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree
Supporting decision making
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree
Timely access to management information anywhere
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree
☐ Other. (If other reason is checked, please name it) ……

Section IV: Mobile ERP Modules	
4. For each of the following ERP's modules, please determine the level of concern of enterprises to access it via mobile device?	
Administration	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Banking	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Business Intelligence	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Customer Relationship Management	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Data Warehouse	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
E-Commerce	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Financial and Accounting	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Human Resources Management	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Inventory	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Logistics	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Marketing	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Procurement	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Production & Manufacturing Resource Management	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Project Management	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Purchases	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Reporting	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Sales	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Services	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
Social Media	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all

Supply Chain Management	☐ Extremely ☐ Moderately ☐ Somewhat ☐ Slightly ☐ Not at all
other	……………………………………………………………
5. For each of the following ERP's modules, please determine the level of difficulty of use when it has been accessed via mobile devices based on your customers' feedbacks?	
Administration	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Banking	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Business Intelligence	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Customer Relationship Management	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Data Warehouse	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
E-Commerce	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Financial and Accounting	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Human Resources Management	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Inventory	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Logistics	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Marketing	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Procurement	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Production & Manufacturing Resource Management	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Project Management	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Purchases	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Reporting	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Sales	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Services	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
Social Media	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy

Supply Chain Management	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
other	……………………………………………………………
6. For each of the following ERP's modules, please determine the level of acceptability of your clients when it has been accessed via mobile devices?	
Administration	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Banking	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Business Intelligence	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Customer Relationship Management	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Data Warehouse	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
E-Commerce	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Financial and Accounting	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Human Resources Management	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Inventory	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Logistics	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Marketing	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Procurement	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Production & Manufacturing Resource Management	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Project Management	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Purchases	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable

Reporting	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Sales	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Services	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Social Media	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
Supply Chain Management	☐ Perfectly acceptable ☐ Acceptable ☐ Neutral ☐ Unacceptable ☐ Totally unacceptable
other	…………………………………………………………………
7. For each of the following ERP's modules, please determine the required amount of time to learn how to use it when it has been accessed via mobile devices?	
Administration	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Banking	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Business Intelligence	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Customer Relationship Management	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Data Warehouse	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
E-Commerce	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Financial and Accounting	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Human Resources Management	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Inventory	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Logistics	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Marketing	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Procurement	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Production & Manufacturing Resource Management	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short

Project Management	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Purchases	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Reporting	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Sales	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Services	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Social Media	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
Supply Chain Management	☐ Too long ☐ Long ☐ Neutral ☐ Short ☐ Too short
other	…………………………………………………………………
Section IV: Mobile OSes and Devices	
8- For the following mobile OSes, determine the frequency of use in operating mobile ERP apps?	
Apple iOS	☐ A great deal ☐ A moderate amount ☐ Occasionally ☐ Rarely ☐ Never
Android	☐ A great deal ☐ A moderate amount ☐ Occasionally ☐ Rarely ☐ Never
Windows phone	☐ A great deal ☐ A moderate amount ☐ Occasionally ☐ Rarely ☐ Never
Symbian	☐ A great deal ☐ A moderate amount ☐ Occasionally ☐ Rarely ☐ Never
Blackberry OS	☐ A great deal ☐ A moderate amount ☐ Occasionally ☐ Rarely ☐ Never
Other………………………….	
9- For each of the following types of the mobile devices, determine the frequency of use in installing the mobile ERP apps on it?	
Full screen phones	☐ A great deal ☐ A moderate amount ☐ Occasionally ☐ Rarely ☐ Never
Tablet Computers	☐ A great deal ☐ A moderate amount ☐ Occasionally ☐ Rarely ☐ Never
Wearable devices	☐ A great deal ☐ A moderate amount ☐ Occasionally ☐ Rarely ☐ Never
Other………………………….	
Section V: General	
10- Please, indicate any further comments that could assist in achieving a further understanding in terms of the proliferation, usability challenges, and status of mobile ERP apps in business?	

Appendix D

Statistical analysis of the collected data from the questionnaire of the structured interviews with mobile ERP vendors.

Section I: Demographic Data

Sample distribution of the interviewees by gender, age, country, and job position in the conducted structured interviews with mobile ERP vendors (n=22)

		Frequency	Percent
Gender	Male	17	77.3 %
	female	5	22.7 %
Age	20 or less	0	0%
	21-30	5	22.7 %
	31-40	10	45.5 %
	41-50	5	22.7 %
	51-60	2	9.1 %
	61 or more	0	0%
Country	Belarus	2	9.1 %
	Germany	16	72.7 %
	India	2	9.1 %
	KSA	1	4.5 %
	Serbia	1	4.5 %
Position	Account Manager	1	4.5 %
	Chief Commercial Officer (CCO)	1	4.5 %
	Chief Executive Officer (CEO)	1	4.5 %
	Chief Marketing Officer (CMO)	1	4.5 %
	Director	1	4.5 %
	Division Manager	1	4.5 %
	Marketing Manager	1	4.5 %
	Operation Manager	1	4.5 %
	Project Leader	1	4.5 %
	Sales	10	45.5 %
	Sales Manager	1	4.5 %
	Senior Sales Manager	1	4.5 %
	Technology Consultant	1	4.5 %

Section II: Business Sectors and Sizes

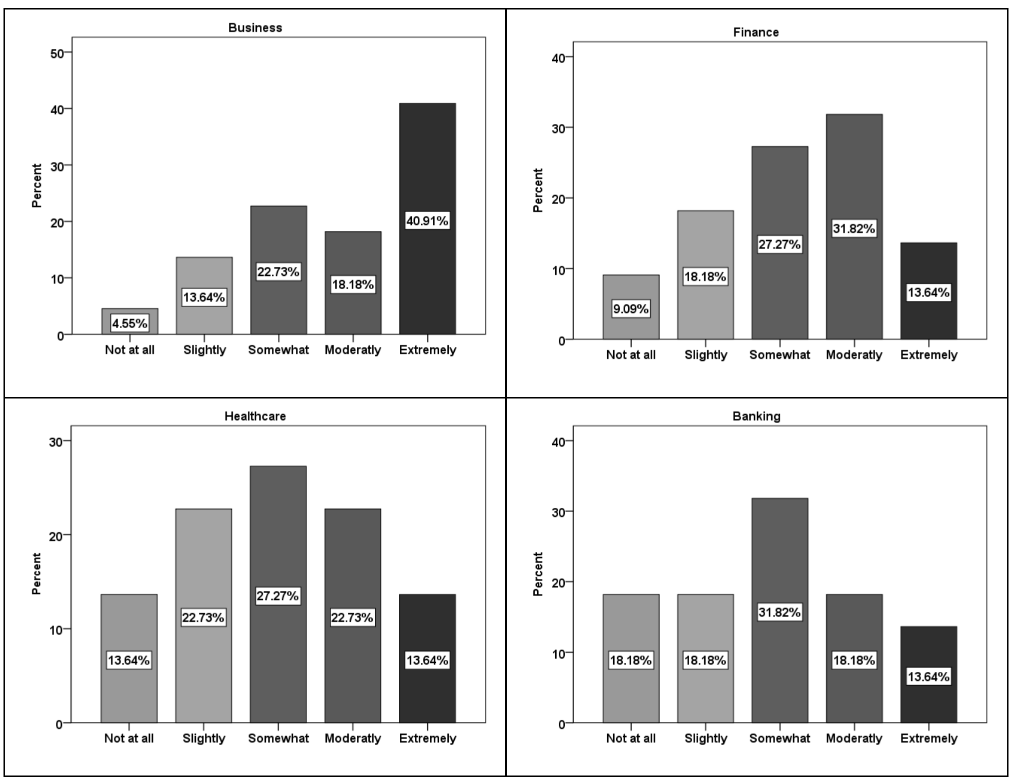
Question 1

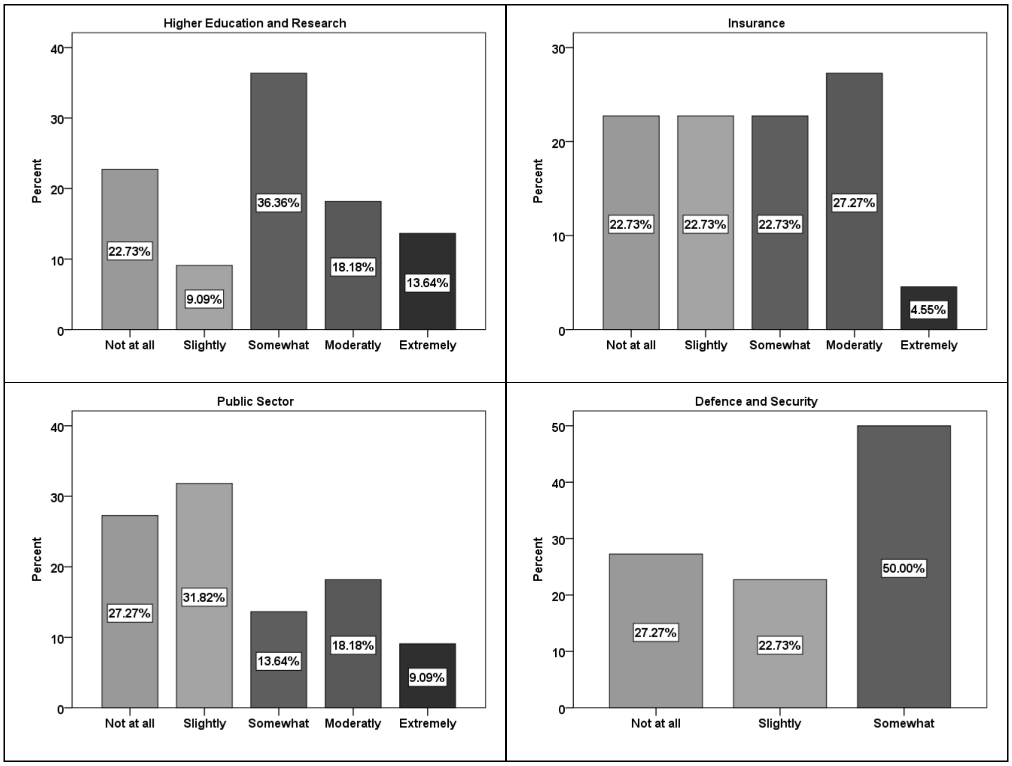
- **Financial and Public Services Category**

The results of the central tendency (mean, median, and mode) and the variability (standard deviation) measures for the responses for each of the given sector that belongs to the financial and public services category (n=22).

Sector	Mean	Median	Mode	Std Deviation
Business	3.7727	4.0	5.0	1.26986
Finance	3.2273	3.0	4.0	1.19251
Healthcare	3.0000	3.0	3.0	1.27242
Banking	2.9091	3.0	3.0	1.30600
Higher Education & Research	2.9091	3.0	3.0	1.34196
Insurance	2.6818	3.0	4.0	1.24924
Public Sector	2.5000	2.0	2.0	1.33631
Defence & Security	2.2273	2.5	3.0	0.86914

The distribution of responses in percentages for each of the given sector that belongs to the financial and public services category (n=22).



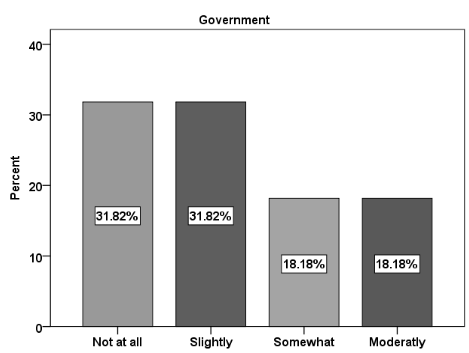


- **Government Category**

The results of the central tendency (mean, median, and mode) and the variability (standard deviation) measures for the responses regarding the government category (n=22).

Sector	Mean	Median	Mode	Std Deviation
Government	2.2273	2.0	1.0	1.10978

The distribution of responses in percentages regarding the government (n=22).



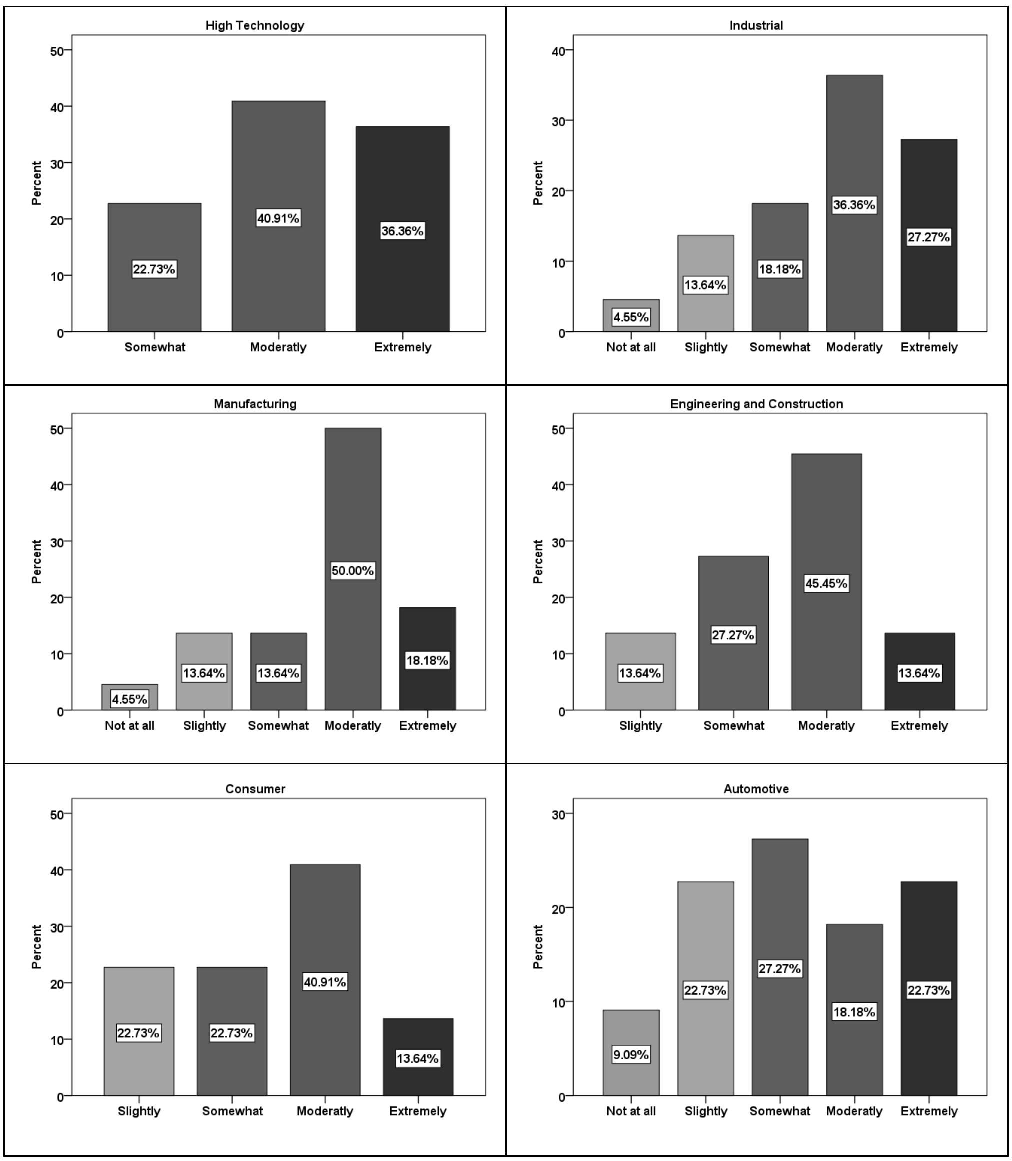
- **Manufacturing Category**

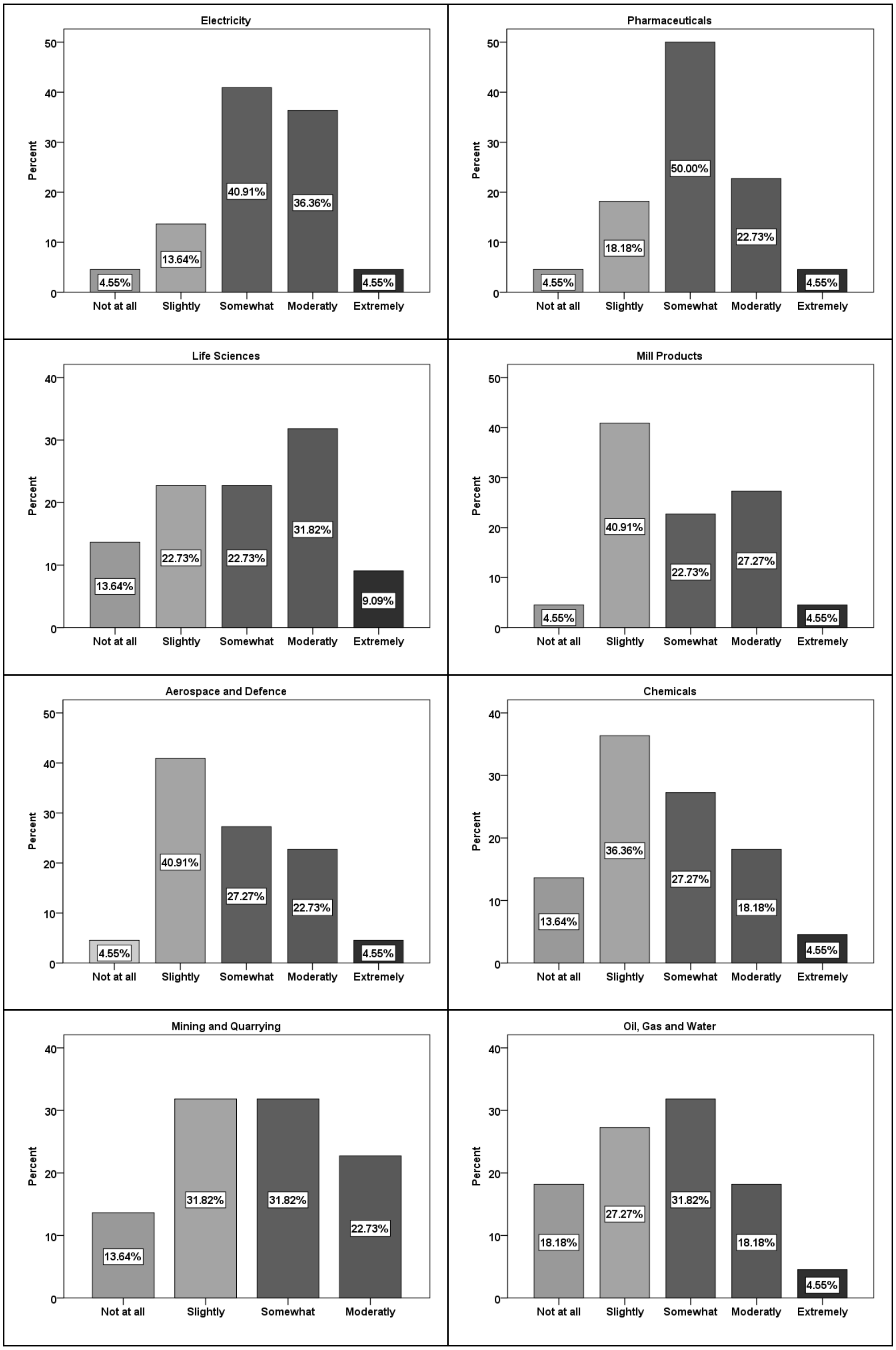
The results of the central tendency (mean, median, and mode) and the variability (standard deviation) measures for the responses for each of the given sector that belongs to the manufacturing category (n=22).

Sector	Mean	Median	Mode	Std Deviation
High Technology	4.136364	4.0	4.0	0.774317
Industrial Machinery & Components	3.681818	4.0	4.0	1.170525

Manufacturing	3.636364	4.0	4.0	1.093071
Engineering & Construction	3.590909	4.0	4.0	0.908116
Consumer Products	3.454545	4.0	4.0	1.010765
Automotive	3.227273	3.0	3.0	1.306825
Electricity	3.227273	3.0	3.0	0.922307
Pharmaceuticals	3.045455	3.0	3.0	0.898532
Life Sciences	3.000000	3.0	4.0	1.234427
Mill Products	2.863636	3.0	2.0	1.037187
Aerospace & Defence	2.818182	3.0	2.0	1.006473
Chemicals	2.636364	2.5	2.0	1.093071
Mining & Quarrying	2.636364	3.0	2.0	1.002162
Oil, Gas and Water	2.636364	3.0	3.0	1.135801

The distribution of responses in percentages for each of the given sector that belongs to the manufacturing category (n=22).



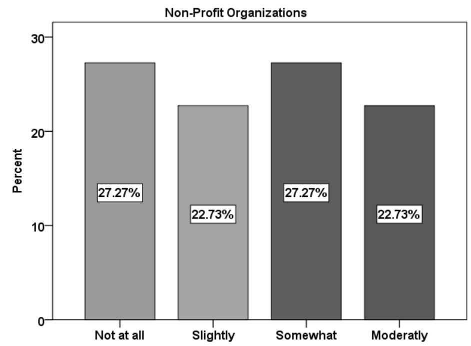


- **Non-Profit Organisations**

The results of the central tendency (mean, median, and mode) and the variability (standard deviation) measures for the responses regarding the non-profit organisations sector (n=22).

Sector	Mean	Median	Mode	Std Deviation
Non-Profit Organisations	2.4545	2.5	1.0	1.14340

The distribution of responses (in percentages) regarding the non-profit organizations sector (n=22).

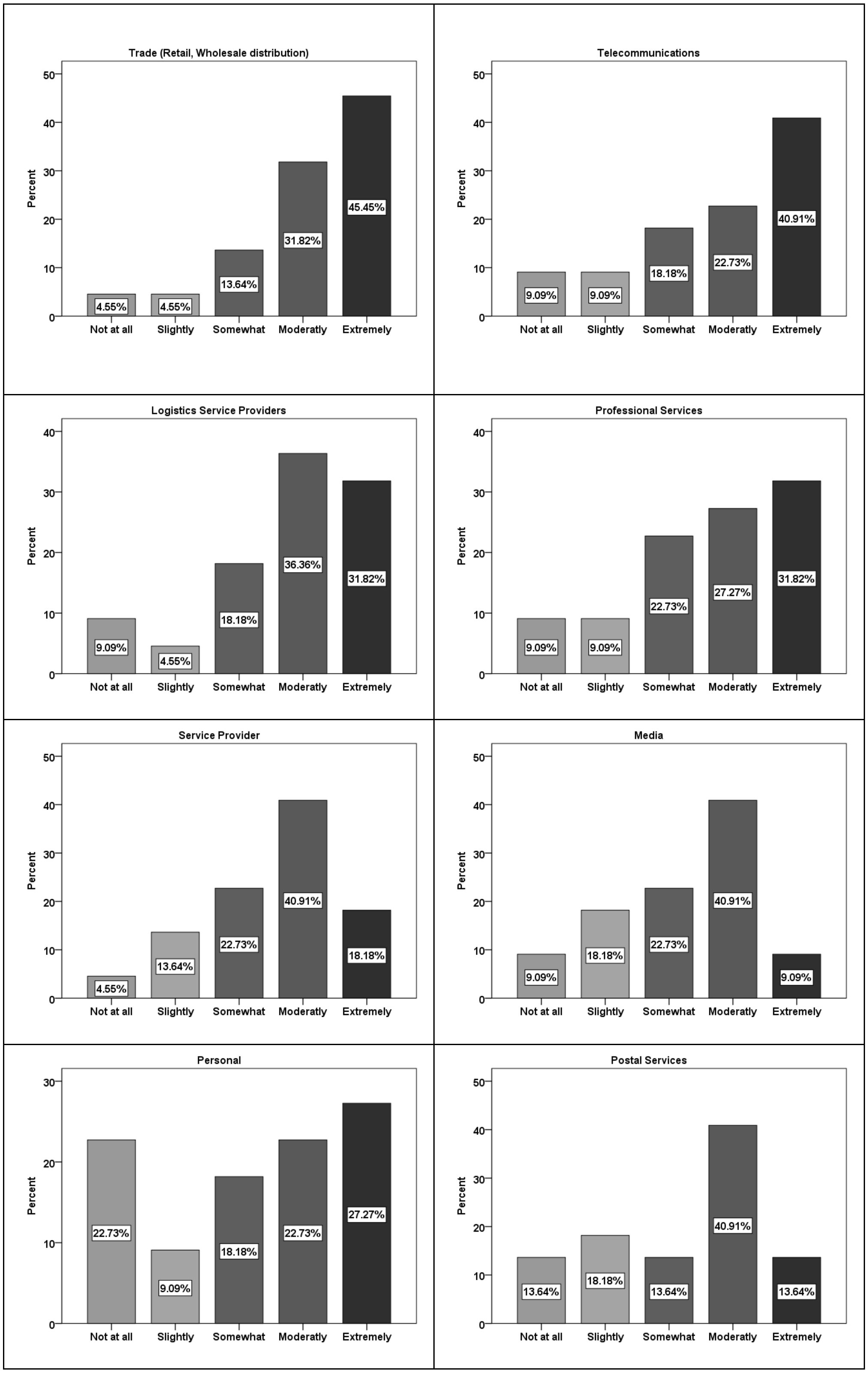


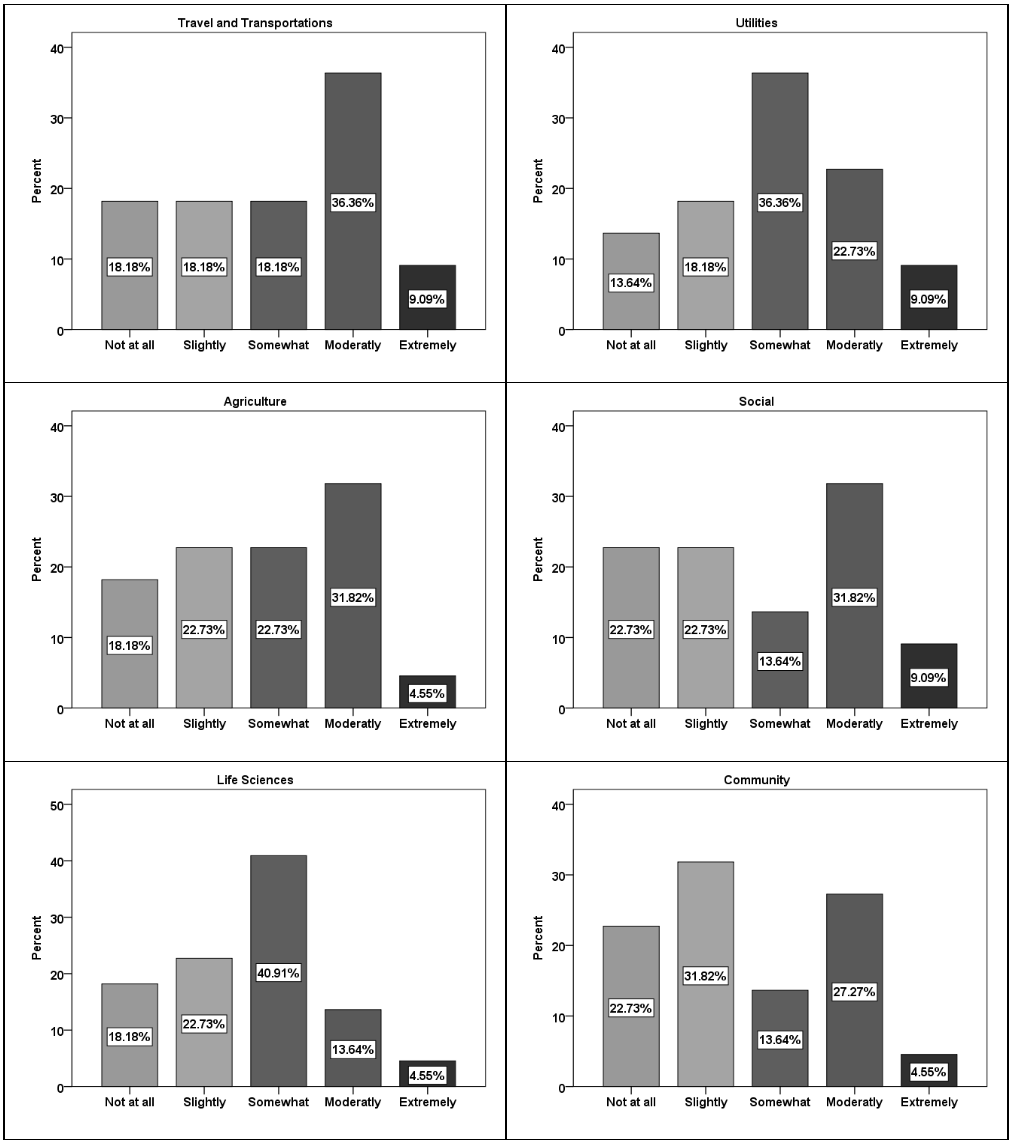
- **Services Category**

The results of the central tendency (mean, median, and mode) and the variability (standard deviation) measures for the responses for each of the given sector that belongs to the services category (n=22).

Sector	Mean	Median	Mode	Std Deviation
Trade (Retail, Wholesale distribution)	4.0909	4.0	5.0	1.10880
Telecommunications	3.7727	4.0	5.0	1.34277
Logistics Service Providers	3.7727	4.0	4.0	1.23179
Professional Services	3.6364	4.0	5.0	1.29267
Service Provider	3.5455	4.0	4.0	1.10096
Media	3.2273	3.5	4.0	1.15189
Personal	3.2273	3.5	5.0	1.54093
Postal Services	3.2273	4.0	4.0	1.30683
Travel & Transportations	3.0000	3.0	4.0	1.30931
Utilities	2.9545	3.0	3.0	1.17422
Agriculture	2.8182	3.0	4.0	1.22032
Social	2.8182	3.0	4.0	1.36753
Life Sciences	2.6364	3.0	3.0	1.09307
Community	2.5909	2.0	2.0	1.25960

The distribution of responses (in percentages) for each of the given sector that belongs to the services category (n=22).


Trade (Retail, Wholesale distribution)
Percent
50
40
30
20
10
0
4.55%
4.55%
13.64%
31.82%
45.45%
Not at all
Slightly
Somewhat
Moderatly
Extremely
Telecommunications
Percent
50
40
30
20
10
0
9.09%
9.09%
18.18%
22.73%
40.91%
Not at all
Slightly
Somewhat
Moderatly
Extremely
Logistics Service Providers
Percent
40
30
20
10
0
9.09%
4.55%
18.18%
36.36%
31.82%
Not at all
Slightly
Somewhat
Moderatly
Extremely
Professional Services
Percent
40
30
20
10
0
9.09%
9.09%
22.73%
27.27%
31.82%
Not at all
Slightly
Somewhat
Moderatly
Extremely
Service Provider
Percent
50
40
30
20
10
0
4.55%
13.64%
22.73%
40.91%
18.18%
Not at all
Slightly
Somewhat
Moderatly
Extremely
Media
Percent
50
40
30
20
10
0
9.09%
18.18%
22.73%
40.91%
9.09%
Not at all
Slightly
Somewhat
Moderatly
Extremely
Personal
Percent
30
20
10
0
22.73%
9.09%
18.18%
22.73%
27.27%
Not at all
Slightly
Somewhat
Moderatly
Extremely
Postal Services
Percent
50
40
30
20
10
0
13.64%
18.18%
13.64%
40.91%
13.64%
Not at all
Slightly
Somewhat
Moderatly
Extremely

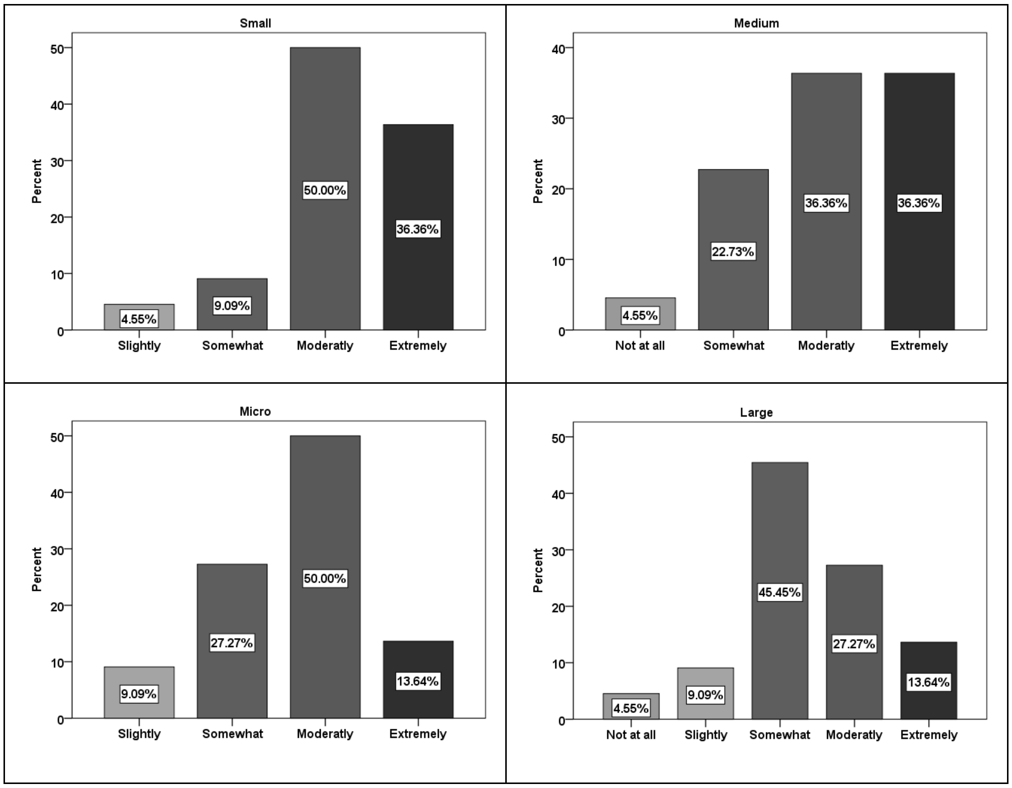


Question 2

The results of the central tendency (mean, median, and mode) and the variability (standard deviation) measures for the responses (n=22).

Enterprise Size	Mean	Median	Mode	Std Deviation
Small (10-49 employees)	4.1818	4.0	4.0	0.79501
Medium (50-249 employees)	4.0000	4.0	4.0	1.02353
Micro (<10 employees)	3.6818	4.0	4.0	0.83873
Large (250 or more)	3.3636	3.0	3.0	1.00216

The distribution of responses (in percentages) for each of the given enterprise size in question number two (n=22).



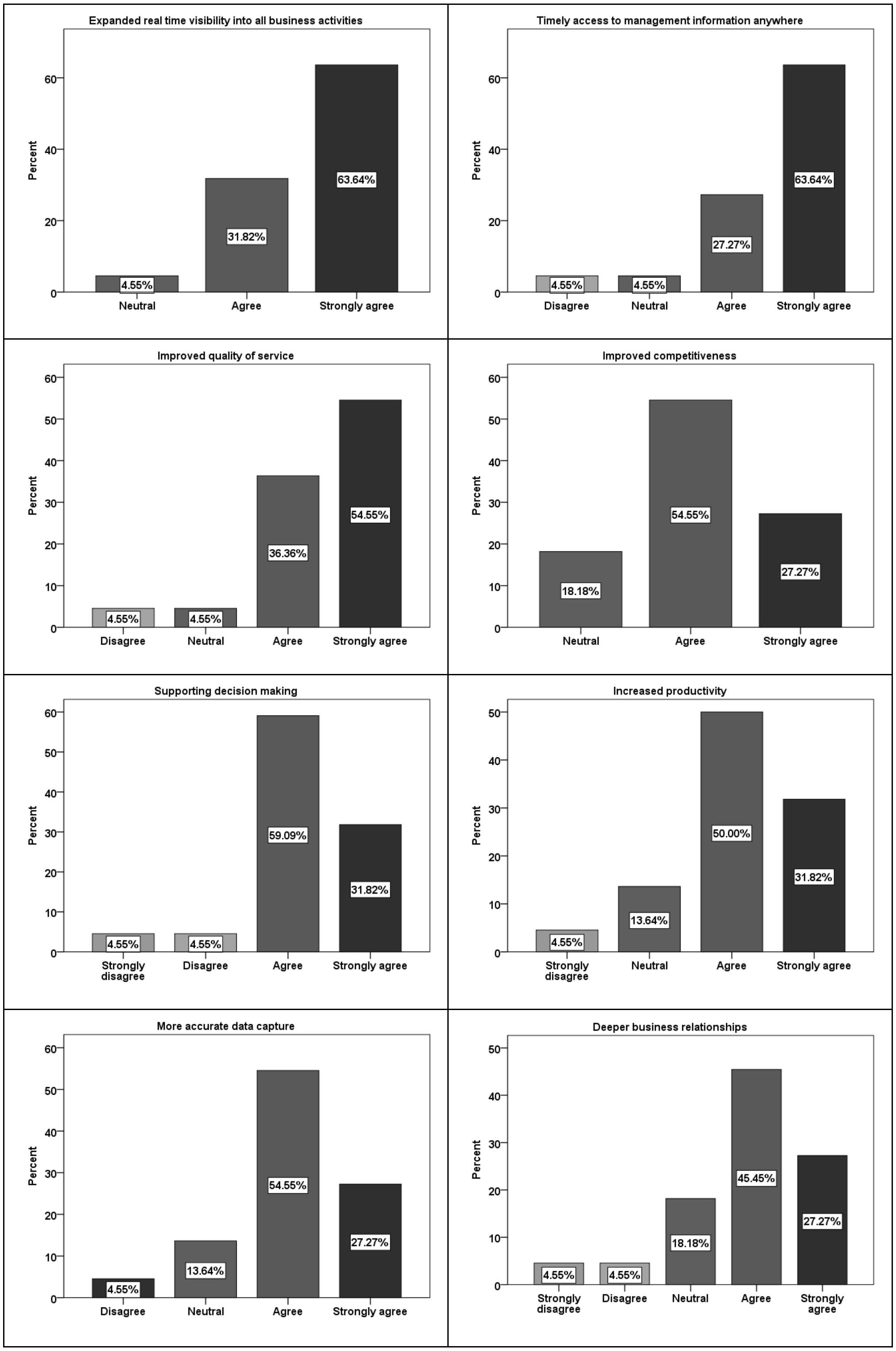
Section III: Motivations and Reasons behind Adopting a Mobile ERP

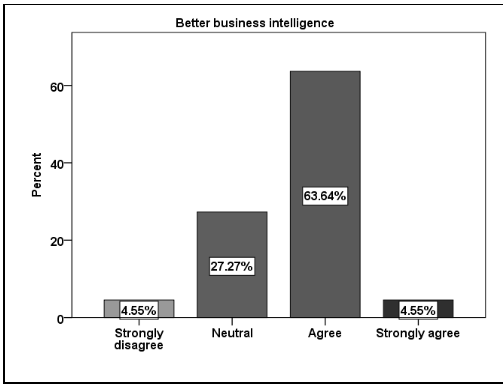
Question 3

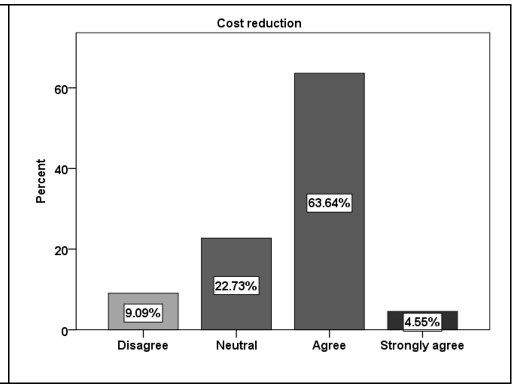
The results of the central (mean, median, and mode) and the variability (standard deviation) measures for the responses of question number three (n=22).

Reason	Mean	Median	Mode	Std Deviation
Expanded real time visibility into all business activities	4.5909	5.0	5.0	0.59033
Timely access to management information anywhere	4.5000	5.0	5.0	0.80178
Improved quality of service	4.4091	5.0	5.0	0.79637
Improved competitiveness	4.0909	4.0	4.0	0.68376
Supporting decision making	4.0909	4.0	4.0	0.97145
Increased productivity	4.0455	4.0	4.0	0.95005
More accurate data capture	4.0455	4.0	4.0	0.78542
Deeper business relationships	3.8636	4.0	4.0	1.03719
Better business intelligence	3.6364	4.0	4.0	0.78954
Cost reduction	3.6364	4.0	4.0	0.72673

The distribution of responses (in percentages) for each of the given reason in question number 3 (n=22).


Expanded real time visibility into all business activities
Percent
0
20
40
60
4.55%
31.82%
63.64%
Neutral
Agree
Strongly agree
Timely access to management information anywhere
Percent
0
20
40
60
4.55%
4.55%
27.27%
63.64%
Disagree
Neutral
Agree
Strongly agree
Improved quality of service
Percent
0
10
20
30
40
50
60
4.55%
4.55%
36.36%
54.55%
Disagree
Neutral
Agree
Strongly agree
Improved competitiveness
Percent
0
10
20
30
40
50
60
18.18%
54.55%
27.27%
Neutral
Agree
Strongly agree
Supporting decision making
Percent
0
10
20
30
40
50
60
4.55%
4.55%
59.09%
31.82%
Strongly disagree
Disagree
Agree
Strongly agree
Increased productivity
Percent
0
10
20
30
40
50
4.55%
13.64%
50.00%
31.82%
Strongly disagree
Neutral
Agree
Strongly agree
More accurate data capture
Percent
0
10
20
30
40
50
60
4.55%
13.64%
54.55%
27.27%
Disagree
Neutral
Agree
Strongly agree
Deeper business relationships
Percent
0
10
20
30
40
50
4.55%
4.55%
18.18%
45.45%
27.27%
Strongly disagree
Disagree
Neutral
Agree
Strongly agree





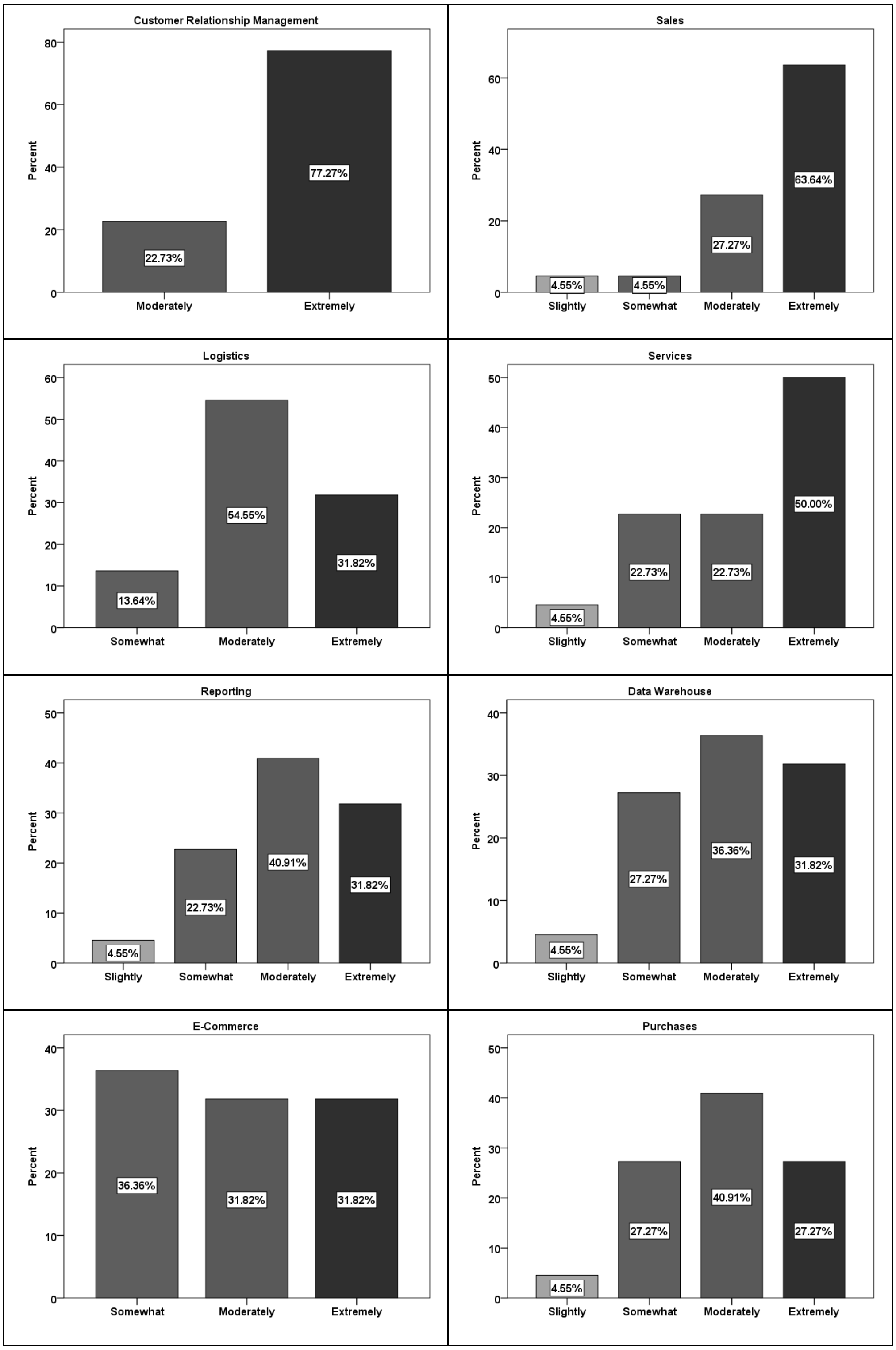
Section IV: Mobile ERP Modules

Question 4

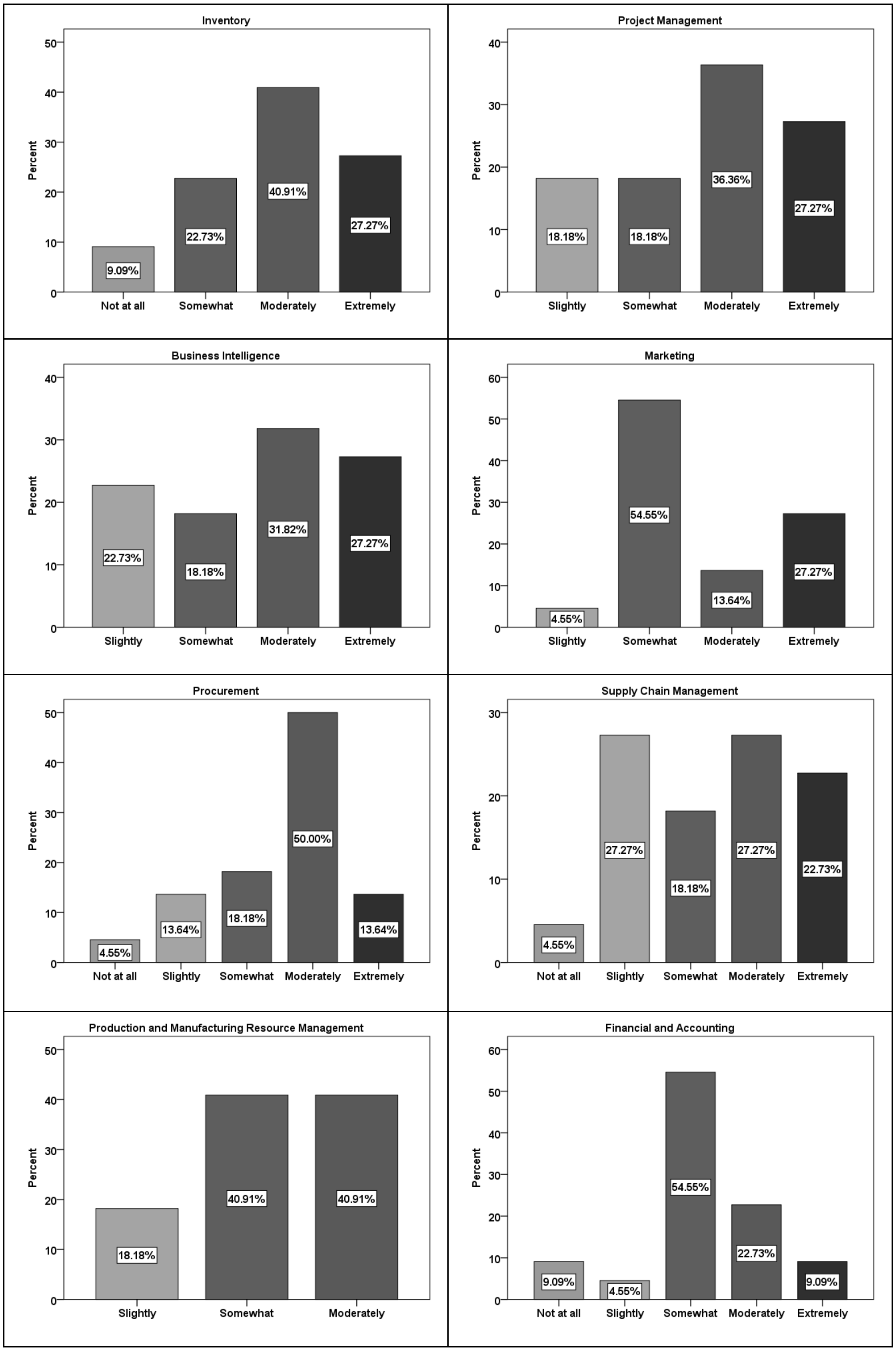
The results of the central tendency (mean, median, and mode) and the variability (standard deviation) measures for the responses of question number four (n=22).

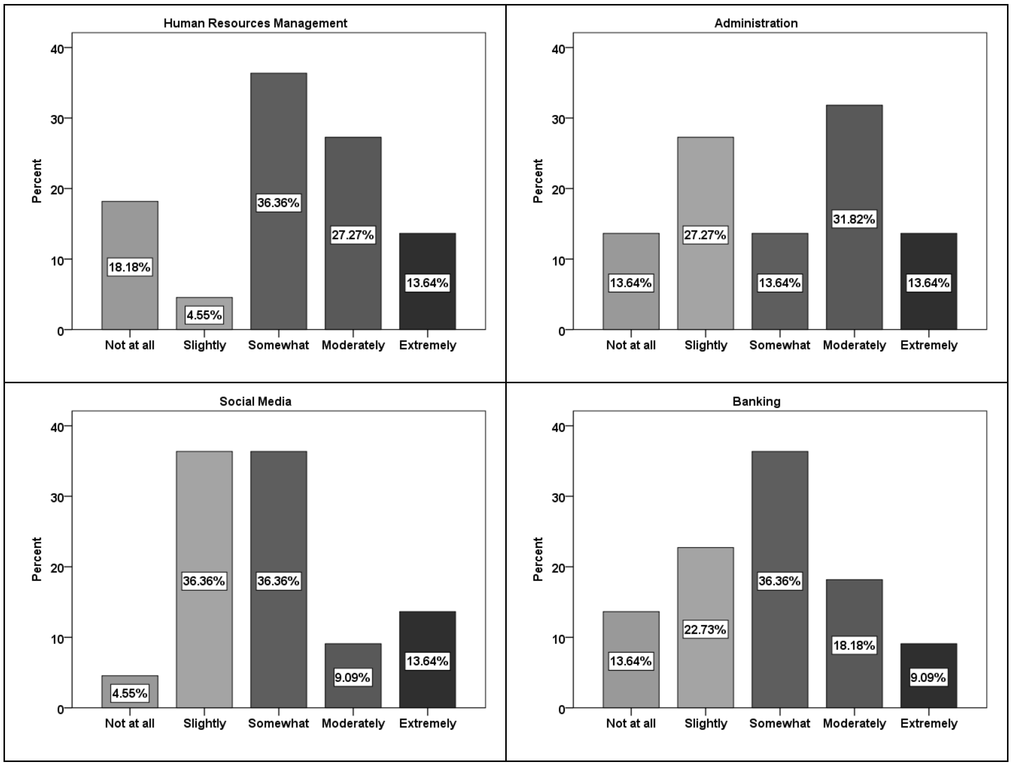
ERP Module	Mean	Median	Mode	Std Deviation
CRM	4.7727	5.0	5.0	0.42893
Sales	4.5000	5.0	5.0	0.80178
Logistics	4.1818	4.0	4.0	0.66450
Services	4.1818	4.5	5.0	0.95799
Reporting	4.0000	4.0	4.0	0.87287
Data Warehouse	3.9545	4.0	4.0	0.89853
E-Commerce	3.9545	4.0	3.0	0.84387
Purchases	3.9091	4.0	4.0	0.86790
Inventory	3.7727	4.0	4.0	1.15189
Project Management	3.7273	4.0	4.0	1.07711
Business Intelligence	3.6364	4.0	4.0	1.13580
Marketing	3.6364	3.0	3.0	0.95346
Procurement	3.5455	4.0	4.0	1.05683
Supply Chain Management	3.3636	3.5	2.0	1.25529
Production & Manufacturing Resource Management	3.2273	3.0	3.0	0.75162
Financial and Accounting	3.1818	3.0	3.0	1.00647
Human Resources Management	3.1364	3.0	3.0	1.28343
Administration	3.0455	3.0	4.0	1.32655
Social Media	2.9091	3.0	2.0	1.10880
Banking	2.8636	3.0	3.0	1.16682

The distribution of responses (percentage) regarding the level of concern (interest) of enterprises to access each of the given ERP module via mobile devices (n=22).



Customer Relationship Management
Percent
0
20
40
60
80
22.73%
77.27%
Moderately
Extremely
Sales
Percent
0
20
40
60
4.55%
4.55%
27.27%
63.64%
Slightly
Somewhat
Moderately
Extremely
Logistics
Percent
0
10
20
30
40
50
60
13.64%
54.55%
31.82%
Somewhat
Moderately
Extremely
Services
Percent
0
10
20
30
40
50
4.55%
22.73%
22.73%
50.00%
Slightly
Somewhat
Moderately
Extremely
Reporting
Percent
0
10
20
30
40
50
4.55%
22.73%
40.91%
31.82%
Slightly
Somewhat
Moderately
Extremely
Data Warehouse
Percent
0
10
20
30
40
4.55%
27.27%
36.36%
31.82%
Slightly
Somewhat
Moderately
Extremely
E-Commerce
Percent
0
10
20
30
40
36.36%
31.82%
31.82%
Somewhat
Moderately
Extremely
Purchases
Percent
0
10
20
30
40
50
4.55%
27.27%
40.91%
27.27%
Slightly
Somewhat
Moderately
Extremely


Inventory
Percent
0
10
20
30
40
50
9.09%
22.73%
40.91%
27.27%
Not at all
Somewhat
Moderately
Extremely
Project Management
Percent
0
10
20
30
40
18.18%
18.18%
36.36%
27.27%
Slightly
Somewhat
Moderately
Extremely
Business Intelligence
Percent
0
10
20
30
40
22.73%
18.18%
31.82%
27.27%
Slightly
Somewhat
Moderately
Extremely
Marketing
Percent
0
10
20
30
40
50
60
4.55%
54.55%
13.64%
27.27%
Slightly
Somewhat
Moderately
Extremely
Procurement
Percent
0
10
20
30
40
50
4.55%
13.64%
18.18%
50.00%
13.64%
Not at all
Slightly
Somewhat
Moderately
Extremely
Supply Chain Management
Percent
0
10
20
30
4.55%
27.27%
18.18%
27.27%
22.73%
Not at all
Slightly
Somewhat
Moderately
Extremely
Production and Manufacturing Resource Management
Percent
0
10
20
30
40
50
18.18%
40.91%
40.91%
Slightly
Somewhat
Moderately
Financial and Accounting
Percent
0
10
20
30
40
50
60
9.09%
4.55%
54.55%
22.73%
9.09%
Not at all
Slightly
Somewhat
Moderately
Extremely

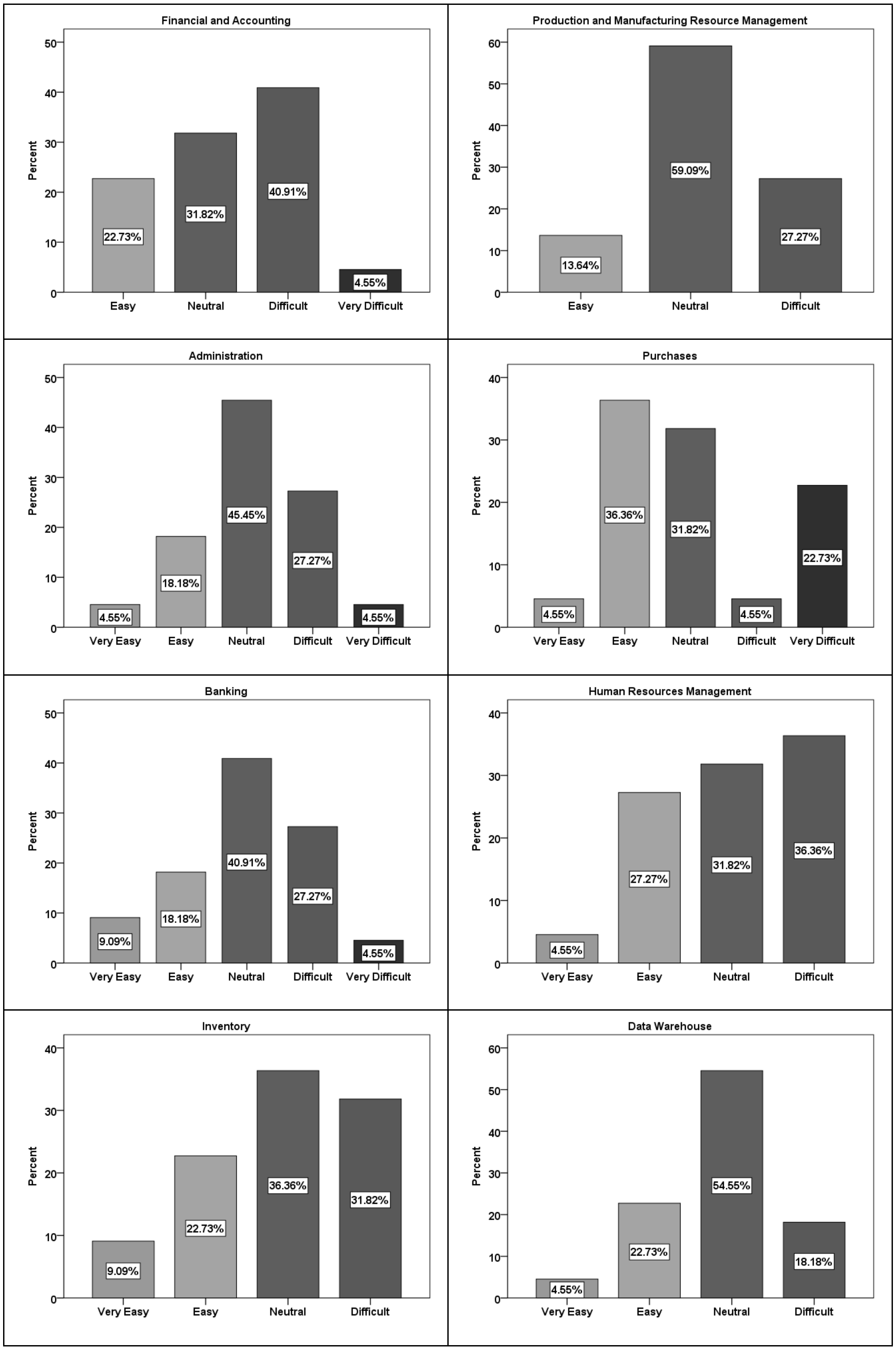


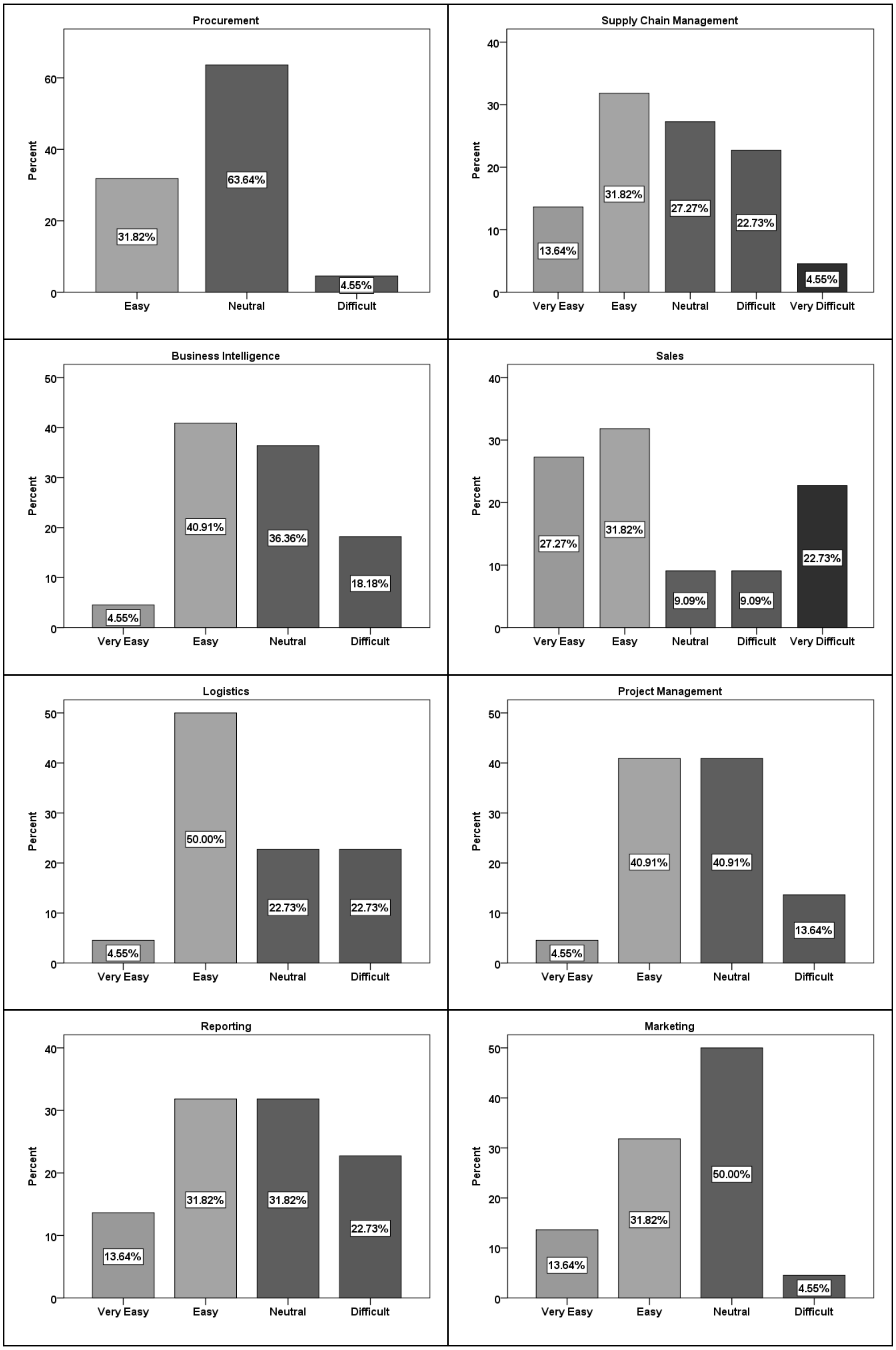
Question 5

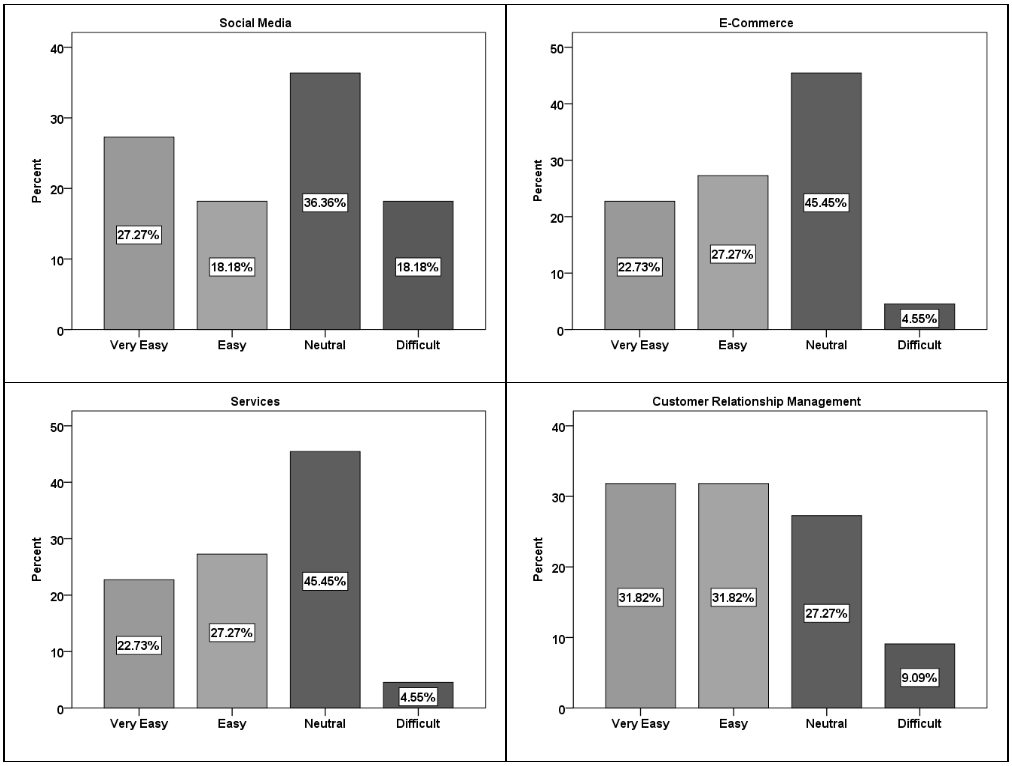
The results of the central tendency (mean, median, and mode) and the variability (standard deviation) measures for the responses of question number five (n=22).

ERP Module	Mean	Median	Mode	Std Deviation
Financial and Accounting	3.2727	3.0	4.0	0.88273
Production & Manufacturing Resource Management	3.1364	3.0	3.0	0.63960
Administration	3.0909	3.0	3.0	0.92113
Purchases	3.0455	3.0	2.0	1.25270
Banking	3.0000	3.0	3.0	1.02353
Human Resources Management	3.0000	3.0	4.0	0.92582
Inventory	2.9091	3.0	3.0	0.97145
Data Warehouse	2.8636	3.0	3.0	0.77432
Procurement	2.7273	3.0	3.0	0.55048
Supply Chain Management	2.7273	3.0	2.0	1.12045
Business Intelligence	2.6818	3.0	2.0	0.83873
Sales	2.6818	2.0	2.0	1.55491
Logistics	2.6364	2.0	2.0	0.90214
Project Management	2.6364	3.0	2.0	0.78954
Reporting	2.6364	3.0	2.0	1.00216
Marketing	2.4545	3.0	3.0	0.80043
Social Media	2.4545	3.0	3.0	1.10096
E-Commerce	2.3182	2.5	3.0	0.89370
Services	2.3182	2.5	3.0	0.89370
CRM	2.1364	2.0	1.0	0.99021

The distribution of responses (in percentages) regarding the level of difficulty of use for each of the given ERP module when it is being accessed via mobile device (n=22).




Procurement
Percent
Easy
Neutral
Difficult
31.82%
63.64%
4.55%
Supply Chain Management
Percent
Very Easy
Easy
Neutral
Difficult
Very Difficult
13.64%
31.82%
27.27%
22.73%
4.55%
Business Intelligence
Percent
Very Easy
Easy
Neutral
Difficult
4.55%
40.91%
36.36%
18.18%
Sales
Percent
Very Easy
Easy
Neutral
Difficult
Very Difficult
27.27%
31.82%
9.09%
9.09%
22.73%
Logistics
Percent
Very Easy
Easy
Neutral
Difficult
4.55%
50.00%
22.73%
22.73%
Project Management
Percent
Very Easy
Easy
Neutral
Difficult
4.55%
40.91%
40.91%
13.64%
Reporting
Percent
Very Easy
Easy
Neutral
Difficult
13.64%
31.82%
31.82%
22.73%
Marketing
Percent
Very Easy
Easy
Neutral
Difficult
13.64%
31.82%
50.00%
4.55%



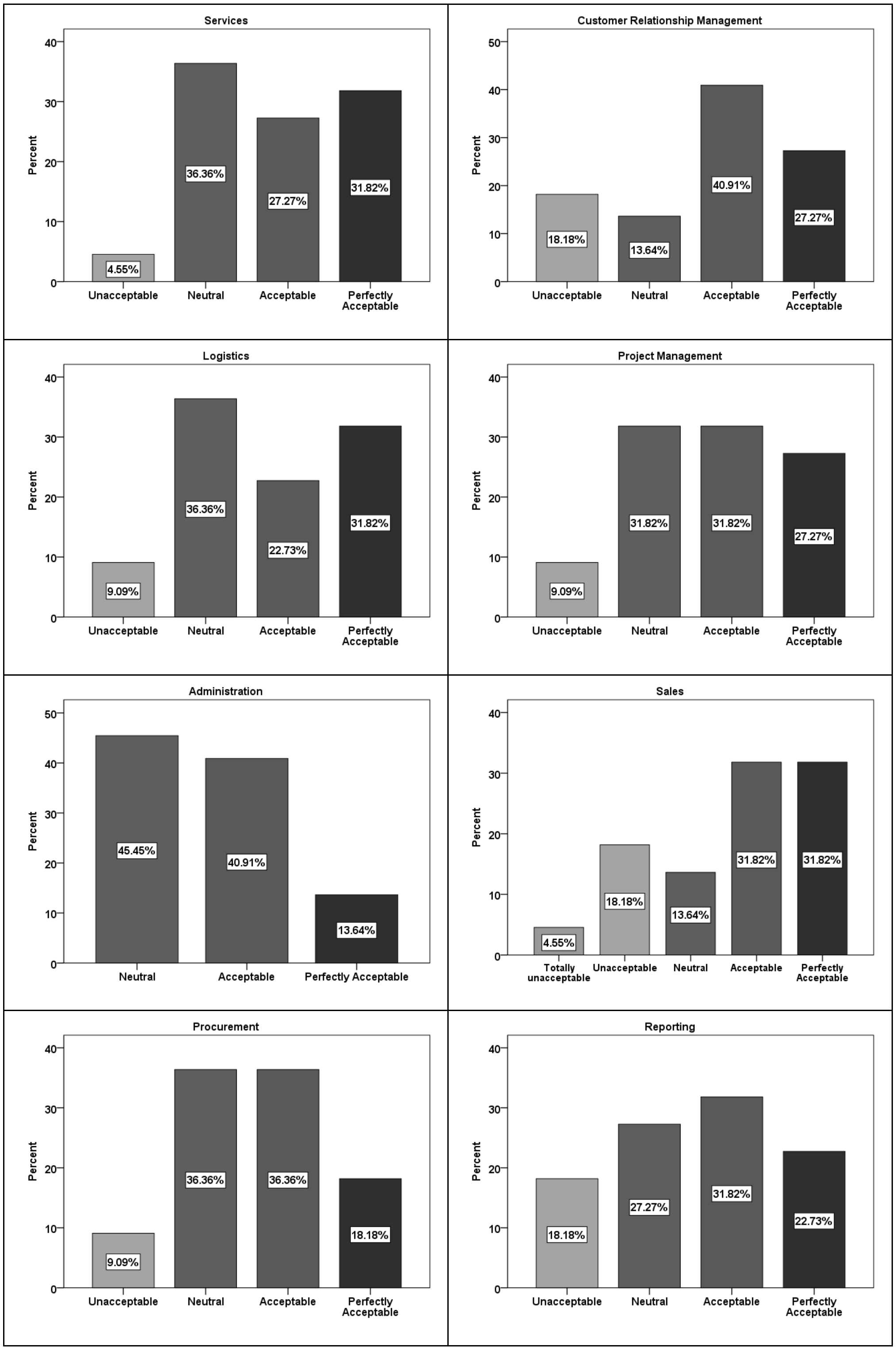
Question 6

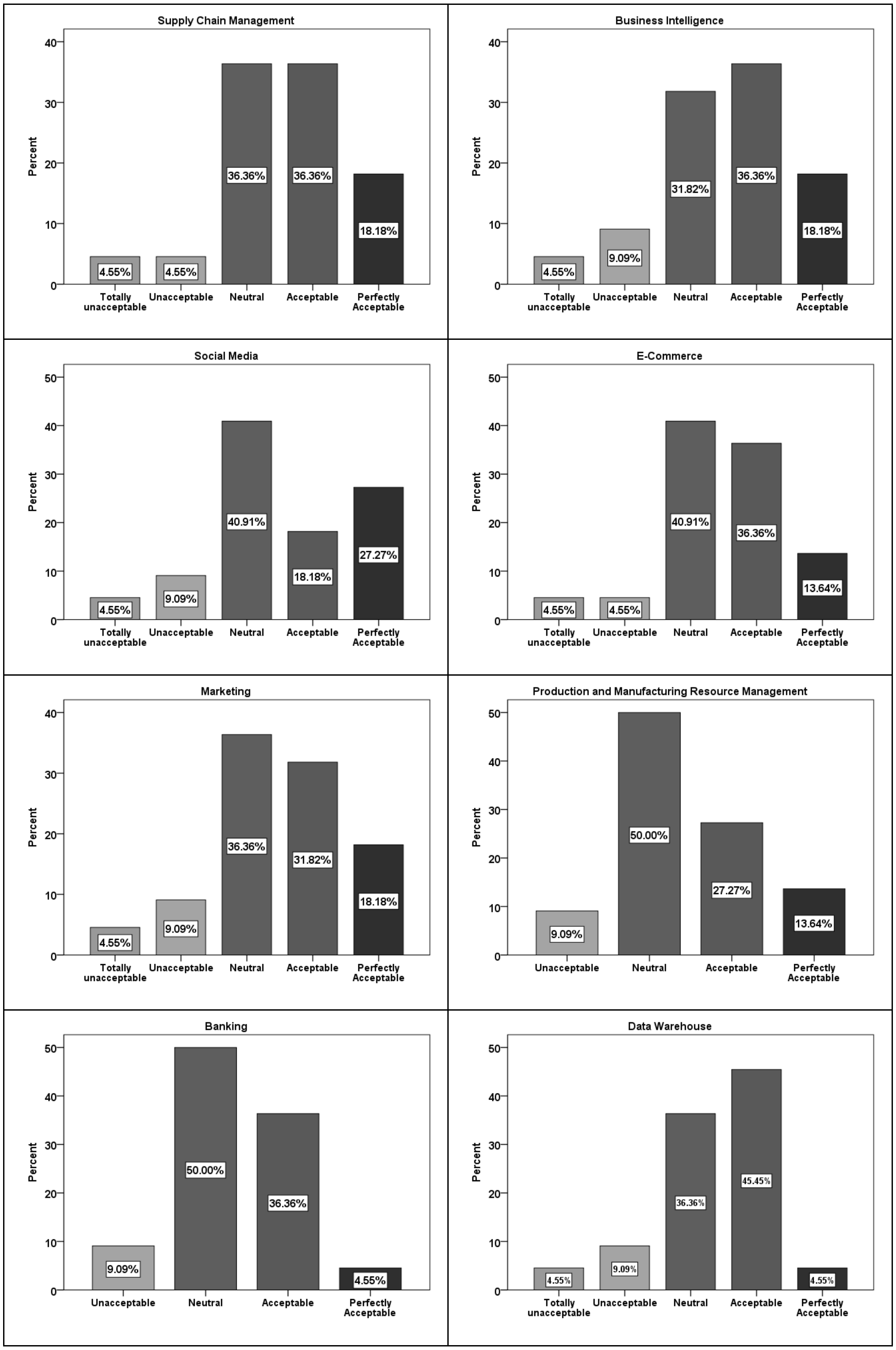
The results of the central tendency (mean, median, and mode) and the variability (standard deviation) measures for the responses of question number six (n=22).

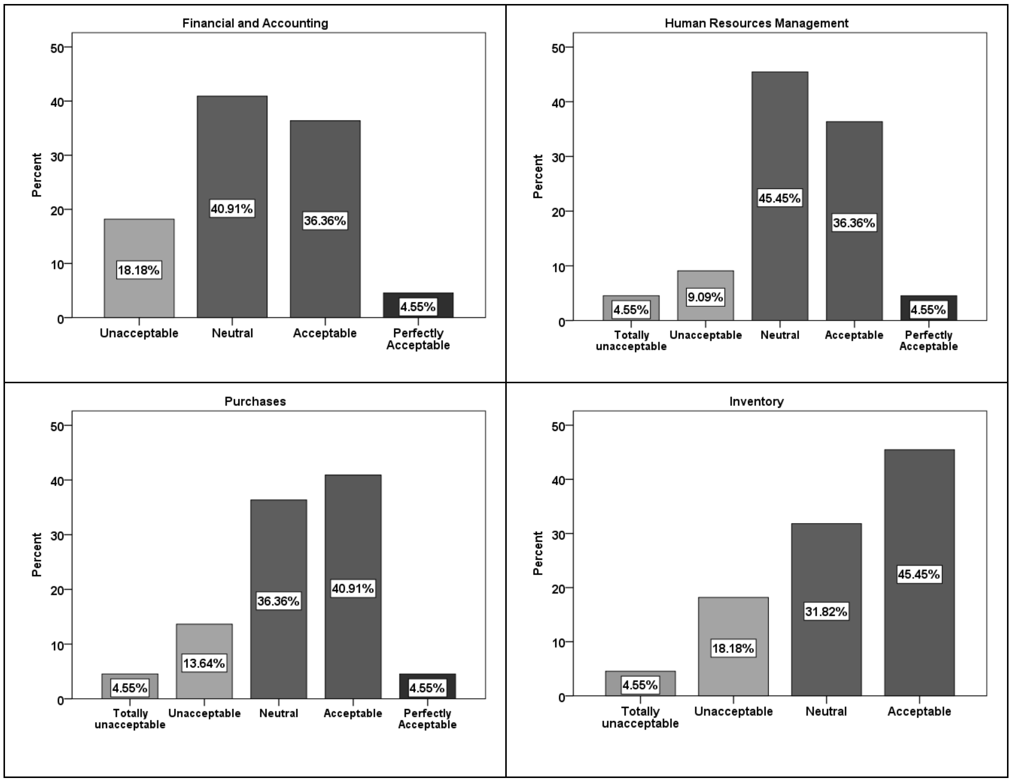
ERP Module	Mean	Median	Mode	Std Deviation
Services	3.8636	4.0	3.0	0.94089
CRM	3.7727	4.0	4.0	1.06600
Logistics	3.7727	4.0	3.0	1.02036
Project Management	3.7727	4.0	3.0	0.97257
Administration	3.6818	4.0	3.0	0.71623
Sales	3.6818	4.0	4.0	1.24924
Procurement	3.6364	4.0	3.0	0.90214
Reporting	3.5909	4.0	4.0	1.05375
Supply Chain Management	3.5909	4.0	3.0	1.00755
Business Intelligence	3.5455	4.0	4.0	1.05683
Social Media	3.5455	3.0	3.0	1.14340
E-Commerce	3.5000	3.5	3.0	0.96362
Marketing	3.5000	3.5	3.0	1.05785
Production & Manufacturing Resource Management	3.4545	3.0	3.0	0.85786
Banking	3.3636	3.0	3.0	0.72673
Data Warehouse	3.3636	3.5	4.0	0.90214
Financial and Accounting	3.2727	3.0	3.0	0.82703
Human Resources Management	3.2727	3.0	3.0	0.88273
Purchases	3.2727	3.0	4.0	0.93513

Inventory	3.1818	3.0	4.0	0.90692

The distribution of responses (in percentages) regarding the level of end-user acceptability of use for each of the given ERP module when it is being accessed via mobile devices (n=22).




Supply Chain Management
Percent
0
10
20
30
40
4.55%
4.55%
36.36%
36.36%
18.18%
Totally unacceptable
Unacceptable
Neutral
Acceptable
Perfectly Acceptable
Business Intelligence
Percent
4.55%
9.09%
31.82%
36.36%
18.18%
Totally unacceptable
Unacceptable
Neutral
Acceptable
Perfectly Acceptable
Social Media
Percent
50
4.55%
9.09%
40.91%
18.18%
27.27%
Totally unacceptable
Unacceptable
Neutral
Acceptable
Perfectly Acceptable
E-Commerce
Percent
4.55%
4.55%
40.91%
36.36%
13.64%
Totally unacceptable
Unacceptable
Neutral
Acceptable
Perfectly Acceptable
Marketing
Percent
4.55%
9.09%
36.36%
31.82%
18.18%
Totally unacceptable
Unacceptable
Neutral
Acceptable
Perfectly Acceptable
Production and Manufacturing Resource Management
Percent
9.09%
50.00%
27.27%
13.64%
Unacceptable
Neutral
Acceptable
Perfectly Acceptable
Banking
Percent
9.09%
50.00%
36.36%
4.55%
Unacceptable
Neutral
Acceptable
Perfectly Acceptable
Data Warehouse
Percent
4.55%
9.09%
36.36%
45.45%
4.55%
Totally unacceptable
Unacceptable
Neutral
Acceptable
Perfectly Acceptable



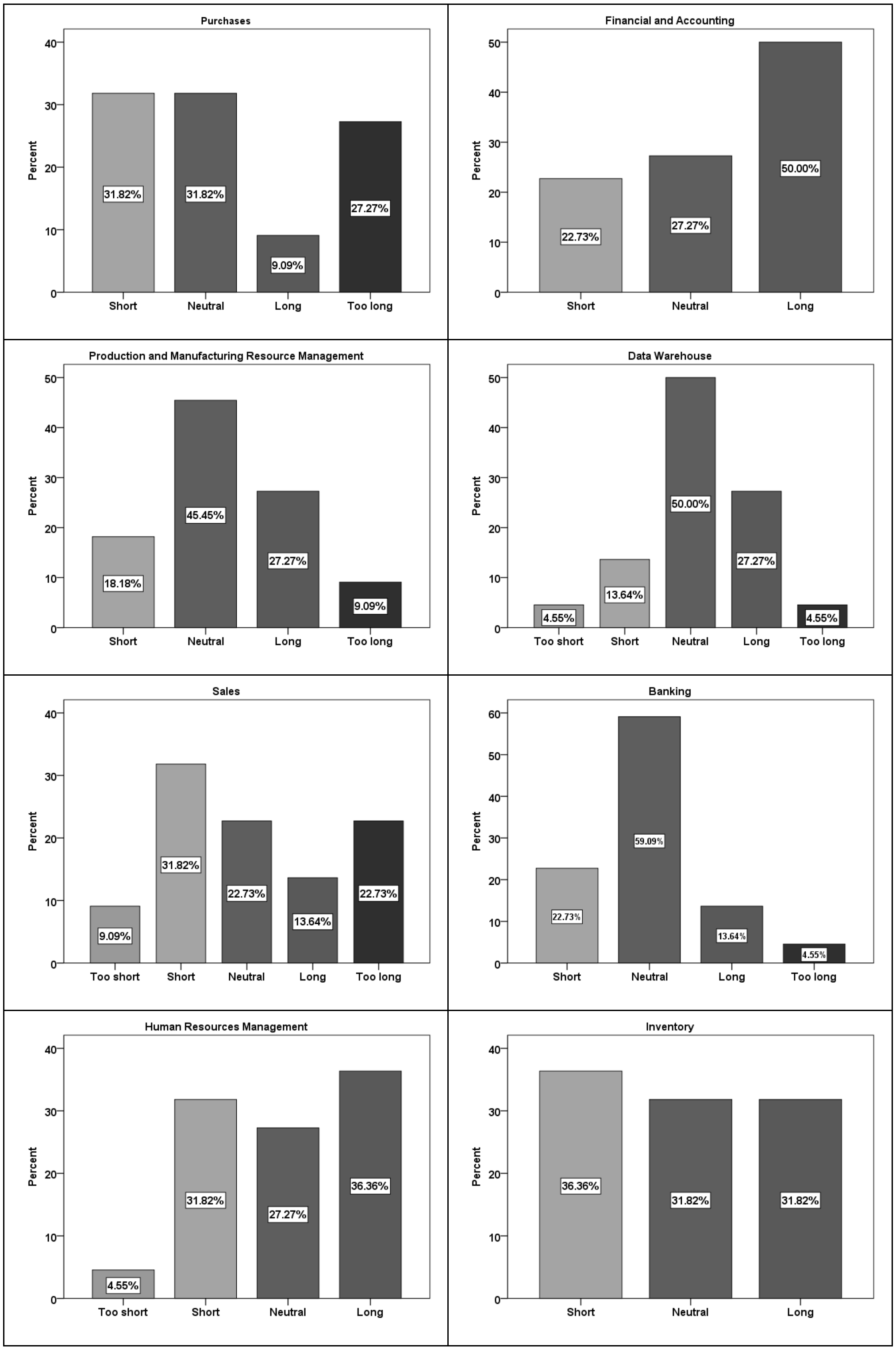
Question 7

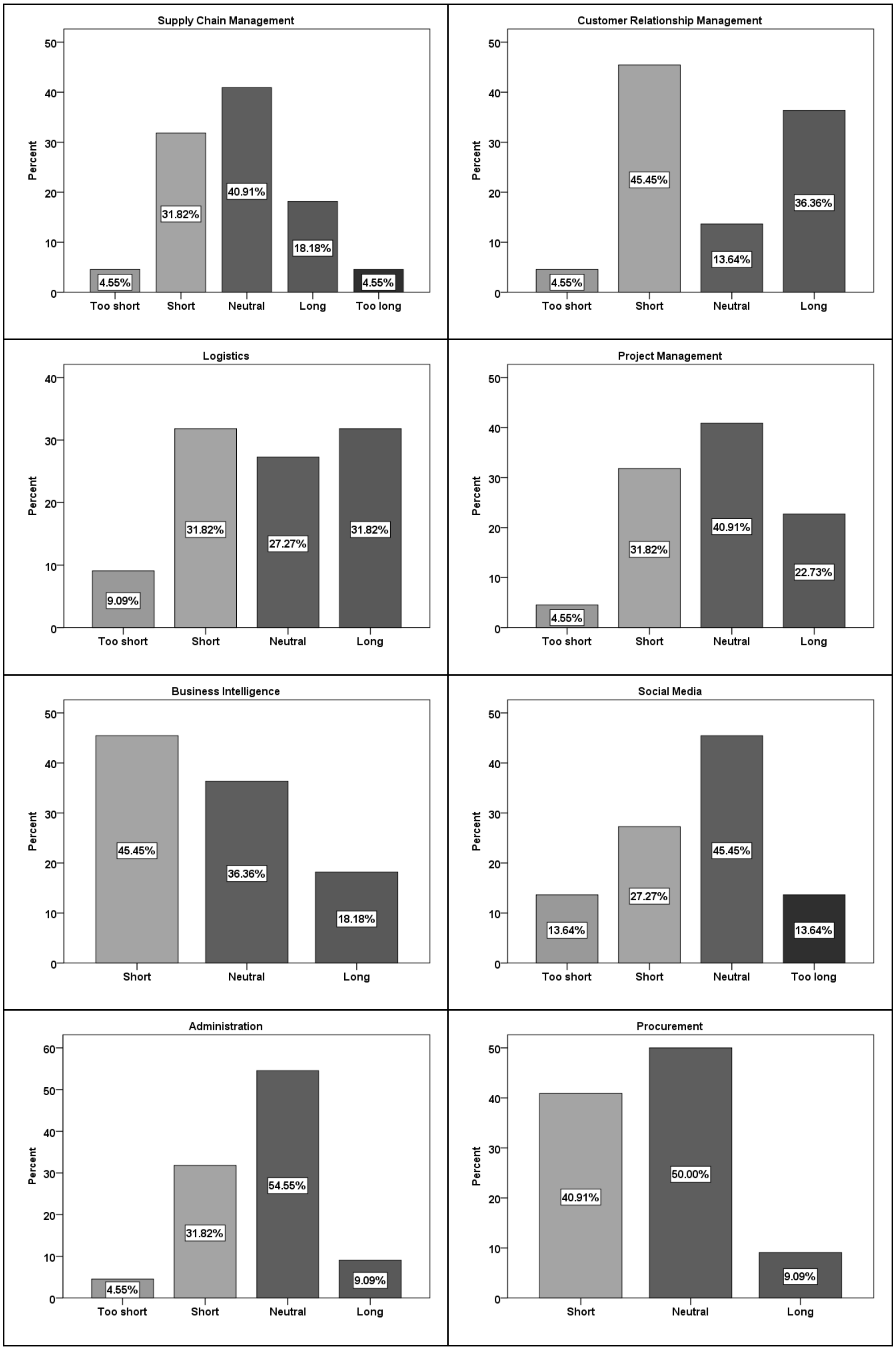
The results of the central tendency (mean, median, mode) and the variability (standard deviation) measures for the responses of question number seven (n=22).

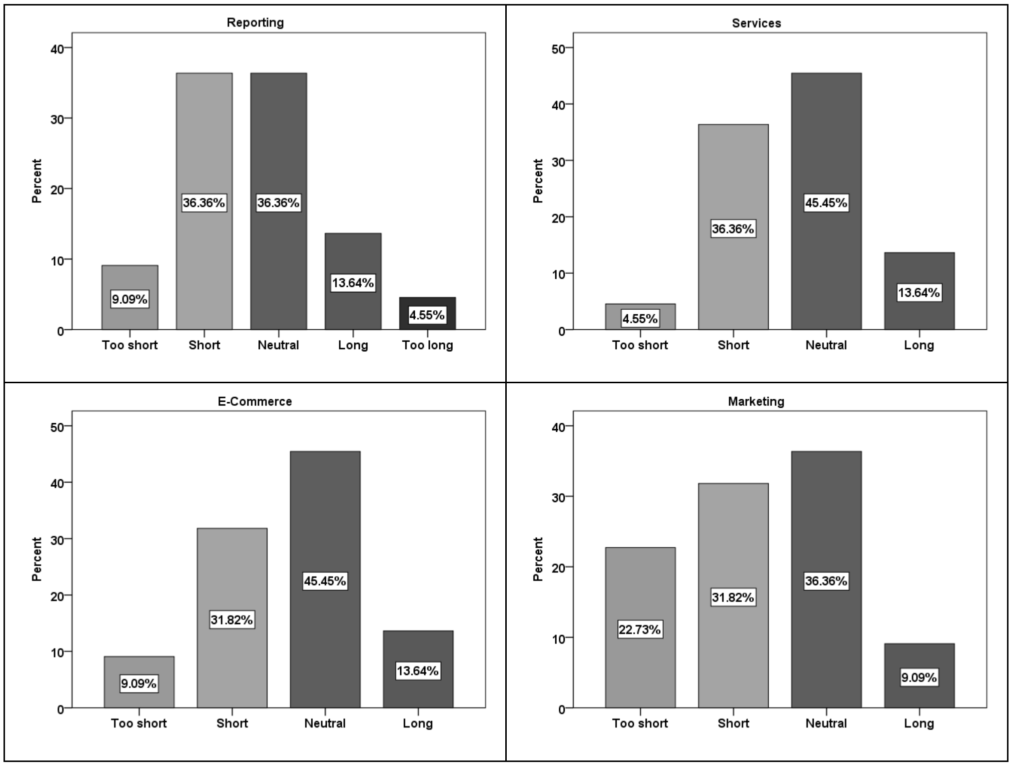
ERP Module	Mean	Median	Mode	Std Deviation
Purchases	3.3182	3.0	2.0	1.21052
Financial and Accounting	3.2727	3.5	4.0	0.82703
Production & Manufacturing Resource Management	3.2727	3.0	3.0	0.88273
Data Warehouse	3.1364	3.0	3.0	0.88884
Sales	3.0909	3.0	2.0	1.34196
Banking	3.0000	3.0	3.0	0.75593
Human Resources Management	2.9545	3.0	4.0	0.95005
Inventory	2.9545	3.0	2.0	0.84387
Supply Chain Management	2.8636	3.0	3.0	0.94089
CRM	2.8182	2.5	2.0	1.00647
Logistics	2.8182	3.0	2.0	1.00647
Project Management	2.8182	3.0	3.0	0.85280
Business Intelligence	2.7273	3.0	2.0	0.76730
Social Media	2.7273	3.0	3.0	1.16217
Administration	2.6818	3.0	3.0	0.71623
Procurement	2.6818	3.0	3.0	0.64633
Reporting	2.6818	3.0	2.0	0.99457
Services	2.6818	3.0	3.0	0.77989
E-Commerce	2.6364	3.0	3.0	0.84771

Marketing	2.3182	2.0	3.0	0.94548

The distribution of responses (in percentages) regarding the amount of time that is required to learn how to use each of the given ERP module when it is being accessed via mobile device (n=22).




Supply Chain Management
Percent
0
10
20
30
40
50
4.55%
31.82%
40.91%
18.18%
4.55%
Too short
Short
Neutral
Long
Too long
Customer Relationship Management
Percent
4.55%
45.45%
13.64%
36.36%
Too short
Short
Neutral
Long
Logistics
Percent
9.09%
31.82%
27.27%
31.82%
Too short
Short
Neutral
Long
Project Management
Percent
4.55%
31.82%
40.91%
22.73%
Too short
Short
Neutral
Long
Business Intelligence
Percent
45.45%
36.36%
18.18%
Short
Neutral
Long
Social Media
Percent
13.64%
27.27%
45.45%
13.64%
Too short
Short
Neutral
Too long
Administration
Percent
60
4.55%
31.82%
54.55%
9.09%
Too short
Short
Neutral
Long
Procurement
Percent
40.91%
50.00%
9.09%
Short
Neutral
Long



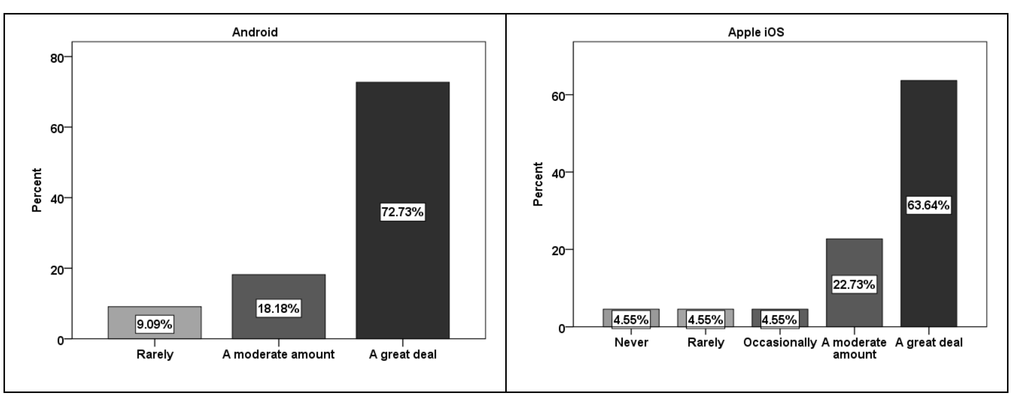
Section V: Mobile OSes and Devices

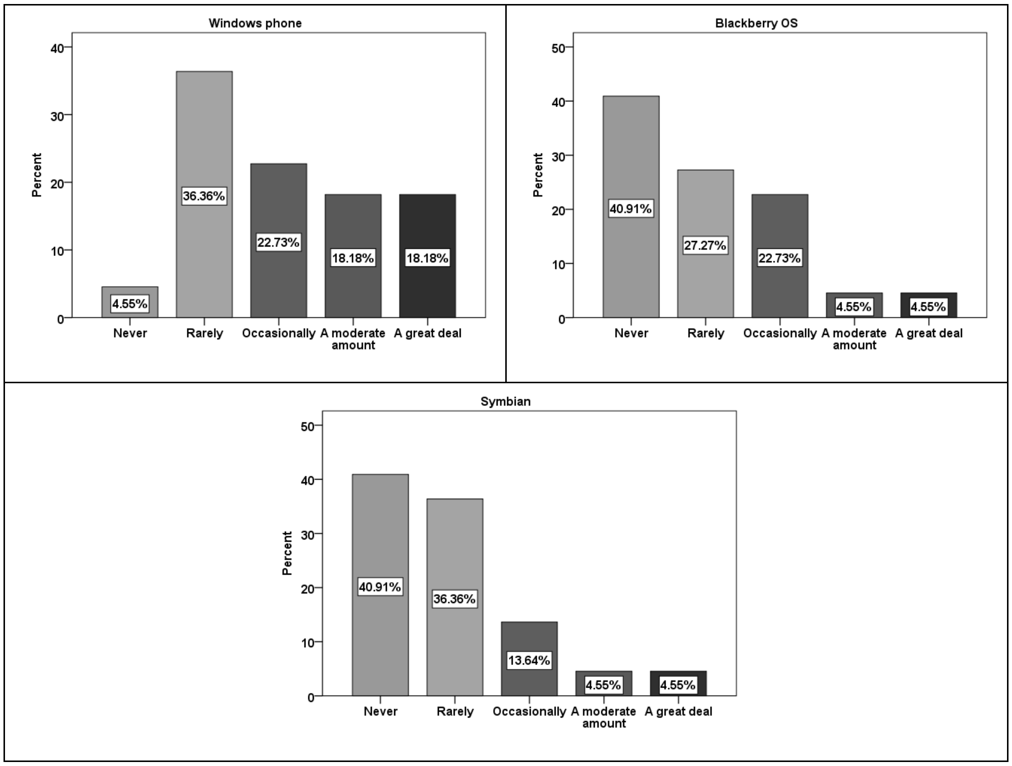
Question 8

The results of the central tendency (mean, median, and mode) and the variability (standard deviation) measures for the responses of question number eight (n=22).

Mobile OS	Mean	Median	Mode	Std Deviation
Android	4.5455	5.0	5.0	0.91168
Apple iOS	4.3636	5.0	5.0	1.09307
Windows phone	3.0909	3.0	2.0	1.23091
Blackberry OS	2.0455	2.0	1.0	1.13294
Symbian	1.9545	2.0	1.0	1.09010

The distribution of responses (in percentages) regarding the frequency of use for a given mobile OSes that are used in operating mobile ERP apps in question number eight (n=22).



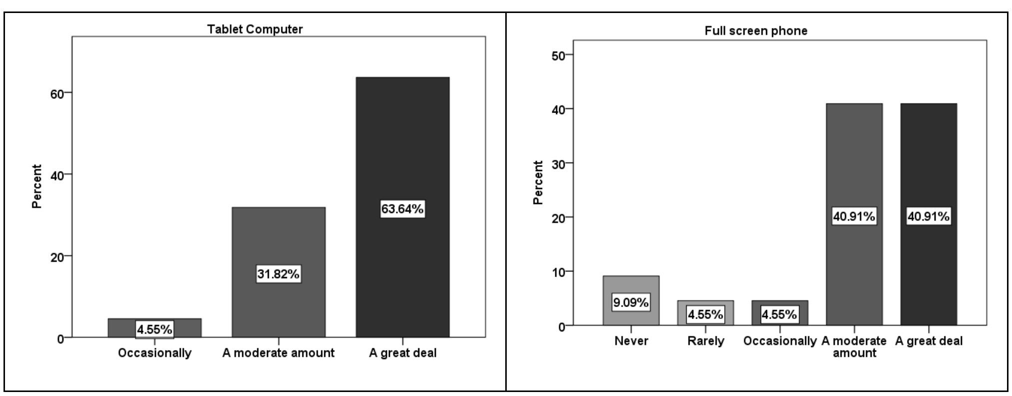


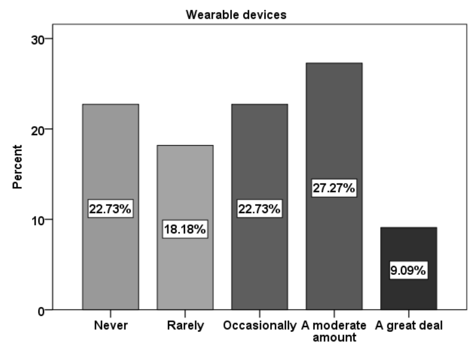
Question 9

The results of the central tendency (mean, median, and mode) and the variability (standard deviation) measures for the responses of question number nine (n=22).

Mobile device type	Mean	Median	Mode	Std Deviation
Tablet computers	4.5909	5.00	5.00	0.59033
Full screen phones	4.0000	4.00	4.00	1.23443
Wearable devices	2.8182	3.00	4.00	1.33225

The distribution of responses (in percentages) regarding the frequency of use for each of the given type of mobile devices in question number nine that are used in installing mobile ERP apps on it (n=22).




Wearable devices
Percent
30
20
10
0
22.73%
18.18%
22.73%
27.27%
9.09%
Never
Rarely
Occasionally
A moderate amount
A great deal

Appendix E

Median Severity Rating for the Identified Usability Problems for each Heuristic that Used to Evaluate the Usability of mERP App’s UIs.

1. Visibility of system status

Identified usability problem that was detected by the evaluators	Median severity rating
Is there some form of feedback for system failures?	2
Is there some form of feedback for non-availability of resources to execute certain operation?	2
Is there some form of feedback whether there is a problem with an external resource that is used by the system?	2
Is there some form of feedback for every user action?	2
Is the system capable of updating only content that has actually changed, such as news updates?	2
In multi-page data entry screens, is each page labelled to show its relation to others?	3
If a page is programmed to “time out”, is there a form of warning users before time expires so they can request additional time?	2
If pop-up windows are used to display error messages, do they allow the user to see the field in error?	2
If a list of items can be sorted according to different criteria, does it provide the option sort them according to all those criteria?	2
If the list contains only one item, is the user taken directly to that item?	2
If multiple options can be selected in a menu or dialog box, is there visual feedback about which options are already selected?	2
Are links recognizable?	2
Is there any characterization according to the state (visited, active...)?	2
Is a single, selected icon clearly visible when surrounded by unselected icons?	2
Is the system capable of providing navigational options?	2
Is there any type of feedback on user’s location within the application?	2
Is there any link to detailed information about the enterprise, web site, webmaster…?	2
Is there visual feedback in menus or dialog boxes about which choices are selectable?	2
Is the current status of an icon clearly indicated?	2
Is there visual feedback when objects are selected or moved?	2
Are low discoverable areas as touch buttons well identifiable?	2
When swiping gesture is possible, is a visible clue offered to users? Is swiping used with a unique meaning in the same screen?	2

2. Match between system and the real world (mental model accuracy)

Identified usability problem that detected by the evaluators	Median severity rating
If the site or mobile app uses hierarchical structure, are depth and height balanced?	2
Is too much navigation avoided?	2
Is the language clear and concise?	3
Is an imperative language used for mandatory tasks or qualify the statement appropriately, such as "Enter a City or Zip Code"?	2
Are standard abbreviations used? Such as p.m. or P.M.	2
Does the system automatically enter commas in numeric values greater than 9999?	2
Are integers right-justified and real numbers decimal-aligned?	2
Is a series of related items displayed in a vertical list rather than as continuous text?	2

3. User control and freedom

Identified usability problem that detected by the evaluators	Median severity rating
Is there any way to inform user about where they are and how to undo their navigation?	2
Is accidental activation avoided or foreseen (a back button is offered)?	2
If setting up windows is a low-frequency task, is it particularly easy to remember?	2
Can users set their own system, session, file, and screen defaults?	2
When a user's task is complete, does the system wait for a signal from the user before processing	2
Can users easily reverse their actions?	2
Is there an "undo" function at the level of a single action, a data entry, and a complete group of actions?	2
Can users cancel out of operations in progress?	2
If the system allows users to reverse their actions, is there a retracing mechanism to allow for multiple undos?	2
Can users reduce data entry time by copying and modifying existing data?	2
Does the system provide the user the option to turn on or turn off the AutoFill function for data entry fields?	2

4. Consistency and standards

Identified usability problem that detected by the evaluators	Median severity rating
Are soft tones used for regular positive feedback and harsh for rare critical conditions?	2
Do on-line instructions appear in a consistent location across screens?	2
Are integers right-justified and real numbers decimal-aligned?	2
Are there salient visual cues to identify the active window?	2

5. Recognition rather than recall

Identified usability problem that detected by the evaluators	Median severity rating
Are high levels of concentration not required and remembering information doesn't take more than two to fifteen seconds?	2
Are all data a user needs on display at each step in a transaction sequence?	2
After the user completes an action (or group of actions), does the feedback indicate that the next group of actions can be started?	2
Are optional data entry fields clearly marked?	2
Do data entry screens and dialog boxes indicate when fields are optional?	2
On data entry screens and dialog boxes, are dependent fields displayed only when necessary?	2
Is the first word of each menu choice the most important?	2
Are inactive menu items grayed out or omitted?	2
Are there menu selection defaults?	2
Is there an obvious visual distinction made between "choose one" menu and "choose many" menus?	2
Do GUI menus offer affordance: that is, make obvious where selection is possible?	2

6. Flexibility and efficiency of use

Identified usability problem that detected by the evaluators	Median severity rating
Is there any advanced search option?	2
Is the user assisted if the search results are impossible to calculate?	2
Does the system offer "find next" and "find previous" shortcuts for database	2

searches?	
Are links with good information scent (that is, links which clearly indicate where they take the users)?	2
Are there links to related content to help the user navigate more quickly between similar topics?	2

7. Aesthetic and minimalist design

Identified usability problem that detected by the evaluators	Median severity rating
Are images well sized? Are they understandable? Is the resolution appropriate?	2

8. Help users recognise, diagnose and recover from errors

Identified usability problem that detected by the evaluators	Median severity rating
Is sound or another reaction like device vibrating used to signal an error?	2
If an error is detected in a data entry field, does the system place the cursor in that field or highlight the error?	2
Do error messages inform the user of the error's severity?	3
Do error messages suggest the cause of the problem?	2
Do error messages provide appropriate semantic information?	2
Do error messages indicate what action the user needs to take to correct the error?	2
If the system supports both novice and expert users, are multiple levels of error-message detail available?	2
Does the app preserve the user's work in order to correct errors by editing their original action instead of having to do everything over again?	2
Does the app reduce the work of correcting the error? Does it guess the correct action and let users pick it from a small list of fixes?	2
If an error is detected, does the app provide contact options for any assistance?	2

9. Help and documentation

Identified usability problem that detected by the evaluators	Median severity rating
Are on-line instructions visually distinct?	2
Do the instructions follow the sequence of user actions?	2
If menu choices are ambiguous, does the system provide additional explanatory information when an item is selected?	2
If menu items are ambiguous, does the system provide additional explanatory information when an item is selected?	2
Is the help functioning visible; for example, a key labelled HELP or a special menu?	2
Is the help system interface (navigation, presentation, and conversation) consistent with the navigation, presentation, and conversation interfaces of the application it supports?	2
Navigation: Is information easy to find?	2
Presentation: Is the visual layout well designed?	2
Conversation: Is the information accurate, complete, and understandable?	2
Is the information relevant? It should be relevant in the following aspects: Goal-oriented (What can I do with this program?), Descriptive (What is this thing for?), Procedural (How do I do this task?), Interpretive (Why did that happen?) and Navigational (Where am I?)	2
Is there context-sensitive help?	2
Can the user change the level of detail available?	2
Can users easily switch between help and their work?	2
Is it easy to access and return from the help system?	2
Can users resume work where they left off after accessing help?	
If a FAQs section exists, is the selection and redaction of questions and answers correct?	2
Does the app contain the panel of tips and tricks or orientation screens for the app?	2

Are data entry screens and dialog boxes supported by navigation and completion instructions?	2
If users are working from hard copy, are the parts of the hard copy that go on-line marked?	2
Does the app provide the user with an interactive help?	2
Does app provide the user with gesture interaction guidelines?	2

10. Skills

Identified usability problem that detected by the evaluators	Median severity rating
Does the system provide a brief explanation for technical jargon and confusing acronyms if been used?	2
Does mobile app's user interface tailored to serve different user groups with different intentions, ages and levels of expertise? for example novice, expert users and older people	3
If users are experts, usage is frequent, or the system has a slow response time, are there fewer screens (more information per screen)?	2
If users are novices, usage is infrequent, or the system has a fast response time, are there more screens (less information per screen)?	2
If the system supports both novice and expert users, are multiple levels of error message detail available?	2
If the system supports both novice and expert users, are multiple levels of detail available?	2
Are the important buttons designed in a way to give an indication of their importance?	2
Does the system correctly anticipate and prompt for the user's probable next activity?	2
Does the system automatically color-coded items, with little or no user effort?	2
Does the system perform data translations for users?	2
Does the app support a Multi-Layered Interface in order to improve its learnability?	2

11. Pleasurable and respectful interaction with the user

Identified usability problem that detected by the evaluators	Median severity rating
Does the mobile app's UI able to nominate the most appropriate interaction modality that match environmental constraints of a mobile context of use?	2
Does the interface provide performance feedback about how close the user is to achieving the goal?	2
Does the interface embody emotionally appealing fantasies?	2
Are the mobile app's UI gestures being intuitively discoverable?	2
Does the mobile app's UI provide an alternative method of interaction in the case if the primary method failed?	2
Does the mobile app's UI use modal alerts in a case of serious wrong?	2
Does the mobile app's UI use modal confirmations when the app needs to confirm an action by the user?	2
Are mobile app's UI elements placed at a comfortable and ideal position?	2
Are the most frequently used function keys in the most accessible positions?	2
Does the app maintain the accessibility for users with various physical special needs? For example: people with disabilities or left-handed people	2
If users are working from hard copy, does the screen layout match the paper form?	2
Is the users' work protected? For example, for data entry screens with many fields or in which source documents may be incomplete, can users save a partially filled screen? Do data entry screens allow users to save partially completed tasks?	3
Users dislike typing. Is information computed for the users? For instance, ask only for the zip code and calculate state and town; possibly offer a list of towns if there are more under the same zip code.	2

Does the system complete unambiguous partial input on a data entry field?	2
Is the input data tolerant of typos and offers corrections? (Don't make users type in complete information. For example, accept "123 Main" instead of "123 Main St.")	3
Can users save history and select previously typed info?	2
Is the mobile app's UI rotated to enhance the completion of user task? For example: If the user interface requires a lot of typing, does the app rotate to a landscape orientation?	2
When logging in must be done, are graphical passwords used at least some of the time, to get around typing?	2
When logging in must be done, is there an option that allows the user to see the password clearly?	2
Does the app provide the user an alternate method of authentication?	2
Has colour been used specifically to draw attention, communicate organization, indicate status changes, and establish relationships?	2
Whenever users conduct transactions on the phone, can they save confirmation numbers for that transaction by emailing themselves? If the phone has an embedded screen-capture feature, are there instructions about how to take a picture of their screen?	2

12. Privacy

Identified usability problem that detected by the evaluators	Median severity rating
Does the mobile app allow the user to prevent mobile phone from connecting automatically to available internet connections or Bluetooth devices? And notify the user with available connections?	3
Can protected or confidential areas be accessed with a certain authentication method (log-in, two-step log-in, QR, biometric, etc.)?	2
Is this feature effective and successful?	2
If the app does store any information that is sensitive (e.g., credit card), Can the app allow users to decide if they want to be kept logged-in or if they want to log-in again each time they use the app?	2
In case keep log-in has been selected, Will the user be informed of the possible risks?	2
Does the app instantly notify the user about any suspicious activity in using the app?	3
Does the mobile app briefly explain the purpose of accessing to such mobile data and resources?	2
Does it provide a full explanation if the user needs more explanation?	2
Does the mobile app UI inform the user to whom the mobile data is being sent or shared?	2
Does the mobile app UI allow the user to manage permissions like disabling the access to the mobile data or resources?	2
Does the app accept to the remote commands such as log out in case of loss?	2
Does the mobile app UI allow to its user to generate a backup in a safe place and recover it?	2
Does the mobile app's UI log out if the user doesn't interact with the app for a long-time (idle time)?	3

13. Navigation and access to information

Identified usability problem that detected by the evaluators	Median severity rating
Can functionality be found quickly and easily (e.g. Transactions)?	2
Is there sufficient help provided for finding the correct functionality, information and screens?	3
Can the system can guide the user through the correct sequence of transactions to complete a business process?	2
Is the GUI easy to understand to enable efficient and accurate navigation of the system?	2

Does the navigation suit different interaction styles of the users?	2
Are there alternative ways of navigating the system?	2
Is Guidance-type information always available?	2
Are the next sequence steps for a transaction clear?	2

14. Presentation of screen and Output

Identified usability problem that detected by the evaluators	Median severity rating
Is the visual layout well designed?	2
Is information timely, accurate, complete and understandable?	2
Does the information presented support informed decision making?	2
Does the output provided by the system provide clear visibility into the various other business units and departments?	2
Has the system an intuitive GUI?	2
Does the system present the user with complex and busy GUIs, resulting in information overload?	2

15. Appropriateness of task support

Identified usability problem that detected by the evaluators	Median severity rating
Is the response from the system quick and efficient?	2
Does the system automate routine and redundant tasks and data?	2
Is easy to operate and use the system?	2

16. Intuitive nature of system

Identified usability problem that detected by the evaluators	Median severity rating
Can the user learn how to use the system without a long introduction?	3
Is there sufficient on-line help to support the learning process?	2
Is it easy to become skilful at using the system within a short amount of time?	2
Is the system intimidating and complex to learn and use?	2

17. Ability to customise

Identified usability problem that detected by the evaluators	Median severity rating
Does the system support customisation to the level of user preferences?	2
Does the system support customisation to enable and promote business agility?	2
Does the system support customisation of reports?	2
Is the system easy to change and re-configure over a period of time without making the system more complicated?	2
Can the GUI be configured without affecting the underlying business logic?	2

18. Ability to support adaptive UIs

Identified usability problem that detected by the evaluators	Median severity rating
Does the application have the ability to adapt its content according to the context of use?	3
Does the application have the ability to adapt its presentation according to the context of use?	3
Does the application have the ability to adapt its navigation structure according to the context of use?	3

Appendix F

A Questionnaire to Determine the Usability Issues of mERP App.

1- What is the type of device you are using to operate mERP app?

◎ Smartphone (For example: iPhone, Samsung Galaxy, Huawei, etc.)

◎ Tablet Computers (For example: iPad, Samsung Tabs, etc.)

◎ Mobile Handheld Computers (For example: Motorola Mobile Computer, Zebra Handheld computer, etc.)

◎ Other……………………………………………………………………………..

2- What are the frequent tasks that you perform through mERP? (Please select more than one task)

▢ Messaging - Inbox, To-do, etc.

▢ Messaging- Processing Calendar (Add event, delete, remainder, etc.)

▢ Messaging- Discussion

▢ Sales- Sales Teams/ Customers (create, edit, and following up)

▢ Sales- Leads/ Opportunities

▢ Sales- Quotations/Sales Orders

▢ Sales- Products (create, edit, inquiry, create variants, and categories)

▢ Project- Projects (create, edit, delete, etc.)

▢ Project- Tasks/Issues

▢ Accounting- Customer Invoices/Supplier Invoices

▢ Accounting- Suppliers Refunds/ Customer Refunds

▢ Accounting- Customer Payments/supplier Payments

▢ Accounting - Bank Statements/ Cash Registers

▢ Purchases- Request for Quotation/ Purchase Order

▢ Purchases- Calls for Bids

▢ Purchases- Suppliers

▢ Warehouse- Inventory Adjustments

▢ Warehouse- Stock Moves

▢ Warehouse- Procurements

▢ Warehouse- Products

▢ Warehouse- Inventory Locations

▢ Manufacturing- Manufacturing Orders

▢ Manufacturing-Order Planning

▢ Manufacturing- Bill of Materials

▢ Human Resources- Employees /Job Positions/ Departments (Create, edit, delete, and listing)

▢ Human Resources- Job Applications

▢ Human Resources- My Current Timesheet

▢ Human Resources- Time sheets to Validate/time sheet activities

▢ Human Resources- Leave Requests to Approve/Leaves summary

▢ Other:…………………………………………………………………………………….

3- What do you think about the quality of efficiency of mERP app in terms of finding the desired information timely (speed) in a specified context of use (i.e. distraction, walking, different environments, mobile data disconnection)?

◯ Excellent

◯ Very Good

◯ Good

◯ Fair

◯ Poor

Please add any further notes:

………………………………………………………………………………………………..

4. What do you think about the quality of efficiency of mERP app in terms of accessing the desired functionality timely (speed) in a specified context of use (i.e. distraction, walking, different environments, mobile data disconnection)?

◯ Excellent

◯ Very Good

◯ Good

◯ Fair

◯ Poor

Please add any further notes:

………………………………………………………………………………………..

5. What do you think about the quality of the effectiveness of mERP app in terms of finding correctly the desired information in a specified context (i.e. distraction, walking, different environments, mobile data disconnection)?

◦ Excellent

◦ Very Good

◦ Good

◦ Fair

◦ Poor

Please add any further notes:

………………………………………………………………………………………..

6. What do you think about the quality of the effectiveness of mERP in terms of accessing the desired functionality and complete it correctly (A low rate of errors) in a specified context (i.e. distraction, walking, different environments, mobile data disconnection)?

◦ Excellent

◦ Very Good

◦ Good

◦ Fair

◦ Poor

Please add any further notes:

………………………………………………………………………………………..

7. Does the presentation of mERP's UIs and their layouts components support the completion of your tasks?

◦ Yes

◦ No

Please add any further notes:

………………………………………………………………………………………..

8. What do you think about mERP app learnability? (i.e. Was it easy to learn? Does it support how to use it intuitively? (if not, why?)

◎ Yes ◎ No Please add any further notes: …………………………………………………………………………………………..
9. What do you think about mERP app Memorability? (i.e. Was it easy to remember how to use it in case it was not being used for a long period of time? (if not, why?)) ◎ Yes ◎ No Please add any further notes: …………………………………………………………………………………………..
10. Does mERP app provide an appropriate, sufficient, and intuitive help approach? ◎ Yes ◎ No Please add any further notes: …………………………………………………………………………………………..
11. What are the features that you would like to find in mERP app? (the existence of these features will motivate the use of mERP proficiently by you) …………………………………………………………………………………………
12. What do you like about mERP app? …………………………………………………………………………………………
13. What do you dislike about mERP app? …………………………………………………………………………………………
14. What are the usability challenges that you have experienced while using mERP app? …………………………………………………………………………………………..

Appendix G

The consent form for evaluating the adaptive prototype and non-adaptive prototype of the mERP app.

Consent Form

Evaluation of the adaptive prototype and non-adaptive prototype
Name of Researcher: Khalil Omar

Please tick as appropriate	**Yes**	**No**
Have you received enough information about these experiments?		
Have you had the opportunity to ask questions regarding these experiments?		
Have you received satisfactory answers to all of your questions?		
Do you understand that you will not be referred to by name in any report concerning the experiments?		
Do you understand that your participation is voluntary, and you are free to withdraw at any time, without giving any reason, and without any penalty?		
Do you agree to participate in these experiments?		

Participant Name:…………………………………………………………

Signature:………………………………………………………………………………..

Date:…………………………………………………………………………………..

Appendix H

Task lists for the first-day and the second-day evaluations.

First Day:

- **Walking Experiment**

RFQ for purchase order 1			
Main information			
Supplier	Izz		
Supplier reference	P40022		
Order date and time	1/6/2017 8:00 AM		
Deliver to company	VLBA		
Products			
Product details	**Product 1**	**Product 2**	**Product 3**
Product name	iPhone 4s white	iPhone 4s black	Xbox 360
Description	64 GB	64 GB	white
Scheduled date	5/6/2017	5/6/2017	5/6/2017
Quantity	5	8	3
Price	150	170	350
Tax type	Sales Tax	Sales Tax	Sales Tax
Terms and conditions	5% discount based on agreement number 1566		
RFQ & Bid			
Bid Valid Until	31/5/2017		
Deliveries & Invoices			
Expected date	5/6/2017		
Destination (warehouse)	VLBA		

- **High Ambient Sound Experiment**

RFQ for purchase order 2			
Main information			
Supplier	Izz		
Supplier reference	P40022		
Order date and time	15/6/2017 10:00 AM		
Deliver to company	University of Petra		
Products			
Product details	**Product 1**	**Product 2**	**Product 3**
Product	LG - 65" Class (64.5" Diag.) - OLED - 2160p	MSI - 15.6" Laptop - Intel Core i7	MSI - GS Series STEALTH PRO 15.6"
Description	Black	Silver Deutsch keyboard	White
Scheduled date	20/6/2017	20/6/2017	20/6/2017
Quantity	4	5	2
Price	350	470	450
Tax type	Sales Tax	Sales Tax	Sales Tax
Terms and conditions	10% discount based on agreement number 1566		
RFQ & Bid			
Bid Valid Until	12/6/2017		
Deliveries & Invoices			
Expected date	20/6/2017		
Destination (warehouse)	University of Petra		

- **Experiment of High Ambient Sound with Walking altogether**

RFQ for purchase order 3			
Main information			
Supplier	Eduard		
Supplier reference	Vlba 5224		
Order date and time	1/7/2017 9:00 AM		
Deliver to company	Wechloy		
Products			
Product Details	**Product 1**	**Product 2**	**Product 3**
Product	Toshiba - 55" Class (54.6" Diag.) - LED - 216	Yamaha - AVENTAGE 665W 7.2-Ch	Yamaha - 150W 2-Ch. Stereo Receiver
Description	Black	Silver	White
Scheduled date	5/7/2017	5/7/2017	5/7/2017
Quantity	2	3	1
Price	500	150	300
Tax type	Sales Tax	Sales Tax	Sales Tax
Terms and conditions	Used but in a good condition		
RFQ & Bid			
Bid Valid Until	28/6/2017		
Deliveries & Invoices			
Expected date	5/7/2017		
Destination (warehouse)	Wechloy		

- **Direct Sunlight Experiment**

RFQ for purchase order 4			
Main information			
Supplier	Izz		
Supplier reference	P40022		
Order date and time	2/7/2017 9:00 AM		
Deliver to company	Haarentor campus		
Products			
Product Details	**Product 1**	**Product 2**	**Product 3**
Product	Samsung S7	Sony PS4	Xbox 360
Description	Black	Black	White
Scheduled date	5/7/2017	5/7/2017	5/7/2017
Quantity	2	3	1
Price	300	150	350
Tax type	Sales Tax	Sales Tax	Sales Tax
Terms and conditions	new		
RFQ & Bid			
Bid Valid Until	28/6/2017		
Deliveries & Invoices			
Expected date	5/7/2017		
Destination (warehouse)	Haarentor		

Second day:

- **Walking Experiment**

RFQ for purchase order 1			
Main information			
Supplier	Zack		
Supplier reference	Vlba203		
Order date and time	7/6/2017 10:00 AM		
Deliver to company	Wechloy		
Products			
Product Details	**Product 1**	**Product 2**	**Product 3**
Product	Yamaha - AVENTAGE 665W 7.2-Ch	Xbox 360	Toshiba - 55" Class (54.6" Diag.) - LED - 216
Description	White	White	LED
Scheduled date	10/6/2017	10/6/2017	13/6/2017
Quantity	7	4	4
Price	600	300	500
Tax type	Sales Tax	Sales Tax	VAT Tax
Terms and conditions	10% discount based on agreement number 7421		
RFQ & Bid			
Bid Valid Until	5/6/2017		
Deliveries & Invoices			
Expected date	10/6/2017		
Destination (warehouse)	Wechloy campus		

- **High Ambient Sound Experiment**

RFQ for purchase order 2			
Main information			
Supplier	Mario		
Supplier reference	Vlba34		
Order date and time	20/6/2017 11:00 AM		
Deliver to company	Haarentor campus		
Products			
Product Details	Product 1	Product 2	Product 3
Product	MSI - 15.6" Laptop - Intel Core i7	Sony PS4	Xbox 360
Description	White	White	Black
Scheduled date	25/6/2017	25/6/2017	25/6/2017
Quantity	6	7	3
Price	600	300	300
Tax type	Sales Tax	Sales Tax	Sales Tax
Terms and conditions	7% discount based on agreement number 1234		
RFQ & Bid			
Bid Valid Until	18/6/2017		
Deliveries & Invoices			
Expected date	25/6/2017		
Destination (warehouse)	Haarentor		

- **Experiment of High Ambient Sound with Walking altogether**

RFQ for purchase order 3			
Main information			
Supplier	Zack		
Supplier reference	vlba44		
Order date and time	25/6/2017 8:00 AM		
Deliver to company	University of Petra		
Products			
Product Details	**Product 1**	**Product 2**	**Product 3**
Product	LG - 65" Class (64.5" Diag.) - OLED - 2160p	Toshiba - 43" Class (42.5" Diag.) - LED - 216	Xbox 360
Description	Black	Black	White
Scheduled date	1/7/2017	1/7/2017	1/7/2017
Quantity	3	6	4
Price	500	500	300
Tax type	Sales Tax	Sales Tax	Sales Tax
Terms and conditions	5% discount based on agreement number 1433		
RFQ & Bid			
Bid Valid Until	20/6/2017		
Deliveries & Invoices			
Expected date	1/7/2017		
Destination (warehouse)	University of Petra		

- **Direct Sunlight Experiment**

RFQ for purchase order 4			
Main information			
Supplier	Zack		
Supplier reference	Vlba44		
Order date and time	28/6/2017 10:00 AM		
Deliver to company	Wechloy		
Products			
Product Details	**Product 1**	**Product 2**	**Product 3**
Product	iPhone 4s black	iPhone 4s white	Xbox 360
Description	64 GB	64 GB	White
Scheduled date	1/7/2017	1/7/2017	1/7/2017
Quantity	7	5	4
Price	150	170	300
Tax type	Sales Tax	Sales Tax	Sales Tax
Terms and conditions	10% discount based on agreement number 1477		
RFQ & Bid			
Bid Valid Until	25/6/2017		
Deliveries & Invoices			
Expected date	1/7/2017		
Destination (warehouse)	Wechloy campus		

Appendix I

Post-Test Satisfaction Questionnaire.

General Instructions

Purpose

This questionnaire aims to measure the attitudes towards the usage of the developed mobile application to create the required RFQs over the two-day evaluation in the determined environmental contexts.

Confidentiality and Anonymity

All information provided in this questionnaire is strictly private and confidential. Furthermore, all individuals or their responses are completely anonymous.

Sections

- This questionnaire consists of 2 sections:
  - I. Overall all reactions to the application.
  - II. Attitudes towards a set of usability challenges.
- The abovementioned sections consist of total 24 items that need to be evaluated by using the given 5-point Likert scale.
- Please evaluate these items precisely.

If you have any questions, comments or concerns about this questionnaire, please contact the researcher.

Thank you for your participation in completing this questionnaire.

User Id:

Day:

Section I: Overall all reactions to the application

1. Creating a purchase order:

	1	2	3	4	5	
Very Difficult	○	○	○	○	○	**Very Easy**

2. Level of satisfaction and reaction to the app:

	1	2	3	4	5	
Very Frustrating	○	○	○	○	○	**Very Satisfying**

3. Level of stimulation:

	1	2	3	4	5	
Very Dull	○	○	○	○	○	**Very Stimulating**

4. Level of flexibility:

	1	2	3	4	5	
Very Rigid	○	○	○	○	○	**Very Flexible**

5. Over all screens design

	1	2	3	4	5	
Very Frustrating	○	○	○	○	○	**Very Satisfying**

Section II: Usability Challenges

6. Time required compared with the conventional approach to complete a task:

	1	2	3	4	5	
Slower	○	○	○	○	○	**Faster**

7. The app responds to the context of use variability:

	1	2	3	4	5	
Not Noticeable	○	○	○	○	○	**Very Noticeable**

8. A lack of correction and validation techniques that suit the context of use:

	1	2	3	4	5	
Not Noticeable	○	○	○	○	○	**Very Noticeable**

9. The app supports an intuitive learning:

	1	2	3	4	5	
Not Noticeable	○	○	○	○	○	**Very Noticeable**

10. The app has the ability to handle environmental distractions in order to support task completion:

	1	2	3	4	5	
Not Noticeable	○	○	○	○	○	**Very Noticeable**

11. UIs are bloated:

	1	2	3	4	5	
Not Noticeable	○	○	○	○	○	**Very Noticeable**

12. Number of interaction steps to complete a task:

	1	2	3	4	5	
Many	○	○	○	○	○	**Few**

13. Remembering the performed interaction steps:

	1	2	3	4	5	
Very Difficult	○	○	○	○	○	**Very Easy**

14. Finding the desired information and functionalities:

	1	2	3	4	5	
Very Difficult	○	○	○	○	○	**Very Easy**

15. Guidance through task and its sub-tasks:

	1	2	3	4	5	
Not Noticeable	○	○	○	○	○	**Very Noticeable**

16. The app enables personalisation:

	1	2	3	4	5	
Not Noticeable	○	○	○	○	○	**Very Noticeable**

17. The app enables contextual help:

	1	2	3	4	5	
Not Noticeable	○	○	○	○	○	**Very Noticeable**

18. Time to learn the app:

	1	2	3	4	5	
Very Long	○	○	○	○	○	**Very Short**

19. The interaction with the app's UIs with the ambient light:

	1	2	3	4	5	
Very Difficult	○	○	○	○	○	**Very Easy**

20. The interaction with the app's UIs with ambient sound:

	1	2	3	4	5	
Very Difficult	○	○	○	○	○	**Very Easy**

21. The interaction with the app's UIs while moving:

	1	2	3	4	5	
Very Difficult	○	○	○	○	○	**Very Easy**

22. The app's UIs are adapted to the end-user physiological characteristics:

	1	2	3	4	5	
Not Noticeable	○	○	○	○	○	**Very Noticeable**

23. The app's UIs are adapted to the platform specifications:

	1	2	3	4	5	
Not Noticeable	○	○	○	○	○	**Very Noticeable**

24. The app's UIs are adapted to the end-user knowledge of the app:

	1	2	3	4	5	
Not Noticeable	○	○	○	○	○	**Very Noticeable**

Publications

1. Omar, K., & Marx Gómez, J. (2015). Usability challenges for mobile ERP systems, ERP Management (Online).
2. Omar, K. (2015). Towards Improving the Usability of Mobile ERP: A Model for Devising Adaptive Mobile UIs to Improve the Usability of Mobile ERP. In Douglas W. Cunningham, Petra Hofstedt, Klaus Meer (Ed.), 45. Jahrestagung der Gesellschaft für Informatik INFORMATIK 2015: Informatik, Energie und Umwelt (pp. 1783–1794). Gesellschaft für Informatik e.V. (GI).
3. Omar, K., Rapp, B., & Marx Gómez, J. (2016). Heuristic evaluation checklist for mobile ERP user interfaces. In proceedings of the 7th International Conference on Information and Communication Systems (ICICS) (pp. 180–185). IEEE.
4. Omar, K., & Marx Gómez, J. (2016). A selection model of ERP system in mobile ERP design science research: Case study: mobile ERP usability. In proceedings of the 13th ACS/IEEE International Conference on Computer Systems and Applications AICCSA 2016, Agadir, Morocco: IEEE.
5. Omar, K., & Marx Gómez, J. (2016). A conceptual framework for Devising Adaptive User Interfaces for Mobile ERP: In Eureka International Virtual Meeting Eureka 2016 y OPTISAD 2016.
6. Omar, K., & Marx Gómez. (2017). An investigation of the proliferation of mobile ERP apps and their usability. In proceedings of the 8th International Conference on Information and Communication Systems (ICICS) (352–357). IEEE.
7. Omar, K., & Marx Gómez (2017). An Adaptive System Architecture for Devising Adaptive User Interfaces for Mobile ERP Apps. In proceedings of the 2nd International Conference on the Applications of Information Technology in Developing Renewable Energy Processes and Systems (IT-DREPS 2017) (pp. 80–85). IEEE.

Ich versichere, dass ich die vorliegende Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt und die allgemeinen Prinzipien wissenschaftlicher Arbeit und Veröffentlichungen, wie sie in den Leitlinien guter wissenschaftlicher Praxis der Carl von Ossietzky Universität Oldenburg festgelegt sind, befolgt habe.

Khalil Omar, 09.05.2018