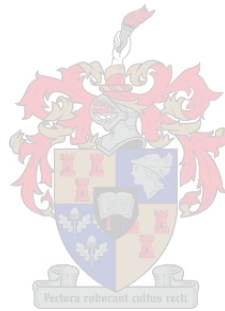# A Decision Support Model to Identify Causes of Human Error Creating Information Systems Failure

by

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Thesis presented in partial fulfilment of the requirements for the degree of Master of Engineering in the Faculty of Engineering at Stellenbosch University

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March 2016

Declaration

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Abstract

A Decision Support Model to Identify Causes of Human Error Creating Information Systems Failure

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Thesis: MEng (Industrial)

November 2015

The smooth operation of information systems has a powerful impact on an organisation's financial performance and success. The failure of information systems continues to be an issue for organisations and the human errors connected to these failures are not fully understood nor is there a set of guidelines that can identify these errors and their causes.

The study identifies the most common human errors and seeks to ultimately create a decision support model that aids in minimising human errors that result in the failure of information systems. Case studies are used to create a model which can identify relevant human errors. Focus is set upon the different classifications of errors and their possible environments, and then linked to the identified errors. This creates a path to identifying the causes, as well as their solutions.

In order to link the causes and solutions to each context, validation is done through the use of surveys. The output is a simple model that can be used by managers to find the causes of human error, rather than treating the symptoms thereof. The model's accuracy is measured with the use of Face validity.

Uittreksel

'n Model wat Besluitneming Ondersteun om die Oorsake van Menslike Foute in Inligtingstelsel-falings te Identifiseer

("A Decision Support Model to Identify Causes of Human Error Creating Information Systems Failure")

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Inligtingstelsels wat vlot loop het 'n reuse positiewe impak op 'n organisasie se finansiële doelwitte en sukses. Tekortkominge van dié stelsels, en veral die rol van menslike foute daarin, bly steeds 'n probleem. Die rol van menslike foute in falings van inligtingstelsels is steeds onduidelik en daar bestaan nie 'n stel riglyne wat hierdie foute en hul oorsprong kan identifiseer nie.

Die studie het ten doel om die mees algemene menslike foute te identifiseer, en 'n besluitnemings-model te skep wat menslike foute se rol in inligtingstelsel-falings minimeer.

Daar word gefokus op verskillende klassifikasies van foute en die moontlike omgewings waarbinne die foute plaasvind, en dit word verbind met reeds identifiseerde foute. Dit baan die weg om oorsake en oplossings vir stelsel-falings te identifiseer.

Vraelys-opnames word gebruik om die geldigheid van die verband tussen oorsaak en oplossing in elke konteks te bevestig. "Face validity" word implementeer om die model te valideer.

Dedications

Hierdie tesis word opgedra aan my ouers, Rian en Elmarie.

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Nomenclature

Acronyms

DSS Decision Support Systems

$HAZOP$ Hazard and Operability Study

HEI Human Error Identification

IS Information System/s

RE Requirements Engineering

$SHARP$ The Systematic Human Action Reliability Procedure

SRK Skill, Rule and Knowledge-based

$TRACEr$ Technique for the Retrospective and Predictive Analysis of Cognitive Errors

Chapter 1

Introduction

This chapter aims at providing an introduction to the research. The reasoning that created the research problem and the relevant research questions is provided. An overview of the research objectives, and the research design and methodology is then presented. To conclude, an outline of the thesis is drawn.

1.1 Theoretical Background

To understand an organisation, the study of organisation theory is essential. Organisation theory can be seen as the discipline that studies an organisation's structure and design (Robbins 1983; Shafritz and Steven Ott 2001; Daft *et al.* 2010). This theory describes how organisations are structured and offers suggestions to the most suitable structure for an organisation (Shafritz and Steven Ott, 2001).

The issue that organisation theory is concerned with is the difficulties that arise with the implementation of strategic and structural changes that should aid in achieving organisational effectiveness (Daft *et al.*, 2010). Difficulties for example: coping with problems that arise due to an organisation's large size, the lack of control and adaption to environmental and technological change (Daft *et al.*, 2010).

A difficulty that is crucial in order for an organisation to survive and flourish and that continues to be a barrier to achieving organisational effectiveness, is information systems (IS) inefficiencies (Daft *et al.* 2010; Buruncuk and Gulser 2001). IS have become increasingly important as the ability of organisations to generate and make use of information grows (Lissack, 2002). Practitioners have realised that human errors can be extremely costly, therefore the aim to avoid or minimise these errors (Wickens *et al.*, 2013).

Organisational theory aids in the identification of the structures and con-

texts in which IS inefficiencies can exist (Howcroft and Trauth 2005; Daft *et al.* 2010). The perspective that failure is highly contextual creates a path to trace failures in IS (Jaffal *et al.*, 2015). Context is dependent of factors which form the different circumstances and situations which affect the success or failure of IS (Buruncuk and Gulser, 2001).

Classifying and identifying the causes of IS failure are a complicated and commonly problematic task, as these failures depend on the training received, the ease by which a problem can be traced, the complexity of the IS or the nature of change (Howcroft and Trauth, 2005). A very diverse set of possibilities exists that possibly is the root causes of IS failure. Literature confirms that any problem or failure in IS cannot be properly identified without first gathering information relevant to its background, which can be explained by the context (Bondarouk and Riemsdijk 2007; Buruncuk and Gulser 2001; Jaffal *et al.* 2015).

The proportion of IS failures that can be linked to human error is considerably greater than that of technology, or any other, failures (Wickens *et al.*, 2013). Knowing that human error is a frequent occurrence that has not been fully researched, the need for research therefore exists due to the interaction between humans and IS and the organisational inefficiencies they can create. (Lissack, 2002). Investigating and understanding these interwoven factors or possible circumstances in which IS are present can provide a route for identifying and classifying the causes of inefficiencies caused by IS users within a defined context (Howcroft and Trauth 2005; Heintze and Bretschneider 2000).

The research aims to identify failure, or inefficiencies, through individuals, technology, systems and structures (Howcroft and Trauth, 2005). The existing literature has evolved to perceiving a failed situation as a system error, rather than separating human behaviour and technology. This means that there are multiple ways in which human performance can fall short which has an influence on IS failure, though human factors should not be the explicit focus (Jaffal *et al.*, 2015). Not only must the user of the system and the IS itself be considered, but also the organisational structure and organisational factors (Howcroft and Trauth 2005; Atkin *et al.* 2007).

Beliefs and assumptions concerned with the existing relationship between IS, organisational factors and human resources, are the starting point to finding these human related inefficiencies. The concepts of IS, organisational factors and human resources are very much interrelated and co-dependent when searching for causes of IS failure (Howcroft and Trauth 2005; Bondarouk and Riemsdijk 2007).

An example of a common problem is that IS users fail to learn from their

experiences, and in turn they learn to fail. The acceptance of failure and its commonality is an issue that holds back the development of skills within an organisation. Over time, an organisation is blinded from seeing failure and the alternatives to avoiding failure are not investigated (Lyytinen and Robey, 1999).

The majority of the existing literature's focus regarding the failure of IS, investigates and blames inefficiencies to the failure of the technology itself (Knolmayer *et al.*, 2002). Technological failure is an issue that exists due to errors in the programming of software, bad system designs, over complicated designs, incompatibility, bad planning and even faulty hardware. This type of failure can only be corrected by the creators and designers of the technology.

Literature identifying causes of IS failure such as technology failure, during the pre-implementation and implementation phase, is another field that has been thoroughly investigated (Joshi, 1991). The failure of IS was originally only considered as a technological problem. It has been found that the general cause of failure during the implementation phase is software errors and complexity and the internal struggle existing due to change and people's resistance to change. In order to solve the problem, the technology would be adapted and redesigned to meet the user's requirements (Jaffal *et al.*, 2015).

Besides the failure of technology, IS failure during the implementation phase is commonly explained by resistance to organisational change (Joshi, 1991). An organisation is not at all times capable of adapting to change (Robbins, 1983). At the implementation stage it is easy to blame a lack of training and motivation to explain IS user's resistance to participate.

While these technological and change management related issues are important to address, these common inefficiencies do not thoroughly explain why IS tend to fail at the post-implementation stage. Literature has become increasingly aware that causes of failure are more complex and inefficiencies caused by human error should be considered and investigated (Jaffal *et al.* 2015; Buruncuk and Gulser 2001; Southon *et al.* 1999; Kay 2007). This is due to the fact that research finds that IS continue to fail at an alarming rate, which is a major concern for organisations and creates motivation for further research into human errors in the IS field (Howcroft and Trauth 2005; Davis *et al.* 1992; Bondarouk and Riemsdijk 2007; Lyytinen and Robey 1999; Buruncuk and Gulser 2001).

The most basic definition of failure is not achieving desired goals, which is the consequence of human errors. Failures are limited to actions that humans make whilst interacting with an IS. A list of general human errors that leads to IS failure is identified:

- Pressing the wrong key

- Typing mistakes - the omission of a letter/number

- Typing mistakes - the substitution of one letter/number for another

- Spelling mistakes

- Typing or selecting information in the wrong order

- Misinterpreting information

- Using the incorrect information for the task

- Accidentally deleting information

(Wickens *et al.* 2013; Walia and Carver 2009)

These human errors may seem small and insignificant, but they may result in inefficient operations and major financial losses.

1.2 Problem Statement and Research Questions

With IS being a critical component of organisational efficiency, its continuous functioning is both a necessity and an opportunity for creating a competitive advantage. The flow of accurate information and meaningful communication through IS are essential.

The problem is the limited understanding of the human errors which cause IS failure and an absence of guidelines to identify these causes of failure.

In order to address the problem, the following research questions should be answered:

1. **What are the possible organisational contexts and conditions in which IS can exist where human error is a possibility?**

2. **What are the most likely human errors leading to IS inefficiencies and can they be classified in groups to simplify identification and then linked to the identified contexts and conditions?**

3. **What are the most likely causes and related solutions to human error in IS and can they be linked to the context identifiers?**

4. With the answers from questions one to three, what will a reliable decision making model look like?

By providing answers to the research questions there is an opportunity to contribute to the practice of IS and a possibility to improve the functioning of IS in organizations.

1.3   Research Objectives

The goal of the research is to create a failure identification model that identifies the possible causes of inadequate human performance which leads to IS failure. A model is to be created which can be used by managers or HR personnel in an organisation to identify these causes of failure associated with the use of IS. Resolving the problem may lead to multiple benefits for organisations such as cost savings, competitive advantage, higher productivity rates and timely feedback and operations (Buruncuk and Gulser, 2001).

Table 1.1 summarises the objectives of the research to aid in solving the problem.

Seq.	Objectives	Chapter
1.	Establish the backgroud and investigate the importance of researching IS failures caused by human errors	2
2.	Provide research regarding the contextual and organisational relevance of IS failure identification	
3.	Formulate an applicable research methodology	3
4.	By using existing literature, identify specific contexts where IS failures can exist, human errors and generic causes of IS failure	4
5.	Create a short list of contexts, human error, and causes and solutions of IS failure	5
6.	Create the IS failure identification model	6
7.	Validate the IS failure identification model	7
8.	Derive conclusions and recommendations for the model created	8

Table 1.1: Summary of the research objectives

Chapter 2 has two primary objectives, it investigates the literature necessary that creates an understanding of the concept of IS in organisations and

justifies the human resource orientated focus. The second objective pursued is the creation of a context where these IS failures can exist.

In chapter 3 the objective is to devise a sound methodology to implement in the research. The point of view from which the methodology is created is shaped by the findings in the first two objectives.

Chapters 4 and 5 are related to the identification of commonalities across varied literature that can be used to build the new model. Chapter 4 will reply on literature in chapter 2 to create its basis and then these contexts are analysed and refined through deduction of the logical structures existent in literature. Chapter 5 uses existing literature and case studies to identify generic causes of failure, irrelevant of background or context. The aim is to firstly identify and define the context wherein the IS function and then, identify how the IS influences and is influenced by its context.

In chapter 6 the main objective of the research is shaped and constructed. The findings in chapters 4 and 5 are used to create a short list for causes of IS failure. The failure identification model is created using information gathered in chapters 4 and 5. Chapter 7 then intends to validate the model created in chapter 6. Conclusions are drawn in chapter 8 after the validation of the created model, along with shortcomings of the research and recommendations to the industry.

The achievement of the objectives will lead to a model which aids managers (or the relevant organisational decision maker) to identify causes of human behavioural failures. Managers must have the necessary knowledge to be able to use and understand the model. All that is required is an understanding of the organisation in order to identify exactly where the cause of failure lies. The model will assist the managers at higher levels of hierarchy in identifying IS failures, caused by the user, within their organisation, in order to be able to solve, prevent or avoid failures.

1.4   Research Design and Methodology Overview

The research design is non-empirical, where existing and secondary data that has been gathered for other distinct purposes is used and reviewed to answer the research questions.

The existing literature is reviewed by using a qualitative approach in or-

der to build an original model, by using the content analysis technique. This theory building study uses relevant and existing published research to identify commonalities and contextualised interpretations, and re-organises the work in order to systematically abstract a new trustworthy taxonomy.

After a theoretical model is built, consensus and legitimacy of a part of the model is created through the gathering of survey information via persons in positions that acclaim the necessary expertise and knowledge on the subject. The model is then validated with the use of face validation.

1.5   Delimitations and Limitations

The research has certain delimitations and limitations. Delimitations are the boundaries set for the research, while limitations are the factors that are outside the researchers control.

It is important to note that the research does not aim to disprove causes of failure that are not caused by human behaviour. Existing research identifies situations that are excluded from the focus of the research, namely the failure of change management (the altering of work processes), complexity and failure of technology or a misalignment of the IS and the company's strategies. These are conventional explanations of IS failure. The technological errors and change management related causes of IS failures are not delimitations, but merely forms a part in the greater problem. Both are existent issues, though it does not shape the focus of the research.

The focus of the research is to find mainly human related causes of failure, as research suggest that it may be the most prevalent cause which has not been extensively researched (Reason 1995a; Reason 1995b; Wickens et $al.$ 2013).

These common human errors, referred to as failures, are defined in a comprehensive sense and are not limited to one specific definition. The definitions of failure in the theoretical background of the research are merely a collection of the most prevalent and common examples of failures.

With the use of existing literature, common human errors are identified which creates the concept of failure to which the research focus is delimited and a particular defined view of organisational context is formed that creates the situations (Howcroft and Trauth, 2005). The influential factors have been identified as technology, design, structure and the environment (Howcroft and Trauth 2005; Hall 1982).

The fact that the majority of literature regarding IS and the failure of IS is related to the health care sector is a limitation to the research (Southon *et al.* 1999; Lorenzi and Riley 2004; Lorenzi *et al.* 1995; Hovenga 1996; Devaraj and Kohli 2003) and case studies of IS failure are also very scenario specific, which both can lead to shortcomings in the research. Unfortunately due to the existing literature being undoubtedly scenario specific, it cannot be assumed to have the same effect or results on other IS situations. Even so, much can be learned from the literature and even applied to new research when a contextual scenario is identified. This is where the delimitation of context becomes essential.

Failure's dependence on its situational context means that causes of failure may differ depending on the type of organisation or corporate structures. For the purposes of the research the context will be limited to the internal operations in an organisation, an area where the organisation can exercise control.

Another delimitation is the exclusion of the focus on the type of technology or software used. Interactions with external organisations and the technical design of the technology itself will not be considered. Cooperation with external organisations can however realize greater advantages or weaknesses according to how these relationships are managed (Howcroft and Trauth 2005; Southon *et al.* 1999). While these benefits from communication between organisations cannot be ignored; nevertheless it lies outside the context of the research.

1.6   Thesis Outline

The first two chapters cover introduction to the research and the literature studied. Chapter 3 captures the steps to be taken in data collection, by covering the design and methodology of the research. Chapters 4 and 5 are based on the reviewed literature, where in depth and narrowed down research is done. In chapter 6 the model is constructed and in chapter 7 the constructed model is validated. The final chapter, chapter 8, includes the conclusions and recommendations which can be derived from the research completed.

Chapter 1 Introduction

Chapter 2 Literature Review

Chapter 3 Research Design and Methodology

Chapter 4 Identifying Generic Contexts and Human Errors

Chapter 5 Identifying Generic Causes and Solutions

Chapter 6 A Decision Support Model for IS Failures

Chapter 7 Validation of the Model

Chapter 8 Conclusions and Recommendations

The introductory chapter, **Chapter 1**, offers insight into the research. The background which leads to the problem statement and research questions is presented. The research objectives are formulated and an overview of the methodology used is included. The delimitations and limitations to the research are stated and it concludes with an outline of the thesis.

In **Chapter 2** an all-inclusive literature review is conducted on the topics relevant to the research. The main fields studied are human operated IS, the contexts where these IS may exist and causes to human errors. The work in this chapter serves as a basis for the remaining research process.

The research design and methodology are covered in **Chapter 3**. The chapter starts with an introduction to the concept of scientific research. The research design and methodology are discussed, as well as the reasoning methods contained in the research.

In **Chapter 4** the possible contexts where IS failure may occur and the human errors are identified. A list of the peer reviewed journal articles used to collect human errors are given with a description for each. The contextual part of the model is refined. The chapter is linked to Appendices A and B.

Chapter 5 provides the possible human errors and their causes and solutions. This leads to the building of the model itself in Chapter 6. Appendices C and D are linked to this chapter.

As all the factors are identified to build the model in the previous chapters, **Chapter 6** includes the constructed decision support model. The steps of the model are summarised and the actual model is visually represented.

Chapter 7 validates the model's applicability to a real world situation through face validity. The concept of validation is introduced and the actual validating actions are explained with the validation outputs.

The research concludes with **Chapter 8**, which summarises the research results. The contributions of the research are discussed and feedback is given on the validation, conclusions and recommendations for future research.

Chapter 2

Literature Review

2.1 Information Systems

This section's focus is to introduce IS, the value of IS in an organisation and how human resources are an essential factor to the functioning of IS.

2.1.1 An Introduction to IS

To comprehend the influence of IS and its importance to an organisation, the concept of IS must be understood (Curtis and Cobham, 2005). The two interdependent components of IS are technology and, through the application of scientific knowledge, people (Bourgeios, 2014).

Information in the form of numbers, text or unprocessed data is meaningless to an organisation (Stair *et al.*, 2008). Through the use of technology that processes the data, strategic value is added to information, creating what is called IS (Curtis and Cobham 2005; Daft *et al.* 2010). IS are then used by people in an organisation whom collect information to be processed and interpret the said information. IS can therefore be defined as the collection of information subsystems that interact with the organisational database, in order to provide feedback (Stair *et al.*, 2008).

Defining the type of IS used within an organisation is an important part of understanding the organisational environment wherein the IS operate (Howcroft and Trauth, 2005). While the type of IS used is important, the success of IS does not rely on sophisticated technologies or the type of technology used as tool to implement IS (Buruncuk and Gulser, 2001). The impact of implementation and skilled management of the technology used are the causes of successful or unsuccessful IS (Buruncuk and Gulser, 2001).

IS have three different phases, pre-implementation, implementation and post-implementation. Each phase has its unique characteristics, that creates

different environments of structure and coordination.

Pre-implementation of IS is concerned with the technology acquired and used within an organisation, and these technologies can vastly differ from one organisation to the other. The fit and the functioning of technology are within the control of a provider external to the organisation. Problems caused by the technology's design, software complexity or software malfunction are all caused by the developer (Bourgeios, 2014). The process of technology implementation is widely recognised as a determinant of the successful, or unsuccessful, use of IS (Joshi, 1991).

Thereafter is the implementation of the IS, which occurs post-sale, where the software or technology is usually installed, integrated, customised, tested and very importantly, the user is trained (Pathak 2005; Parthasarathy 2010). The software developer provides support after the IS has been deployed as insurance that the organisation's requirements are met (Pathak, 2005).

Following the conclusion of the implementation, is the post-implementation where the system is already operational (Sedera *et al.*, 2015). Here the new IS is encouraged as a normal activity and the hope is that the IS causes the organisation to realise its full potential (Parthasarathy, 2010).

2.1.2   IS and its Importance

With the application of IS tools are acquired that improve the performance of the organisation as a whole (Daft *et al.*, 2010). The timely and cost effective flow of information is a major component of organisational effectiveness and success (Hage *et al.*, 1971).

There are certain IS attributes that justify its value and importance to an organisation. Besides being timely and cost effective, information should additionally be accessible, accurate and relevant to the organizational operations (Stair *et al.*, 2008). Only with the correct input data can IS fulfil its role successfully and create a system of communication between the people in an organisation (Beynon-Davies 2009; Curtis and Cobham 2005; Gibson *et al.* 2012).

Feedback is however not easily obtained, the dynamic environment in which organisations operate results in complexities, volatility and ultimately a strong dependence on IS (Huber *et al.*, 2008). The need for current and more targeted information is necessary not only to gain competitive advantage, but for survival (Curtis and Cobham, 2005).

The system of communication between the people in an organisation created by IS, both internally and externally, shapes the way the organisation is structured (Gibson *et al.* 2012; Huber *et al.* 2008; Beynon-Davies 2009). From the external perspective organisations need to be up to date with for example demand and supply, market preferences and competitor actions (Curtis and Cobham, 2005). Internally there is pressure to be efficient and profitable and this requires current and meaningful information in order for an organisation to function (Curtis and Cobham, 2005). IS are the means by which people accomplish their routine or special tasks (Stair *et al.*, 2008). Organisations depend on the execution of their day-to-day activities (and long-term activities) to attain success (Huber *et al.* 2008; Beynon-Davies 2009).

The value of IS lies in its ability to aid in accurate and informed decision making in order to create business value (Huber *et al.*, 2008). The benefits observed include the reduction of uncertainty and faster, more timely decision making (Curtis and Cobham, 2005). Each organisation's IS therefore has its own objectives and their own measure of performance aligned with their strategy which should be applied to accurately achieve effectiveness and success (Curtis and Cobham 2005; Daft *et al.* 2010).

Organisations use IS every day and it is therefore an essential commodity for effective operations and should be aligned with the organisational strategy in order to be beneficial (Stair *et al.* 2008; Sprague and McNurlin 1993). Decision making forms part of an organisation's strategy, as decisions are based on the strategy followed. The strategic role of IS is to re-engineer business processes, to serve as an inter-organisational link that results in effortless communication and a higher quality of decision making (Sprague and McNurlin 1993; Curtis and Cobham 2005; Gibson *et al.* 2012).

To summarise, the most general purpose of IS is to support business processes and operations and ultimately aid in decision making (Howcroft and Trauth 2005; Davis *et al.* 1992; Bondarouk and Riemsdijk 2007; Lyytinen and Robey 1999).

2.1.3 The Role of Humans in IS

Organisational behaviour is the field of study that investigates the relationship between an organisation and the human resources within an organisation.

Organisational performance is highly dependent upon individual performance, creating the requirement for capable and competent human capital (Gibson *et al.*, 2012). Human capital is a resource created through learning that should lead to competitive advantage (Gambardella *et al.*, 2015).

More specifically human capital can be seen as the intangible asset consisting of knowledge and skills that are embodied in the people of an organisation (Abdel-khalik 2003; Coff *et al.* 2012), therefore an organisation's effectiveness is immensely influenced by human behaviour (Gibson *et al.*, 2012).

It has become increasingly evident that human capital has a powerful impact on an organisation's financial performance or success (Yuki and Lepsinger 2008; Gambardella *et al.* 2015). Growth in financial performance is influenced by cost reductions achieved by investing in human capital (Hatch and Dyer, 2004). In the continuously changing environment organisations find themselves in, their responsiveness and flexibility to change are critical (Yuki and Lepsinger, 2008). Only with strong human capital can organisations achieve these goals.

Past research has identified human resources as a key contributor to organisational performance and success (Barney and Wright 1998; Gambardella *et al.* 2015; Hatch and Dyer 2004). Research regarding humans and their social reality is a difficult concept to analyse due to its variability. Research tends to assume that humans are unpredictable and that human behaviour is strongly correlated to certain contexts or situations (Howcroft and Trauth, 2005). Therefore there exists a lack of clarity in understanding and interpreting human behaviour.

The implementation of IS is mainly seen as a technological problem, where it is most important to ensure the technology meets the human requirements (Southon *et al.*, 1999). Even though this remains important, it has become increasingly more important to consider more complex people related factors (Southon *et al.*, 1999). The importance of the relationship between people and the IS in an organisation is explained by the concept of social constructivism.

Social constructivism is defined as the belief that any social problem without technical components does not exist, and also that any technical problem without a social problem cannot exist (Howcroft and Trauth, 2005). Any attempt to separate the two components will lead to failure, where the desired outcome should be the sufficient utilization of human potential (Walsham, 1995).

Constructivism therefore sees technological, social and environmental aspects related to IS as indistinctive. It is rather seen as a system, where failures could occur because of misaligned interests within the system (Howcroft and Trauth, 2005). Misalignment exists between the people and the technology when people form their own views and interpretations of the technology, instead of accepting the truth as offered by training or managers (Bondarouk and Riemsdijk, 2007).

2.2 Contexts Where IS Exist

The organisational contexts where IS can exist serves as a basis for identifying causes of IS failure. This section's focus is to explain contextual relevance to identifying failures.

2.2.1 Organisational Theory

Organisational theory is the study of organisations, where amongst other similar definitions, (Daft *et al.*, 2010) defines organisations as:

1. A social entity,

2. driven and directed by goals,

3. that has a deliberately designed structure and coordinated activity system

4. and is linked to the external environment.

The success of an organisation to an overwhelming extent depends on its structure and coordination, which exist of human resources, to achieve desired goals. Organisations are deliberately structured to accomplish the organisation's purpose (Daft *et al.*, 2010). Coordination of resources within a structure is not possible without the effective use of IS. In turn, the successful use of IS therefore depends on the organisational context, the type of technology used and the capabilities or actions of the end user or operator of the IS (Bondarouk and Riemsdijk, 2007).

To resolve problems within an organisation, the created structure and coordination should be defined. While the structure of an organisation is developed through organisational design, coordination of resources is achieved by the implementation of IS, through the existence of technology.

2.2.2 Organisational Design

The structure of an organisation depends on the pre-planned design that should be created to fit that organisation best. Organisational design can be seen as the constructing and the changing of an organisation's structure to achieve its goals (Robbins 1983; Gibson *et al.* 2012).

The manner in which organisations are designed is essential to an organisation's performance and competitive advantage (Worley and Lawler III, 2010). The understanding of how organisations operate and how organisations influence and is influenced by the environment in which it operates, is key to organisational design. An organisation is designed to fit its operations, while operations should be aligned with the strategic goals set by the organisation (Hall 1982; Buruncuk and Gulser 2001). Only with knowledge of the organisational design, can the structure be analysed and organisational problems be diagnosed, in aim to solve these problems (Jones, 2004).

The main challenge of organisational design is the management of differentiation. Through the process of differentiation people and resources are allocated to their specific tasks. Here the division of labour establishes the degree of specialisation in an organisation (Jones, 2004). Differentiation in a complex organisation will be high, as the division of labour is higher. In contrast, differentiation in a simple organisation will be low. The division of labour is lower and fewer coordination problems exist due to the simplistic hierarchical layout (Jones, 2004).

The structural dimensions of an organisation are a result of choices made regarding the organisational design (Daft *et al.*, 2010). By identifying the structure of an organisation, key internal characteristics can be identified in order to distinguish between the different contexts in which organisations can exist (Daft *et al.*, 2010).

2.3   Organisational Structure

An organisation's structure is designed for an exact purpose, influences all activities and is shaped by the people within the organization. Gibson *et al.* (2012) and Daft *et al.* (2010) state that organisations are social systems. Within these social systems there are expectations for certain behaviours and roles to be played. A structure needs to be set in place for persons to take up their different roles and this creates the organisational structure.

Organisational structure can be expressed as the formal distribution of people along their different levels or groups and the social positions that influence the relations among these people (Gibson *et al.* 2012; Hall 1982; Daft *et al.* 2010). This expression can be separated into two parts. First, within the organisation there is a division of labour and the people are given tasks to execute. Secondly, organisations require hierarchy that divide people and position or group them together in their various tasks, each task operational under different regulations and authority (Hall 1982; Daft *et al.* 2010).

In order to produce their outputs and accomplish their goals, organisations need to control and shape the behaviour of persons employed (Daft *et al.*, 2010). Through control, human resources are coordinated and integrated in order to achieve set goals and organisational structure creates this basis of control (Jones, 2004). More importantly structure serves as a basic positioning of people, where it divides people of different power levels, formal reporting relationships, different decision making responsibilities and personal responsibility. Structure creates the lines of communication between people in their different department or division (Hall 1982; Daft *et al.* 2010).

The structure of an organisation relevant to human behaviour, explains how the nature and the content of IS are determined (Howcroft and Trauth, 2005), as structural context influences human activities and choices (Jaffal *et al.*, 2015). The structure of an organisation should be in harmony with the structure of IS (Buruncuk and Gulser, 2001). If the IS of an organisation does not fit it's structure, it will result in a lack of information or delayed operation that reduces effectiveness (Daft *et al.*, 2010). Research has identified characteristics, though they are not all inclusive, to assist in defining an organization's structure. These characteristics are size, centralisation, formalisation and complexity. (Robbins 1983; Daft *et al.* 2010).

2.3.1 Size

The size of an organisation may appear to be a simple variable, by assuming an organisation size can be found by counting the number of people in an organisation. As organisations are social systems, it is typical that size is described by the number of people employed (Daft *et al.*, 2010). The size factor is however more complex (Hall, 1982).

There are four identified components that collectively can define the size of an organisation (Hall, 1982). The most commonly acknowledged component is the people available to an organisation. The amount of people is a strategic decision and therefore the choice between a large amount of people or a small amount of people is formed coherently with an organisation's strategy (Hall, 1982).

Except for the amount of people in an organisation, the physical capacity of an organisation is another component when defining the size of an organisation (Southon *et al.*, 1999). Furthermore there is the component of organisational inputs or outputs, which involves factors such as the number of clients an organisation has (Hall, 1982). In additional a component affecting the size is the discretionary resources available to an organisation, in terms of assets or wealth (Hall, 1982). All these components of defining size are in most instances

highly correlated, yet at the same time they are distinctive concepts.

2.3.2 Centralisation

The centralisation of an organisation considers where the decision making authority lies and can be measured by the number of groups that participate in strategic decision making, relative to the total number of groups present (Hage *et al.* 1971; Robbins 1983; Gibson *et al.* 2012; Daft *et al.* 2010). The level of participation should also be emphasized (Hall, 1982). The smaller the level of participation exercised by a smaller number of groups, usually retained at the top of the hierarchy, the more centralised an organisation will be (Jones, 2004).

Centralisation is dependent of the geographical location and dispersion of an organisation (Segura *et al.*, 2013). Due to the complexity of organisations, collaboration is required across all levels and people. If an organisation is geographically dispersed, this can affect its ability to reach strategic goals due to a lack of coordination and collaboration (Segura *et al.*, 2013).

Amongst other influences, the degree of centralisation depends most critically on the level of authority people hold and the degree of delegation (Gibson *et al.*, 2012). Usually when an organisation's people are spatially dispersed, the differentiation causes that important decisions are only made by the higher levels of authority and the situation can be considered as centralised (Segura *et al.*, 2013). In contrast, in organisations that have one or more, but geographically close, physical locations decision making is delegated and spread amongst people. This situation can be considered as decentralised (Hall, 1982).

It is important to note that even if many decisions are made by the lower levels hierarchy, or say operating personnel, they may be preprogrammed by policies. If the situation is highly influenced by such decision making policies, the structure still remains centralised (Hall, 1982).

Decentralised structures are identified by few policies and procedures and centralised structures are identified by many policies and procedures (Hall, 1982). With decentralisation the authority to make important decisions is delegated to more, or all, levels of hierarchy (Jones, 2004) and the level of participation is spread through these levels (Hage *et al.*, 1971). The delegated authority enables people at lower levels to make decisions and gain skills which enable them to cope with problems higher management could face (Gibson *et al.*, 2012).

Large organisations are assumed to be centralised more often, as the increasing size of an organisation is related to the increase of policies and proce-

dures(Hall *et al.*, 1967). It becomes more difficult to control an organisation from the top levels of hierarchy when a large group of people, whom are typically separated by space, are employed by an organisation (Gibson *et al.*, 2012). This results in an even higher reliance on IS for coordination and communication (Daft *et al.*, 2010). Even though most see a larger organisation size as a situation of inevitable delegation, size is not the only contributing factor to centralisation (Hage, 1980).

Both centralised and decentralised organisations have their own advantages and disadvantages. Centralised organisations tend to be more coordinated and goal orientated, which strongly follows the organisational strategy. The issue that can occur due to centralised organisations, is when the top level of hierarchy become overloaded, and cannot focus on their strategic decision making responsibilities (Hall, 1982).

Decentralised organisations promote decision making at lower levels of hierarchy, which leads to simplification, flexibility and responsiveness (Southon *et al.*, 1999). Decisions can be made quickly, as there is no need to wait for approval from higher levels of hierarchy (Hall, 1982). When decisions are made at the lower levels it facilitates simplicity and leads to higher success in the implementation of IS (Hall, 1982) (Southon *et al.*, 1999). The problem is that when decision making is so widely spread throughout the organisation, the planning and coordination becomes difficult to control. This may lead to the misalignment of the organisational strategy (Southon *et al.*, 1999).

2.3.3 Formalisation

The concept of formalisation, described as the level of standardisation, is seen as the most fundamental structural variable for people, as human behaviour is highly affected by the degree of formalisation in an organisation (Hall 1982; de Toni and Nonino 2010; Robbins 1983).

There is an inverse relation between the amount of human discretion and the level of pre-set expected behaviour set by the organisation (Hall, 1982). The amount of pre-set behaviour or formalisation is influenced by an organisation's decision makers and to what extent they believe the people are capable of exercising self-control and excellent judgement. If people are viewed as incapable of executing such responsibility, more rules will be needed to guide their actions and the more rules present, the higher the formalisation (Hall 1982; Daft *et al.* 2010).

The extent to which the lines of authority, namely the rules and regulations, vary can be classified as either formal or informal (Ballou, 2004). There

exist different levels of standardisation and variation within each formal and informal organization structure. An organisation can either be formal or informal depending on the degree to which people are responsible for themselves instead of others (Brijball Parumasur, 2012).

A formal structure exists when the rules and regulations are highly preprogrammed for the people within the organisation and these people have little to no input regarding the way their job is executed (Robbins, 1983). The actions of people are highly predictable, as the decision making process is standardised (Jones, 2004). When there is a low range of variation within a job position, the structure can be classified as formal (Hall, 1982). Usually when a structure is formal, the authority within an organisation is centralised (Jones, 2004).

An informal structure is the exact opposite of a formal structure, where people can use their own discretion or intuition. Situations are not preprogrammed and are usually unique, which means a high level of variation and freedom (Hall, 1982).

(Hage, 1980) states that "Formalisation is measured by the proportion of codified jobs and the range of variation that is tolerated within the rules defining the jobs". Therefore it can be said that the level to which an organisation depends on rules, regulations and procedures in order to direct behaviour can classify it as either formal or informal (Robbins, 1983).

2.3.4   Complexity

Complexity in an organisation is another vital component of organisational analysis (Hall *et al.*, 1967). The complexity of an organization has a significant influence on the employed human behaviour, processes internal to an organisation and the external relationship between an organisation and the environment it operates in (Jones, 2004). Complexity is seen as the hierarchical separation or dividing of labour with identifiable aspects such as job titles, separation in divisions, the degree of specialisation, the types of labour, the salary earned by each individual or the geographic dispersion of organisational units (Robbins 1983; Gibson *et al.* 2012). The hierarchical separations are necessary in order to control and coordinate the activities within an organisation (Hall, 1982).

The concept of complexity has three most commonly identified components: horizontal differentiation, vertical differentiation and spatial dispersion (Hall 1982; Hall 1982).

The horizontal differentiation of an organisation is the separation, grouping and subdivision of necessary organizational tasks to people within an organisation (Hall 1982; Robbins 1983), such as the number of job titles (Armandi and Mills, 1982). Even though organisations are composed of all three components, an organisation may be more horizontally than vertically structured, and vice versa.

The degree to which jobs and tasks are divided into separate jobs is called specialisation (Daft *et al.*, 2010). There are two basic ways in which tasks can be divided. Well trained specialists can be assigned a comprehensive range of activities to individually execute tasks or tasks can be subdivided and assigned to unspecialised people (Hall, 1982). Regardless of the division of tasks, each person is responsible for their own task and the completion thereof.

Horizontal complexity is correlated to the level of specialisation within an organization. The specialisation can be determined by the number of occupational specialities and the professional training required by each of these specialities (Hage *et al.*, 1971). Therefore if there are a large number of occupations and the training period required is longer, the more complex an organisation will be (Hall, 1982).

Such horizontal complexities limit communication between the different organisational levels (Hall, 1982). In order to avoid communication difficulties organisations strive to find improved means of integrating functions and tasks (Hage *et al.*, 1971).

Vertical differentiation is less complex than horizontal differentiation. It can be seen as the coordination of activities between the top and bottom levels of an organisation to create control (Daft *et al.*, 2010). Research has found straightforward and simple indicators regarding the depth of vertical differentiation (Robbins, 1983). A few of the indicators or measurements found by researchers are counting the number of job positions, or rather levels, between the highest ranked person of authority and the people that work on the organisational output or finding the number of levels in the deepest single division (Hall, 1982). It should be noted that these indicators do however assume the critical fact that "authority is distributed in accordance with the level in the hierarchy; that is, the higher the level, the greater the authority" (Hall, 1982).

The vertical differentiation within an organisation's goal is to improve its functionality, by establishing hierarchical levels of authority. These authority levels define each person's accountability and responsibility (Hall, 1982).

The majority of research done on vertical differentiation does focus on the size of an organisation. It has been found that size and vertical differentiation

are highly correlated. As the size of an organisation increases, the number of the levels of hierarchy will most probably increase (Hall, 1982).

Each task has a horizontal and vertical dimension and the differentiation caused presents an organisation with issues related to control, coordination and communication (Jones, 2004). The greater the differentiation within an organisation, the greater these issues become and the greater the possibility of these issues occurring (Hall, 1982).

Spatial dispersion can be a form of either horizontal or vertical differentiation. An organisation's activities and people can be dispersed in terms of space, where they are operational in various or distant geographical locations (Hall, 1982).

The effect of complexity caused by structural differentiation is differences in attitude and behaviour by people in the differentiated levels or departments (Hall, 1982). These differences include the goals of each department, the type of structure, the level of formalization and outlooks. Therefore it can be said that the various departments have differing tasks, but also has differences in behaviour and perspectives.

The more unified an organisation is between departments, the higher level of collaboration and levels of integration, which leads to less complexity (Hall, 1982). It is clear that it is difficult to identify the complexity within an organisation as it considers the extent of differentiation, which is definable by a range of aspects (Robbins, 1983).

2.3.5   Summary

With organisational design it should be kept in mind that organisational change may occur, which can change the original structure of the design to be aligned to new strategies and goals (Jones, 2004). Nevertheless, whether change is applicable to current decision making or not, it has always been an organisational challenge to balance complexity, formalisation and centralisation (Jones, 2004).

The effective structure of an organisation depends on the certain circumstances or context of its design. Design, structure and context are therefore highly dependent on one another to achieve the best organisational fit. In order to establish the structure and design of an organisation, it can identify itself with one of the two circumstances per concept.

2.4   Identifying Causes of IS Failure

This section covers the importance of an organisation's environment and the IS user's level of expertise. It concludes with the classification of IS failures caused by human error.

2.4.1   Operational Environment

An organisation's structure and environment are greatly influenced by each another. All organisations depend on its environment to some extent (Robbins 1983; Buruncuk and Gulser 2001). Environmental uncertainty and organisational complexity are inversely related and the same can be said for formalisation. In environments that are stable, it should lead to high levels of organisational formalisation. Lastly, more decentralised organisations are linked to a more complex environment.

The relationships between the environment and complexity, formalisation and centralisation are however complicated (Robbins, 1983). The extent to which the environment has an influence on an organisation is linked to its dependence, in which case each organisation is unique (Robbins, 1983).

One of the most obvious characteristics of an organisation is its dependency on the environment (Robbins, 1983). An organisation's environment can be seen as both general and specific. The general environment includes technological changes, economic conditions, legal and political conditions and the social conditions. All factors that may potentially influence an organisation, but are uncertainties that the organisation has no control over (Robbins 1983; Reason 1995*a*).

The specific environment directly influences an organisation's ability to achieve its goals (Robbins, 1983). The specific environment can be managed by the organisation itself and the manner in which it is managed can result in either it's positive or negative effect on organisational effectiveness (Robbins, 1983). The specific environment is unique to each organisation, therefore it is crucial to identify an organisation's environment to identify causes of IS failures.

Interrelating factors that have been identified directly influencing an organisation's specific environment are politics and power, change, culture and of course the physical environment (Southon *et al.* 1999; Robbins 1983; Shafritz and Steven Ott 2001; Gray and Starke 1984; Daft *et al.* 2010).

Starting with the influence of politics and power, it is important to understand the difference between authority and power (Robbins, 1983). Authority is a person's right to act or make decisions due to their position, while power is any individual's ability to influence decisions. Power is very contextual and relationship specific (Shafritz and Steven Ott, 2001). This means that one does not necessarily require authority to have an influence on decision making. A power struggle typically exists when internal constituencies seek to further their own interests and heavily influences internal relationships in an organisation (Robbins 1983; Shafritz and Steven Ott 2001).

Politics involves how different preferences between organisational members are resolved in conflicts, usually by using power (Gray and Starke 1984; Shafritz and Steven Ott 2001). Conflict in an organisation is seen as behaviour by certain members that are in opposition to other members. It is a purposeful behaviour or effort made by a member, which as a result further their own interests or goals while obstructing the achievement of other member's goals (Robbins 1983; Gray and Starke 1984).

Politics, power and control are highly interrelated concepts. To enhance power and control, people in power will seek structures that are low in complexity (Robbins, 1983). Power has an impact on both the formalisation and centralisation of an organisation. People in power are able to influence the intensity by which policies and procedures are implemented (Shafritz and Steven Ott, 2001). Control is usually desired by those in power, it is expected that an organisation is highly formalized. Centralisation is defined as the degree to which power and decision making are distributed. The more power exercised the more centralised an organisation would generally be (Robbins, 1983).

Another influence on the organisational environment is change and the management thereof (Gray and Starke, 1984). An organisation is continually faced with a dynamically changing business world and therefore adaptability is a crucial characteristic to possess. It is important for an organisation to remain current and effective and therefore change must be confronted (Robbins, 1983).

The levels of change can be analysed by the parties involved in the change process, namely the individual, groups or the entire organisation (Gray and Starke, 1984). The impact of change on each party will be unique to each situation as it depends on the magnitude of the change (Robbins, 1983). Some changes will be large and highly influential and others may be small and have little or no impact (Gray and Starke, 1984). As an example, a change that has little impact on an organisation as a whole can be the creation of a new staff department, while a major change would be the major restructuring of the organisation (Gray and Starke, 1984).

Research suggests that the higher the level of complexity, the greater the rate of change in an organisation (Robbins, 1983). In the case of formalisation, the rate of change is usually lower when the degree of formalisation is high. Corresponding to the case of power, centralisation is inversely related to change (Robbins, 1983). The resistance to change is where the organisational difficulties occur (Gray and Starke, 1984). Typically people within positions of power are resistant to change, as structural changes usually redistribute power (Robbins, 1983).

Culture aids in understanding the hidden and complex social aspects of organisational life (Shafritz and Steven Ott, 2001). Organisational culture can be seen as the basic shared assumptions learned by a group of people while adapting and integrating (Shafritz and Steven Ott, 2001). These assumptions are then considered valid and new members are trained in the same manner.

IS failures that have been caused by human errors can be identified by knowledge of the environment an organisation operates in.

2.4.2   Social Learning and Expertise

The state of employment, identified by considering the level of training, experience and expertise, has an influence on the identification of IS failures caused by human errors (Howcroft and Trauth, 2005). After the organisational context has been be identified, the social learning framework should also be taken into account. The act of social learning can be defined as the discovery, analysis and understanding of an IS (Howcroft and Trauth, 2005).

Kolb (1984) considered the concept of learning as a process, rather than purely outcomes, and this process will always be practice orientated. A user will gain familiarity with the use of a system, herewith gradually improving their performance over time (Bondarouk and Riemsdijk, 2007). This gradual improvement of performance is recognised as the learning curve.

One of the most strategically important requirement of an organisation is the possession of internal knowledge. Internal knowledge can only be generated from an organization's own experience (Lyytinen and Robey, 1999). Experience is gained through learning by using and this provides a valuable source of information for research purposes (Howcroft and Trauth, 2005).

It is important to note that human skills are not easily obtained, these skills are rather expensive and there is no guarantee that the skill will be retained within an organisation (Southon *et al.*, 1999). While the necessary training could have taken place in the past, new employees or users may lack not only

the experience, but adequate training, if not implemented as a continual process (Howcroft and Trauth, 2005). In theory there should be an on-going process of professional development between human resources and information systems (Bondarouk and Riemsdijk, 2007). Organisations seem to be too focused on the present, rather than considering their future (Howcroft and Trauth, 2005).

The level of expertise possessed by a user who has worked with the same IS for five years, cannot be compared to a user who is new to the exact same IS (Kay, 2007). Therefore, whether a person has been employed for say less than a year, versus more than five years, will have a significant influence on their expertise and capabilities due to the level of experience and training (Ericsson and Smith, 1991).

2.4.3 Human Error Identification

There are many different approaches for classifying human error, termed Human Error Identification (HEI) (Cheng and Hwang 2015; Wang and Zhao 2009; Walia and Carver 2009). Most of the existing techniques are based on or influenced by that of Rasmussen *et al.* (1981) and Reason (1990).

The human error analysis technique is the SRK behaviour model, with three categories of human error: skill-based mistakes (slips and lapses), rule-based mistakes and knowledge-based mistakes (Reason 1995*a*; Reason 1995*b*; Wickens *et al.* 2013; Kay 2007; Lopes and Forster 2013).

Skill-based mistakes are deviations from desired outcomes. With slips and lapses failure occurs at the level of execution, while mistakes can present itself only after a problem is detected (Reason 1995*a*; Reason 1995*b*; Kay 2007). Problems are anything that makes an alteration or change of a plan necessary. Either or both of these human errors can possibly occur given a certain situation (Wickens *et al.*, 2013).

Skill-based mistakes are those errors that are caused by the failure of planned actions in order to achieve the desirable goal. They occur when the plan is suitable, but the related actions do not go as planned and failure of execution occurs (Kay 2007; Ju and Burnett 2007). Slips are those failures related to observable actions and are generally identified as attentional failures (Reason, 1995*a*). Lapses are seen as failures of memory and may involve for example the omission of steps in a procedural sequence (Wickens *et al.*, 2013). These failures are mostly the actions that occur with the automatic performance of routine tasks and are unintended, but incorrectly executed (Wickens

et al., 2013).

Mistakes, on the contrary, occur when the plan is inadequate to achieve the desirable goal, while the actions are executed as planned (Reason 1995*a*; Kay 2007; Lopes and Forster 2013). The failure occurs at a higher level and is related to shortcomings of mental processes involving memory, planning, perception, judging and problem solving (Wickens *et al.*, 2013).

Rule-based mistakes are when failures related to familiar or trained-for problems occur, where the user believes they know the rule to deal with the situation (Wickens *et al.*, 2013). A mistake occurs if a user then applies the wrong set of rules, thinking it is correct, to the situation (Kay, 2007). Typically a good rule that is frequently applicable is misapplied by the user, due to the failure to notice contradictions to the problem (Reason, 1995*a*). Or a bad rule that has not yet been corrected, is applied (Reason, 1995*a*).

Knowledge-based mistakes occur when a user is faced with a unique and uncommon situation that is not within the pre-planned problem solving routines that the user possesses (Reason, 1995*a*). As the knowledge and expertise to solve the problem are limited, frequency of error and the time frame to solve the mistake are greater (Wickens *et al.*, 2013).

The SRK behavioural model, though not the only existing classification, satisfies the basic needs prevalent when attempting to classify and understand human error (Kay, 2007).

2.5   Summary

The literature review highlights the importance of IS and human interaction and the requirement thereof, existing due to the continual occurrence of human error. Therefore the organisation and the factors having an influence on the creation of organisational situations where human error may occur, are reviewed in order to identify the causes of these human errors. All factors necessary in identifying human errors are reviewed. With the reviewed literature as a basis for understanding the possibilities of human error, a meta analysis is possible.

Chapter 3

Research Design and Methodology

This chapter is a discussion of the research design and methodology used. First there is an overview research methodology used, followed by the chosen research approach and concluding with the reasoning methods used in the fieldwork stage of the research.

3.1   An Introduction to Scientific Research

Research is a search for knowledge, where scientific research creates truthful and reliable knowledge (Mouton, 2001). Creating knowledge implies that a theory must be generated, developed or tested (Morais, 2010). Science has therefore developed guidelines in order to benchmark the means of measuring the validity and results of research.

Applying guidelines, or scientific methods, means following a set of assumptions and procedures to gain scientific knowledge that is consistent with scientific norms (Morais, 2010). Methodology can therefore be seen as the philosophical worldview or stance that informs a certain style of research.

This leads to the creation of the scientific approach to the research.

3.2   Research Approach

Given the science of research, the research approach is defined. As there is no standard format, the research approach is the specific procedure chosen for research (Davies, 2006). There are three main approaches, namely quantitative research, qualitative research and the pragmatic approach (mixed methods) (Rosaline, 2008).

The research itself, the means of data collection and the type of data to be used dictate which approach is to be used in order to gain relevant scientific knowledge.

3.2.1 Research Design

The design of research defines the type of study, the research questions and even the methods of data collection. The choice of research design is important, as it influences all the outcomes of the study (Miller and Salkind, 2002). There is a need for structure and justification of the logic followed in the research process. Therefore all the elements of research design need to be considered when selecting the appropriate research design.

The possibilities for research design are quantitative, qualitative and pragmatic (Rosaline, 2008). Quantitative research can be seen as empirical enquiry, as it usually involves the collection and conversion of data into numerical forms to be able to draw conclusions (Holliday 2007; Balnaves and Caputi 2001). Qualitative research attempts to uncover the significance of human behaviour, by its recording and analysis. The pragmatic approach uses different yet complementary approaches by using procedures associated with the quantitative and qualitative approaches (Rosaline, 2008). More freedom is used in order to create a method best suited to the situation.

The research opportunity is created by exploring social variables and is descriptive in nature. A qualitative design provides an understanding of these variables created through social processes (Rosaline, 2008). Qualitative research can be a means for social scientists to present their explanations and interpretations as theories, models and frameworks.

In order to answer the research questions, qualitative methods will be used, as the result will be of a descriptive and interpretive nature. The data on which the research is based is taken from different sources, but the common statements based on validated evidence, is the basis on which the research is formed (Rosaline, 2008).

Therefore the research design will be of a qualitative content analysis design. Content analysis is a flexible method for analysing text data and has been defined as "a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" (Hsieh and Shannon, 2015). Content analysis allows the research to understand social reality in a subjective and scientific manner.

Factors that determined, and to a certain extent shaped the research design, are the availability and type of data, the data gathering method which is influenced by the duration of the study and the presence of valid data. Only if all the content analysed is valid, can this research's conclusion be true.

3.2.2 Research Methodology

Through the application of the chosen research design, different stages are used to solve the problem statement through answering the research questions. These stages are adapted from (Wierzbicki *et al.*, 2000) which evaluates the methodology used behind the creation of decision support systems. In the first stage the qualitative method is implemented, by doing a content analysis of valid existing literature. The content analysis is used to shape the research, identify the background and justify inclusions and exclusions to the research.

The second stage encompasses the identification of human errors and the scenarios that may cause these errors. The content analysis in the first stage is the basis from which the sources of peer reviewed journal articles are identified for use. Articles used are then further narrowed down by the use of criteria adapted from (Walia and Carver, 2009). The final model building variables are collected in Microsoft Excel (from here on referred to as Excel), where it is sorted, grouped, interpreted, counted and frequency of occurrence is calculated.

The findings from a part of the model and is then surveyed by a panel of experts by using GoogleForms. The part of the model where there is a need for connection between contexts and causes of human error, lacks scientific evidence. With the input from the panel of experts, the findings are edited and changed accordingly.

After existing research is analysed, model building variables are identified and survey research is completed, the decision making model is built. This stage compiles the findings from the prior stages in order to build the model.

In the final stage after the model is built, face validation is used to measure the representativeness of the decision support model. Face validity is a means of testing the degree to which a research project measures what it claims to measure (Adams and Lawrence, 2014). After validation feedback, the aim is to have developed a decision support model that can easily and repeatedly be used in situations identified by the model. The model must aid decision makers in avoiding or reducing human error.

3.3   Reasoning Methods

Deductive and inductive reasoning are processes of making inferences that are used to ground different approaches to social science research (Salkind 2010; O'Leary 2007). Deductive reasoning starts at a general theory to create specific examples, while inductive reasoning follows the opposite path. Inductive reasoning moves from specific examples to create a general theory (O'Leary, 2007).

Both types of reasoning are present in this research. Deductive reasoning is used to create the problem statement and research questions, as deductive reasoning starts with a theory, by conducting the literature review (O'Leary, 2007). The same reasoning is used when conclusions are drawn from the content analysis.

There is an openness to various possibilities after deductive reasoning is completed. The goal is to put forth findings or even theories that aid in explaining a certain phenomenon. As deductive reasoning starts with a theory, inductive reasoning starts with a question.

Inductive reasoning is applied when conclusions are drawn from the feedback given by the expert panel collected by sending surveys via e-mail through GoogleForms. The validation stage also uses inductive reasoning. The model is tested through the use of and insight is gained from the feedback and can be generalised and conclusions are then drawn.

This chapter discusses the research design, methodology and reasoning methods used. The chapters that follow are an application of the chosen approaches.

Chapter 4

Identifying Generic Context and Human Error

Due to the impact that IS failure have on organisations (as discussed in Section 1.1), it emphasises the need for the decision support model. This chapter covers the identified factors from content analysis of established and existing literature in the development of the decision support model. Firstly the identification of context is justified as a basis that influences the causes of human error. With the content review, a short list of contexts and human error is created. The chapter then concludes with the connection between context and human error related causes of IS failure. To summarise, this chapter identifies contexts where IS failures exist and the human errors that cause these failures.

4.1   Introduction

Content analysis is a research tool used in the creation of a contextualised interpretation by using a wide range of texts. The transformation of the content lies in the creation of new manageable categories and the analysis thereof.

For the purposes of the research the procedure proposed by (Villemuir, 1992) is used. The Systematic Human Action Reliability Procedure (SHARP) is a four phased approach, consisting of the following activities:

1. Identification of potential human error – by using literature suitable for identifying possible human errors (and contexts where they may exist) – Chapter 2.

2. Selecting significant errors – An analysis of all existent errors is not viable, therefore significant errors should be chosen according to set criteria – Chapters 4 and 5.

3. A detailed analysis of significant errors – Chapters 4 and 5

4. Integration into a system model – Chapter 6

The possible human errors and the criteria by which they are chosen is therefore established in this chapter.

4.2   Identifying IS Contexts

Contexts hold information which can be used to characterise a situation (Jaffal *et al.*, 2015). The elements of context have a direct influence on a humans choices and activities (as stated in section 1.1). By understanding its influence, the causes of human error can be best identified (Jaffal *et al.*, 2015).

4.2.1   Structural Contexts of IS

Structural contexts that could exist within an organisation reflects a user's actions and in order to better analyse the impact of structure, elements of structure have been identified (Jaffal *et al.*, 2015).

Despite the literature that investigates the relationship between size and structure (in Subsection 2.3.1), it should be noted that size is not a strong indicator of organisational structure (Hall *et al.* 1967; Robbins 1983). Assumptions such as large organisations are more complex and formalised than small organisations may not be feasible for research purposes (Hall *et al.*, 1967). Knowledge about the impact of size is inconclusive and contradictory and already interlinked with the concepts of centralisation, complexity and formalisation. Therefore focus is set upon the centralisation, complexity and formalisation of an organisation as discussed in Subsections 2.3.2 to 2.3.4 (Hall *et al.*, 1967).

The concepts of complexity, formalisation and centralisation are most generally not taken to their extremes (Jones, 2004). Even so, an organization does lean more towards for example a decentralised than a centralised structure. The classification between these two circumstances, for each concept, is a necessity to the model. An organisation can identify with one of the two circumstances per concept.

Centralisation could be classified as either centralised or decentralised, complexity as either integrated or differentiated and formalisation as either formal or informal (Section 2.3). An organisation could possibly operate under any

combination of these diverse situations.

The criteria for each classification can be described under basic definitions of the structural situations in Table 4.1. The classification criteria have been assembled through the use of mainly the following six sources: Gibson *et al.* (2012), Daft *et al.* (2010), Hall (1982), Jones (2004), Robbins (1983), Hage (1980) and Southon *et al.* (1999).

Centralisation	**Centralised**	**Decentralised**
The distribution of power	Undistributed/top-level power and decision making	Distributed power and decision making
Formalisation	**Formal**	**Informal**
The emphasis on rules and regulations	Many policies and procedures	Few policies and procedures
Complexity	**Integrated**	**Differentiated**
The degree of personal specialisation	Higher levels of inter-departmental coordination; common corporate culture	Lower levels of inter-departmental coordination; diverse corporate culture

Table 4.1: Structure identification criteria

There are three concepts each with two possible scenarios, though within each of the three concepts, more than two different scenarios may exist. From the literature study in Section 2.4.1 these concepts can be broken down into more organisational environment specific levels, namely politics and power, culture, change and the physical environment.

According to the research in Section 2.3, issues regarding politics and power are both centralisation and formalisation orientated. The close relationship between the structural characteristics centralisation and formalisation, means that they mutually reinforce the same political standards (Willems and Jegers, 2012). The complexity of an organisation, according to it's definition and research in Section 2.3, is linked to both culture and change. Each situation is linked to its relevant environment specific level in Table 4.2.

Structure classification	Environmental classification
Centralisation	Politics and power
Formalisation	Politics and power; physical environment
Complexity	Culture; change

Table 4.2: Organisation environment connections to structure

With the alignment between the structural and environmental factors, related identifiers can be formulated based on the research in Section 2.3 and 2.4 in order to depict an organisation's situation. Through the use of these ten identifiers in Table 4.3 the context of an organisation can be linked to the causes of human errors.

Environmental classification	Identifiers
Politics and power	Power to make decisions
	Authority to make decisions
	Number of rules and regulations
	Level of standardisation of work/tasks
	Communication amongst developers (of IS)
Culture	Complexity in terms of communication culture
	Communication amongst users
Change	Has a change recently occurred
Physical environment	Physical environment comfortability
	Physical environment privacy

Table 4.3: Environmental specific identification criteria

4.2.2   IS User Expertise

As stated in Section 1.1, the research is not concerned with the type of technology used and therefore it does not form part of the process of identifying causes of human error. The focus lies in the fit between technology and people and the effect the fit has on the output (Hall, 1982). The research focus is concerned with the people component of failure in IS, as issues exist beyond the technology itself (Bourgeios, 2014). The integration of technologies and people into an organisation is the primary focus of the research in order to

identify possible causes of human error that leads to failure.

Causes of human error occurring within the internal environment and at the post-implementation phase, where the technology is already embedded and operational within an organisation are identified. The pre-implementation phase can be defined as the choice, design and engineering of technology prior to implementation within an organisation (Howcroft and Trauth, 2005). The pre-implementation phase is created in an environment external from the organisation's operations and is not a contributing contextual factor to the research (Section 1.1).

Post-implementation situations where failures are present in IS are related to the internal environment. There exists a lack of literature regarding failure after implementation, implying the time frame after the organisational change has become standard and common and the IS are already in use (Section 1.1). Organisational change has come and gone, but failures continue to occur. The challenge is to find the reason why these failures occur when the technology itself or organisational change cannot be to blame (Bondarouk and Riemsdijk, 2007) (Section 1.1).

Therefore research looks beyond the technology to identify human behavioural causes of failures within an organisation, after implementation has taken place, in order to internally be able to solve, prevent or avoid failures (Southon *et al.*, 1999). The research aims to trace these internal human behavioural causes that follow after the choice of technology and the implementation thereof have been made.

After the establishment of the environment in which IS users can operate, the learning curve, as discussed in Subsection 2.4.2, should be taken into account as another context indicator.

It is to be expected that a user's ability to operate a certain software will affect the frequency and impact of errors that could be made (Kay, 2007). Even so, measuring general basic abilities cannot predict success or failure. The classification of these basic levels of expertise can aid in identifying causes of failure. According to the widely used framework by Ericsson and Smith (1991) users can be classified as either a layperson, beginner, novice, intermediate, subexpert or expert:

Layperson An individual who possesses only common sense or everyday knowledge of the domain.

Beginner An individual who has the prerequisite knowledge assumed by the domain.

Novice A layperson or a beginner.

Intermediate Is by default defined as anyone who is above the beginner level, but below the expert level.

Subexpert An individual with generic knowledge, but has inadequate specialised knowledge of the domain.

Expert An individual with specialised knowledge of the domain.

Ericsson and Smith (1991)

An expert, or advanced user, is expected to outperform a user classified as a beginner, due to differences in familiarity and social learning (Kay 2007; Ericsson and Smith 1991). Insufficient experience, a lack of proper training or unfamiliarity with IS may be a cause of failure for a user at the beginner stage, while an advanced user's causes of failure could be more complex (Howcroft and Trauth, 2005).

For the purposes of the research IS users must be identified under certain criteria. The criteria should be relevant to the environmental scenario identified and scientifically be able to justify classification of users according to their position on the learning curve.

The most socially identified with classification of people still tend to be either one or the other, either beginner or expert (Ericsson and Smith, 1991). Therefore not all six classifications are considered and the levels in between beginner and expert do not form part of the model. A person may however not be a beginner or a expert, but when a user's advancement is closer to that of an expert than a beginner, the user should be classified as an expert, and vice versa.

The simplification of classification to either beginner or expert is justified in Subsection 2.4.2 where the impact of the learning curve is explained.

4.2.3   Short List of Context Indicators

The final list of context indicators and their definitions are as follows:

Domain is defined as the technology employed by an organisation

1. **Decision making power** The extent to which the power (*power is any individual's ability to influence decisions*) to make decisions is distributed. Where many people can influence decisions, an organisation is distributed. Where few people, say only top management, can influence decisions, an organisation is undistributed.

2. **Decision making authority** The extent to which the authority (*authority is a person's right to act or make decisions due to their position*) to make decisions is distributed. Where many people can make decisions, an organisation is distributed or where few people, say only top management, can make decisions, an organisation is undistributed.

3. **Number of rules and regulations** The extent to which the rules and regulations are preprogrammed, which is the level of structured input towards job execution. Where the rules and regulations are highly preprogrammed, the rules are many or where the rules and regulations are minimally preprogrammed, the rules are few.

4. **Level of standardisation of work/tasks** The extent to which human discretion is allowed and the level of pre-set expected behaviour. Where there is little pre-set expected behaviour, standardisation is low and where there is much pre-set expected behaviour, standardisation is high.

5. **Complexity in terms of communication culture** The level to which an organisation is coordinated and shares a common corporate culture. Where high coordination in an organisation exists, it is integrated and where low levels of coordination exist, an organisation is differentiated.

6. **General communication** The level of communication between users of the same IS. Where high levels of communication between users exist, it is classified as high or where there is little communication between users, it is classified as low.

7. **Developer communication** The level of communication between users and the developers of the IS. Where high levels of communication between users and developers exist, it is classified as high or where there is little communication between users and developers, it is classified as low.

8. **Occurrence of organisational change** If a change to the organisation or organisational structure is present, it is still an ongoing process or if change is not present, it has already occurred and been finalised.

9. **Physical environment comfortability** The extent to which the physical environment makes a user comfortable, for example temperature and

lighting. Where a user is uncomfortable, the classification is low or where the user is comfortable, the classification is high.

10. **Physical environment privacy** The extent to which the physical environment creates private and undisturbed work ethic. Where a physical environment with an open seating plan and open door policy would give low levels of privacy or where a physical environment with closed office spaces would give high levels of privacy.

11. **Employment** Where an individual who has the prerequisite knowledge assumed by the domain is a beginner and an individual with specialised knowledge of the domain is an expert.

4.3 Identifying Human Errors

A search is conducted by using human error literature with the purpose of explicitly identifying errors that may cause IS failure. A list of peer-reviewed journal articles (from here on referred to as journal articles) related to the research focus are used in the identification of the most frequent and prevailing human errors. The list of these journal articles is used in the literature review in Subsection 2.4.3 in explaining the concept of HEI.

The journal articles chosen for research are all related to error or fault classification or detection, though each has a contextual focus of their own. While all journal articles are connected to IS and human error, they are scenario and industry specific. A certain journal article is focused on the aviation industry and another is focused on the health care industry.

4.3.1 Article Identification Criteria

Literature used for conducting the research are identified and established through the use of Stellenbosch University's online library services as a primary search engine. The SUNSearch (Stellenbosch University Library and Information Service, 2015*b*) and E-Database (Stellenbosch University Library and Information Service, 2015*a*) options are used to find information.

Both these search spaces are explored through the use of keywords relevant to the research, mainly relating to human error. The terminology used are, "human error", "error", "error identification", "human performance", "failure", "information technology", "information systems", "information systems failure", "information software", "human behaviour" and "ergonomics". No filters related to publication dates, language or authors are applied to the search criteria. The keywords are searched for in the entire document, not only the

title. The abstract of the article in the search result is read in order to classify it appropriate or inappropriate for research.

After these articles are identified, their sources are investigated in order to identify additional applicable articles. The keywords used to identify these articles are the titles and authors of the articles. After all articles are collected, they are read through from beginning to end to establish its inclusion or exclusion to the research.

Articles that aid in answering the research questions are the focus when identifying whether it is appropriate for research purposes. Identification and inclusion of an article are based on the following criteria adapted from (Walia and Carver, 2009):

- Is the article valid and peer reviewed?

- Do these articles address human errors and causes thereof?

- Is there some form of list of results gathered involving human errors and the causes thereof?

- Are the articles diverse (does each context differ)?

- Can the article aid in gathering information to build a human error identification model?

The criteria used in the decision on whether to include or exclude the journal article, is based on its relevance. Journal articles that are based on opinion are excluded, while articles that focus specifically on analysing errors through empirical study, qualitative or quantitative, are included.

It is important that papers are diverse, from multiple scenarios and written by differing authors. The widespread applicability of the findings is what justifies its validity.

4.3.2 Identification of Existing Literature

The combination of diverse journal articles are used to find standard categorization of human errors that lead to IS failure. A list of the journal articles chosen are presented in Table 4.4.

Nr.	Year	Article	Journal
1	2005	The role of errors in learning computer software	Computers and Education
2	2007	Comparison of human performance by knowledge domain: Types, frequency, and sequencing of errors made while interacting with an information system	Library and Information Science Research
3	2013	Application of human error theories for the process improvement of Requirements Engineering	Information Sciences
4	2014	Applications of integrated human error identification techniques on the chemical cylinder change task	Applied Ergonomics
5	2009	A systematic literature review to identify and classify software requirement errors	Information and Software Technology
6	2009	The Application of the Root Causes of Human Error Analysis Method Based on HAZOP Analysis in Using Process of Weapon	Institute of Electrical and Electronics Engineers

Table 4.4: Peer-reviewed journal articles chosen for human error content analysis

The names and details of the article author(s) are summarized in Table 4.5 labelled from one to six according to the numbers attributed to each article in Table 4.4.

Nr.	Author(s)	Author summary
1	R.H. Kay	Dr. Kay is a professor and director of graduate studies at the University of Ontario Institute of Technology with multiple publications related to learning and technology.
2	B. Ju and K.Burnett	Ju is an associate professor at the School of Library and Information Sciene and Burnett an associate professor at the Louisiana State University.
3	M. Lopes and C. Forster	Lopes and Forster, associate professor and contributor, from the Technological Institute of Aeronautics in Brazil
4	C. Cheng and S. Hwang	Cheng and Hwang are both professors at the National Tsing Hua University in Taiwan.
5	G. Walia and J. Carver	Walia is a professor at the Mississippi State University and Carver is a professor at the University of Alabama, both from United States. Both authors are in the computer science field.
6	W. Wang and T.Zhao	Wang and Zhao are both professors at Beihang University in China, in the department of System Engineering.

Table 4.5: Details regarding the authors of the chosen human error journal articles

Journal article number 1 by Kay (2007) uses sampling as data collection to find the role of errors made when new computer software is being learned. The sampling subjects are a diverse group of people from the greater metropolitan Toronto area. (Kay, 2007) agrees that human error is inevitable and acknowledges the lack of a formal classification system of human errors in computer software.

Journal article number 2 by Ju and Burnett (2007) investigates whether certain criteria for finding how different types of domain knowledge can influence human performance when using IS. Two user groups, consisting of geography and computer science experts, are tested in experimental sessions. Observations were made thereby identifying errors made by humans, and consequently being able to measure and interpret these errors.

Journal article number 3 by Lopes and Forster (2013) aims to improve the Requirements Engineering (RE) process. All RE activities are mostly human related and subjective, therefore the paper considers the human error elements. Questionnaires are used in order to extract knowledge from RE practitioners, where the importance of human error types in different contexts is assessed.

The possible correlation between human error and failures in the RE process is explored.

Journal article number 4 by Cheng and Hwang (2015) focuses on the HEI techniques that already exists to assess human error. Many different error modes and possible influential factors are considered and so several frameworks of HEI techniques are integrated to create one framework applicable to the case study. The operational process of changing chemical cylinders at a plant is used as the case study assessment.

Journal article number 5 by Walia and Carver (2009) is focused on finding a different approach to identifying faults in software. A systematic literature review is used to develop a taxonomy of errors that may occur. A total of 149 journal articles from software engineering, psychology and human cognition literature are reviewed in order to find sources of faults. The result is a formal taxonomy that may provide a starting point for research in the appropriate fields.

Journal article number 6 by Wang and Zhao (2009) studies the root causes of human error by using the Hazard and Operability Study (HAZOP) safety analysis method. The paper presents an improved method of human error analysis based on HAZOP, process of by using process of weapon.

These journal articles are collectively studied and analysed to identify relevant human errors.

4.3.3   Short List of Human Errors

The complete list of errors collected from the literature as per the process followed in Section 4.3 is listed in Appendix A. The list of errors is copied from Microsoft Excel where they are compiled and collected.

4.4   Classification and Categorisation of Human Errors

The human errors are now shortened into a realistic and more manageable list through the use of classification and categorisation.

4.4.1 Classification of Human Error Categories by SRK

As there is no single description of human error, it is necessary to categorise these human errors found in the literature within a framework, before causes of failure can be found (Reason 1995*a*; Kay 2007).

A widely used classification system for human errors is the SRK model, developed by James Reason (Reason, 1990). The model aims at identifying human errors and classifying them and the factors that contribute to their existence. The book written by Reason has been cited by 9026 articles online (the number on 27 August 2015 from *Google Scholar* search engine) and has proven itself as a valid basis for many researchers to build their own models or theories. The majority of peer reviewed journal articles used as a basis for the research uses and adapts the SRK model to its own specific needs. The adjusted models in current literature are evaluated and are all scenario specific, therefore the SRK model stands as the best possible choice in aid of creating the decision support model.

Reason's model proposes very general error types. They are: skill-based mistakes (slips or lapses), rule-based mistakes and knowledge-based mistakes (Reason 1990; Kay 2007). Slips are the incorrect execution of actions or tasks, such as a typing mistake, and lapses are commonly memory errors (Kay, 2007). Rule-based mistakes occur when the incorrect set of rules is used to complete an action and knowledge-based mistakes occur when a user's rule-based routine becomes exhausted and incorrect representations of a problem are created (Reason 1990; Kay 2007).

Complexity, communication and information are all classified as situation based causes and are not included in the SKR classification, as according to the definition of the model. These are the human errors created by environmental or operational constraints outside of the control of the user of an IS (Sutcliffe and Rugg, 1998).

With the use of the SRK model (Reason, 1990), a new model is created with a wider set of classifications for a more detailed analysis of human errors. Per definition of SRK the skill-based mistakes made by users can be time, attention or memory based. These three categories are identified as most frequently occurring by the procedure presented in Section 5.4.2. Then the definition of the knowledge-based mistakes made by the users can be training, experience or uncertainty and the same with rule-based mistakes caused by users where procedure is most frequently identified. The categorisation of these classifications are summarised in Table 4.6.

Category	Human Error Classification
Situation based mistakes	Complexity
	Communication
	Information
Skill-based mistakes	Time
	Attention
	Memory
Knowledge-based mistake	Training
	Experience
	Uncertainty
Rule-based mistakes	Procedure

Table 4.6: Human error classifications categorised by SRK

4.4.2   Categorisation of Human Errors

The ten human error classifications and their definitions as per Oxford Dictionary are as follows:

1. **Complexity** A condition of intricacy having many diverse, though interrelated components linked through many connections.

2. **Communication** A process whereby participants reach mutual understanding through the exchange of information, news and ideas.

3. **Information** Data with meaning and relevance that leads to an increase of understanding. It's value lies in affecting behaviour, outcomes or decisions in an advantageous manner.

4. **Time** The measured period or duration in which a process, action or condition exists.

5. **Attention** The application of the mind to a certain object or sense of thought.

6. **Memory** The retaining and recalling of past experiences or information through mental capacity (the storage of information).

7. **Training** The action aimed at improving a user's performance by teaching or giving instructions, in order to attain a required level of skills or knowledge.

8. **Experience** The familiarity with a skill or field of knowledge gained through direct observation or participation, that has resulted in a superior understanding and mastery of the required skill.

9. **Uncertainty** A state of being hesitant and doubtful in a situation where the nature of things are unknown and the consequences and magnitude of the outcome is unpredictable.

10. **Procedure** An established series or sequence of activities, usually step-by-step, that must be followed in a given manner to correctly perform a task. A series of actions conducted in a certain order or manner.

Human errors from the six identified papers can be grouped together under these ten classifications. In Appendix B a complete list of all errors by their classifications is included, where each human error has a corresponding number identifying the paper in which it has been found.

The complete list of errors in Appendix B is summarised in Table 4.7. Papers numbers 1 through 6 are listed and it has been identified with a "*" in which of these papers the relevant human errors are present. The count represents the frequency, where the frequency is calculated by counting the papers in which human errors occur under the specified classification group.

Human error classification	1	2	3	4	5	6
Complexity					*	*
Communication			*	*	*	*
Information			*	*		*
Training		*	*		*	*
Experience	*	*	*	*	*	*
Uncertainty	*		*	*	*	
Time	*	*	*	*		*
Attention	*	*		*		*
Memory	*		*	*		*
Procedure	*	*	*	*	*	*

Table 4.7: Classification of human error frequency of occurrence from each journal article

The frequency of human errors per classification in Table 4.7 is visualised in Figure 4.1.

Experience and procedure both have a frequency of six, followed by time with a frequency of five, then communication, training, uncertainty, attention and memory all with a frequency of four times. The lowest frequencies are information and complexity, with frequencies of three and two respectively.
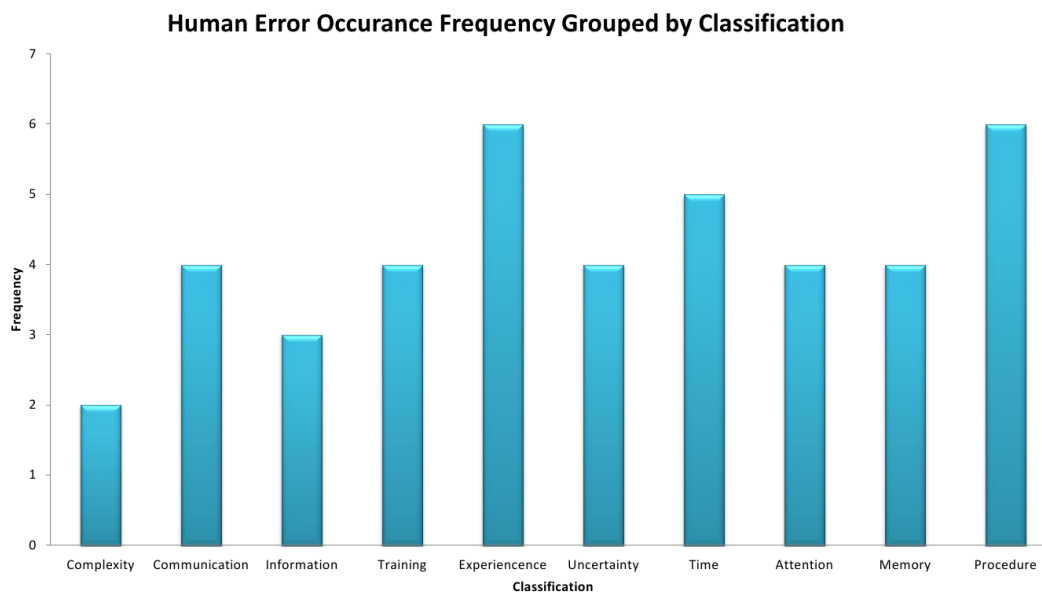
Figure 4.1: Visual Representation of Frequencies

4.5   Connecting Context Indicators and Human Error Classifications

Ergonomics is used to connect the context indicators with the human error classifications. Ergonomics can be seen as the study of humans as a part of a complex system, where the focus is to understand the relationship between humans and their physical environment (Hutchings, 2015).

The process of connecting the two interrelated concepts has been discussed in Section 2.3 and 2.4. The following mapping of human error classification and contextual indicators are derived:

Human Error Classification	Context Indicators
Complexity	General Communication
	Developer Communication
Communication	Decision Making Authority
	Complexity of Communication Culture
Information	Level of standardisation
	Complexity of Communication Culture
Training	Employment
	Level of Standardisation of Work/tasks
	General Communication
Experience	Employment
	Decision Making Power
Uncertainty	Employment
	Occurrence of Organisational Change
	General Communication
Time	Decision Making Power
	General Communication
Attention	Physical Environment Comfortability
	Physical Environment Privacy
Memory	No Contextual Indicators

Table 4.8: The Connection between classifications and contextual indicators

It is important to note that memory has no contextual indicators. Memory is a physical and internal issue, which can only vary due to a person's own capabilities.

4.6   Summary

With selecting significant contexts and human errors, and creating a connection by classifying human error, the next step is to find the causes and solutions to these failures. When these factors can be linked, the integration into a decision support model can take place.

Chapter 5

Identifying Generic Causes and Solutions

5.1 Identifying Causes and Solutions

Contexts have been refined and their relevance to the role of human errors in IS failures is identified based on the occurrence and frequency of specific human errors, given the various situations (Jaffal *et al.*, 2015). This chapter identifies the causes of and solutions to these human errors, given certain situations.

5.1.1 Article Identification Criteria

Literature used for conducting the research was identified and established through the use of Stellenbosch University's online library services as a primary search engine. The SUNSearch (Stellenbosch University Library and Information Service, 2015*b*) and E-Database (Stellenbosch University Library and Information Service, 2015*a*) options are utilised to find information.

All of the same criteria are used in article identification, as with the identification of human error related literature. Please refer to Subsection 4.3.1.

5.1.2 Identification of Existing Literature

As in Section 4.3.2, a combination of diverse journal articles is used to find causes and solutions to human errors that lead to IS failure. A list of the chosen journal articles is presented in Table 5.1.

Nr.	Year	Article	Journal
1	2013	Application of human error theories for the process improvement of Requirements Engineering	Information Sciences
2	2014	Applications of integrated human error identification techniques on the chemical cylinder change task	Applied Ergonomics
3	2009	A systematic literature review to identify and classify software requirement errors	Information and Software Technology
4	2009	The Application of the Root Causes of Human Error Analysis Method Based on HAZOP Analysis in Using Process of Weapon	Institute of Electrical and Electronics Engineers
5	2003	The Reluctance to Report Bad News on Troubled Software	Information Systems Journal
6	1995	Understanding Adverse Events: Human factors	Quality in Health Care
7	2002	Development and Application of a Human Error Identification Tool for Air Traffic Control	Applied Ergonomics
8	2009	A Taxonomy of Error Types for Failure Analysis and Risk Assessment	International Journal of Huamn-Computer Interaction

Table 5.1: Peer-reviewed journal articles chosen for causes and solutions content analysis

The names and details of the article author(s) are summarized in Table 5.2, labelled from one to eight according to the numbers attributed to each article in Table 5.1.

Nr.	Author(s)	Author summary
1	M. Lopes and C. Forster	Lopes and Forster, associate professor and contributor, from the Technological Institute of Aeronautics in Brazil
2	C. Cheng and S. Hwang	Cheng and Hwang are both professors at the National Tsing Hua University in Taiwan.
3	G. Walia and J. Carver	Walia is a professor at the Mississippi State University and Carver is a professor at the University of Alabama, both located in the United States. Both authors are in the computer science field.
4	W. Wang and T.Zhao	Wang and Zhao are both professors at Beihang University in China, in the department of System Engineering.
5	H. Smith and M. Keil	Smith and Keil are both professors, at Wake Forest University and J. Mack Robinson College of Business respectively.
6	J. Reason	Dr. Reason is currently a professor of psychology at The University of Manchester and he has published multiple important papers and books on human error and organizational processes.
7	S. Shorrock and B. Kirwan	Shorrock and Kirwan were both formerly with National Air Traffic Services Ltd.
8	A. Sutcliffe and G. Rugg	Sutcliffe is a British scientist and professor of systems engineering at the University of Manchester and Rugg is a British academic and head of the Knowledge Modelling Group at Keele University.

Table 5.2: Details regarding the authors of the chosen causes and solutions journal articles

Note that articles labelled 1 to 4 are included in the Section 4.3.2 list. Therefore details will not be repeated, please refer to Section 4.3.2 if necessary.

Journal article number 5 is a theory development article. The reluctance to transmit negative information is examined and a theoretical model is built that explains this occurrence within a software context.

Journal article number 6 considers how human errors can contribute to the breakdown of technologies and creates a generic model of accident causation. Two case studies related to the medical field are then used to illustrate the model's practical application.

Journal article number 7 focuses on errors in air traffic control. It uses a HEI technique, TRACEr (technique for the retrospective and predictive analysis of cognitive errors) and compares a number of interrelated taxonomies. Ultimately the article concludes that TRACEr is a valuable aid to air traffic control in the UK.

Journal article number 8 builds on prior research to develop a taxonomy of error types. The taxonomy or method is illustrated with two case studies with differing failures.

These journal articles are collectively studied and analysed to identify relevant causes of and solutions to failure.

5.1.3   Analysis of Existing Literature

Human error is inevitable and undeniably on the rise (Wang and Zhao, 2009). Even though useful human error classification techniques may exist, there is no set of generic or universally agreed upon list of human errors related specifically to IS (Cheng and Hwang, 2015).

The six journal articles in Section 4.3.2 are analysed and all possible human errors present in each paper are collected. A complete list of all the human errors listed per journal article is included in Appendix A. From the list in Appendix A, a short list of human error classifications can be selected.

A total of ten human error classification categories are identified as a route to finding the causes of IS failure. The human error classifications were chosen according to frequency of occurrence in the six chosen journal articles. The final error types included in the list have an occurrence frequency of two to six times. A minimum of two has been selected as a prerequisite to be included in the final short list.

These human error classifications are then categorised by the SRK behavioural model, which aids in linking human errors to the given organisational structure and environment.

After these human errors are classified and categorised, the eight journal articles in Section 4.3.3 are analysed and the causes of human error that lead to failure are collected. A complete list of all the causes of human errors listed per journal article is included in Appendix C. From the list in Appendix C a shortened list can be chosen.

Hereafter causes of failures are linked to each human error classification by using the definition of each classification. These causes are identified by mainly eight chosen journal articles. Each cause of failure will be accompanied by a relevant solution to the problem in order to prevent or avoid human errors causing IS failure.

5.2   Short list of Causes and Solutions to Human Errors

A problem cannot be solved by treating the symptoms. A problem may be temporarily cured, though it is likely that in the long term the problem will continue to occur. Only by finding and identifying the root cause of an IS failure, is there an opportunity to solve the true problem (Bondarouk and Riemsdijk, 2007).

5.2.1   Categorisation of Causes

The causes of IS failure are linked to the same ten classifications as per Section 5.3.2. The causes of human error that result in IS failure from the eight identified papers are grouped according to evidence from the literature reviewed and per definition of each classification. In Appendix D a complete list of all causes by their classifications can be found, where each cause has a corresponding number identifying the paper in which it originates from.

Causes are not identified according to frequency, as is the case with human errors. The ten classifications are already identified, with clear definition and literature background evidence. With the qualitative evidence, human errors can be linked to causes, which means it can be categorised under the same classifications.

5.2.2   Causes and their Solutions

All of the causes of human errors found in the eight journal articles have already been linked to their solutions by the original article. Per the ten classifications a list of all causes to human error and their associated solutions can be grouped. The grouped causes of human error and solutions are listed in Table 5.3 to Table 5.12.

Complexity

Poor communication among developers and users The design and development of systems should be done with users and developers collectively as a team. Where top management may have the correct vision, the users possess the practical knowledge the design of the system needs.

Design impairment The given system should be adapted according to requirements. A system should not be rigid in the sense that it cannot change or alter it's design to accommodate users effectively.

Lack of post implementation support Employ development teams or external companies who can provide post-implementation support. Support should be in the form of a tool with rapid response or a physical assistant.

User needs not well-understood or interpreted by different stakeholders Communication should be between users and developers, not management level employees who are not directly working with the IS.

Lack of involvement of users at all times during requirement development Implement incentives or a culture for motivation and give users a clear sight of the benefits that can be gained by actively being involved.

Hardware malfunction; bugs; clumsy; unreliable Implement a reporting system for hardware malfunction with immediate response IT team and continuously implement hardware quality improvement through user feedback.

Software malfunction; bugs; clumsy; unreliable Implement a reporting system for software malfunction with immediate response IT team and continuously implement software quality improvement through user feedback.

Table 5.3: Complexity related causes and solutions

Communication

Only relying on selected users to accurately define all the requirements Implement responsibility sharing, by creating mutually dependent and beneficial teams and establish an environment for open communication.

Unclear lines of authority There should be a clear hierarchy of authority and the organisational design should be clearly communicated to all users.

Unclear lines of communication A clear hierarchy of reporting and feedback should be created. It should be clear who needs to know what.

Not involvement of all the stakeholders Feedback systems should be put in place and/ or a mediator should be employed between parties to ensure stakeholders are involved via the mediator.

Misunderstandings of requirements by superior An "open door' policy should exist until requirements are clearly communicated and supervisors should "check in" on users to ensure requirements are continuously and correctly communicated. Face-to-face communication, in contrast to e-mailing and phone calls, is essential and ideal when interchanging requirements.

Mood of the communicator Discourage informal communication when user or manager could be distracted and busy when communicating important requirements. Encourage scheduling of meetings for such scenarios.

Mood of the recipient Discourage informal communication when user or manager could be distracted and busy when communicating important requirements. Encourage scheduling of meetings for such scenarios.

Fear of admitting mistakes Create a positive connotation to mistakes where it is associated with learning and establish an approachable reporting system.

Lack of involvement due to internal factors like rivalry The social climate and situation should not interfere with necessary requirements, a mediator should be employed to resolve disputes where all parties are treated fairly.

Table 5.4: Communication related causes and solutions

Information

Constraints on humans as information processors In order to lessen the effect of human constraint, a complete reliance on people should be avoided. Rather an adequate system that ensures that people cannot make mistakes should be the solution.

Carelessness while documenting requirements Inform users of the consequences of inaccurate information as to communicate the bigger picture and enforce timely check ups to ensure accurate information.

No use of standard format used for documenting information Create a standard format for documenting information for all users.

Ease of finding information and lack of information availability Increase the ease of findability for relevant information; make the information openly available and easy to access, on the intranet or any other platform.

Role prescription - user doesn't believe it's their responsibility to check information accuracy Communicate individual responsibility to all users.

Reporting culture, unspoken rule against bad news reporting A solution would be an anonymous reporting system, where users can post issues or problems and solutions can be given online.

Table 5.5: Information related causes and solutions

Training

Poor initial training Ensure the skill level of the trainer is adequate and employ trainers with people skills who are helpful and approachable.

Poor ongoing training Increase user task familiarity with ongoing training.

Poor management of people and resources Re-evaluate and adapt the current training programme and skill placement.

Poor requirement planning and communication Re-evaluate and adapt the current methods of training.

Conflicting requirements by lack of communication Encourage employees to ask questions as part of ongoing learning.

Legitimate higher priority Include prioritisation training, classify tasks according to importance and stress the importance of critical tasks.

Inadequate team support Create a supportive corporate culture.

Insufficient skills Periodically evaluate a user's fitness for duty or implement a trial period for the unskilled before permanent employment.

Complete lack of training Ensure the permanent availability of training staff.

No training staff available Ensure the permanent availability of training staff.

Disincentives for learning Motivate staff and incentivise good performance of employees.

Not ready to use system, but lack option of rejecting it Test the readiness of a user of the system, if the user is not ready continue with in-work training.

Lack of motivation Motivate staff and incentivise good performance of employees.

Table 5.6: Training related causes and solutions

Experience

Limited time a user has spent on specific domain Patience with experience being built and to ensure a support system for users who do not yet have full experience.

Insufficient skills Improve employment methods, prior skills and capabilities are vital to ensure a user's ability to operate an IS.

Inappropriate skills Improve employment methods, prior skills and capabilities are vital to ensure a user's ability to operate an IS.

Heavy workload Ensure the workload given to a user is fair and communicate the vision and goals to users so that they can prioritise their workload according to the bigger picture and it's importance. With a fair workload pressure can be eliminated.

Inadequate assignment of human resources Improve the placement and assignment of users according to their skills and personality.

Lack of process or problem understanding There is a lack of bigger picture and logic of the system, merely by communicating the bigger picture can understanding be gained.

Education level of user Different training should be applied for persons of different skill levels. Persons showing adequacy can be taken out of a training program earlier than others.

Lack of freedom to explore domain Give users the freedom to explore the problem domain by encouraging them to find alternative methods to solve problems.

Educational barriers Different training should be given to persons of different skill levels. Persons showing adequacy can be taken out of a training program earlier than others.

Over confidence of experts Communicate responsibility of tasks.

People have different interpretations of requirements Clearly communicate the organisational vision and requirements to users and encourage management to be a part of managerial briefings.

Lack of confidence Establish a culture that encourages the sharing of ideas and mutually beneficial support in teams.

Pressure created by management Set additional and reasonable expectations if deviations from certain tasks occur.

Pressure because of deadlines Set additional and reasonable extensions if deviations from certain tasks occur.

Fear of negative feedback or evaluation Encourage creativity and mistakes, as people learn from mistakes. Mistakes should never have a negative connotation.

Table 5.7: Experience related causes and solutions

Uncertainty
_____

Lack of change coordination Communicate changes of tasks or requirements; eliminate resistance by ensuring current employees of their job security and value.

Fear of asking for help Create an anonymous query system or forum with expert feedback.

Inadequate setting of goals and objectives Clearly communicate goals and objectives to users.

Inadequate/ insufficient training Delegate less power and authority until adequate training is received.

Inadequate/ insufficient experience Delegate less power and authority until the user is proven worthy of decision making.
_____

Table 5.8: Uncertainty related causes and solutions

Time

Limitation of available time Provide adequate time to users for completion of tasks; learn from past regarding time scheduling and schedule accordingly.

Shifts interfere with sleep cycles Improved scheduling accommodating human "clock".

Heavy workload Ensure the workload given to a user is fair and communicate the vision and goals to users so that they can prioritise their workload according to the bigger picture and it's importance. With a fair workload pressure can be eliminated.

Understaffed Employ more staff to be able to handle current workload, even temporary people can be employed.

Irregular working hours Improved scheduling, close monitoring of after hours work and limiting employees to suitable hours.

Ineffective method of organizing individual requirements A solution is to take a personal interest in staff regarding for example children, illnesses or family issues to better understand and accommodate employees.

Task is rushed due to deadlines Set realistic schedules for work to be completed.

Poor planning Set realistic schedules for work to be completed.

Poor organization of requirements Set realistic schedules for work to be completed.

Table 5.9: Time related causes and solutions

Attention

Noise Adapt or change conditions under which users work to address the cause of the disruption.

Information overload Communicate the importance of tasks and the level of prioritisation it should receive.

Sensory overload Adapt or change conditions under which users work to address the cause of the disruption.

Boss or colleague discussion or loud conversation Ensure the availability of social areas and boardrooms for informal meetings so that it can be done privately without distracting colleagues.

Competing tasks exists Communicate the importance of tasks and the level of prioritisation it should receive.

Commotion in workplace Adapt or change conditions under which users work to address the cause of the disruption.

Lack of proper environment/ inadequate workplace Adapt or change conditions under which users work to address the cause of the disruption.

Irregular working hours Improved scheduling, close monitoring of after hours work and limiting employees to suitable hours.

Environment stress Adapt or change conditions under which users work to address the cause of the disruption.

Table 5.10: Attention related causes and solutions

Memory

Daydreaming Ensure that the work and the workplace are not monotonous and encourage breaks to increase focus as people have a limited attention span.

Long period of time since learning or training Implement adequate ongoing support tools.

Personal fatigue and stress Encourage breaks to increase focus as people have a limited attention span and re-evaluate workload planning.

Overload of information (mental capacity restriction) Increase the availability of information and therefore decreasing need to memorize data, knowledge or actions. Users can now rather focus on one thing at a time.

Table 5.11: Memory related causes and solutions

Procedure

Methods and guidelines incomplete Implement adequate monitoring systems.

Methods or rules that are ambiguous Rules and methods should be clearly communicated and a manual to reference methods and rules should be available.

Methods or rules that are wrong and malformed Rules and methods should be clearly communicated and create obvious means of reversing unintended actions or errors.

Methods or rules that are unenforced Rules and methods should be clearly communicated and a manual to reference methods and rules should be available.

Unclear goals and objectives Communicate the bigger picture and objectives or visions of what the users are working towards or what their role is in the organisation.

Job satisfaction Increase employee motivation.

Lack of motivation Increase employee motivation.

Too standardised, search for new possibilities is limited Encourage the use of creativity in abnormal or unique situations.

Mistakes in developing models for analysing procedural requirements Edit or adjust the currently developed model and procedures.

Change requests are insufficiently formalized Edit or adjust the currently developed model and procedures.

Lack of management leadership Encourage the involvement of management.

Procedural discipline Motivate, train and monitor the implementation of procedures.

Table 5.12: Procedure related causes and solutions

5.3   Connecting Context Indicators and Causes and Solutions

Due to the lack of scientific evidence based on existing literature, surveys are used to validate the connection between context indicators and the causes and solutions of the model. Surveys are used to gather opinions that are considered as the representative of the whole.

5.3.1   Data Collection Process

The method chosen for validation of the link between context indicators and causes and solutions is the creation of a survey which is sent to 20 different organisations where it is asked that an employee, one per organisations, with the relevant knowledge, completes the survey.

The online survey is created by using Google Forms and the link to complete the survey is sent via email, which includes a short description of the research. The survey consists of ten pages with one question per page and all of the questions present a given circumstance with causes of human error linked to each. Questions are fixed where there is only a limited set of predetermined answers based on literature.

Experts are asked to: "Please tick ALL of the boxes where you agree that it is indeed a cause of human error connected to the given circumstance. Where you disagree simply leave the box un-ticked." Underneath the instructions are definitions on each page to clarify the questions that follow.

An example of the survey is included in Appendix E. The boxes to be ticked are represented by bullets.

A total of 8 persons responded to the surveys, creating a response rate of 40%. As this is not particularly a high response rate, sampling bias may exist. Response rate is however not the only indicator of survey feedback quality and research argues that response representativeness is more important (Baruch and Holtom, 2008). Thus for a survey to be valid it does not mean a large sample is necessary, but merely that it represents the widest possible population (Mittal, 2015).

Surveys are completed anonymously due to ethical considerations. It is however known that respondents are from a wide range of industries in order to represent the widest possible population namely pharmaceutical, commu-

nications, retail, municipal, advertising, auditing and economic development.

5.3.2   The Survey Feedback

When the expert chooses a cause of human error from the given list (Appendix E), the expert agrees to the relevance of a cause of human error. A percentage can be attributed to each cause of human error depicting its level of relevance according to the 7 experts.

0% Means all 7 persons disagree that the cause of human error is relevant.

14.3% Means that 1 person agreed that the cause of human error is relevant, while 6 disagreed.

28.6% Means that 2 persons agreed that the cause of human error is relevant, while 5 disagreed.

42.9% Means that 3 persons agreed that the cause of human error is relevant, while 4 disagreed.

57.1% Means that 4 persons agreed that the cause of human error is relevant, while 3 disagreed.

71.4% Means that 5 persons agreed that the cause of human error is relevant, while 2 disagreed.

85.7% Means that 6 persons agreed that the cause of human error is relevant, while 1 disagreed.

100% Means all 7 persons agreed that the cause of human error is relevant.

GoogleForms summarises the responses and creates feedback in the form of horizontal bar charts. These charts are included as representation of the feedback in Figures 5.1 to 5.18. Where the number 0 is next to a cause of human error, it means no one agrees with the statement, where the number 1 is next to a cause of human error it means 1 person agrees to the statement, where number 2 is next to a cause of human error it means 2 person agree to the statement and similar for numbers 3 to 8.
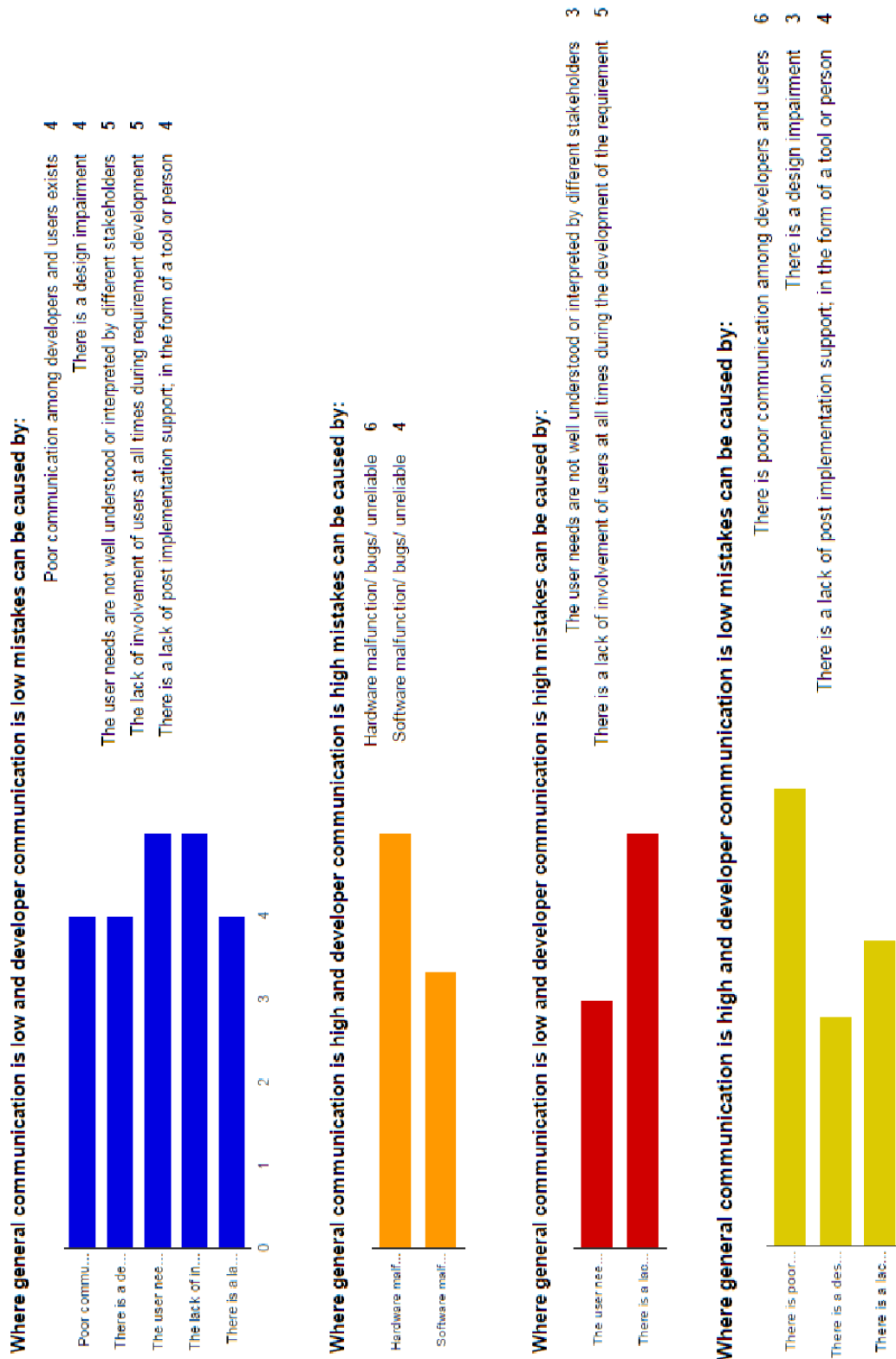
Figure 5.1: Complexity as a Cause of Human Error
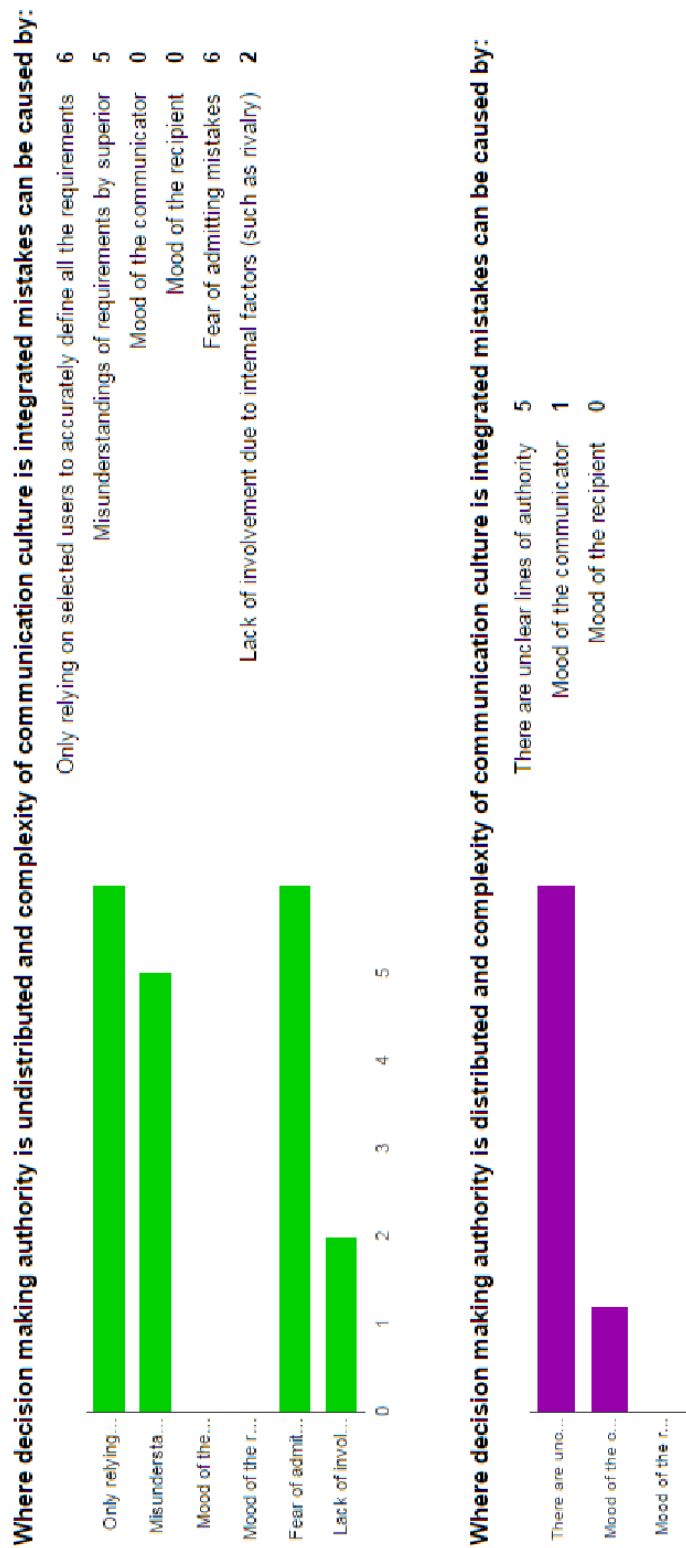
Figure 5.2: Communication as a Cause of Human Error
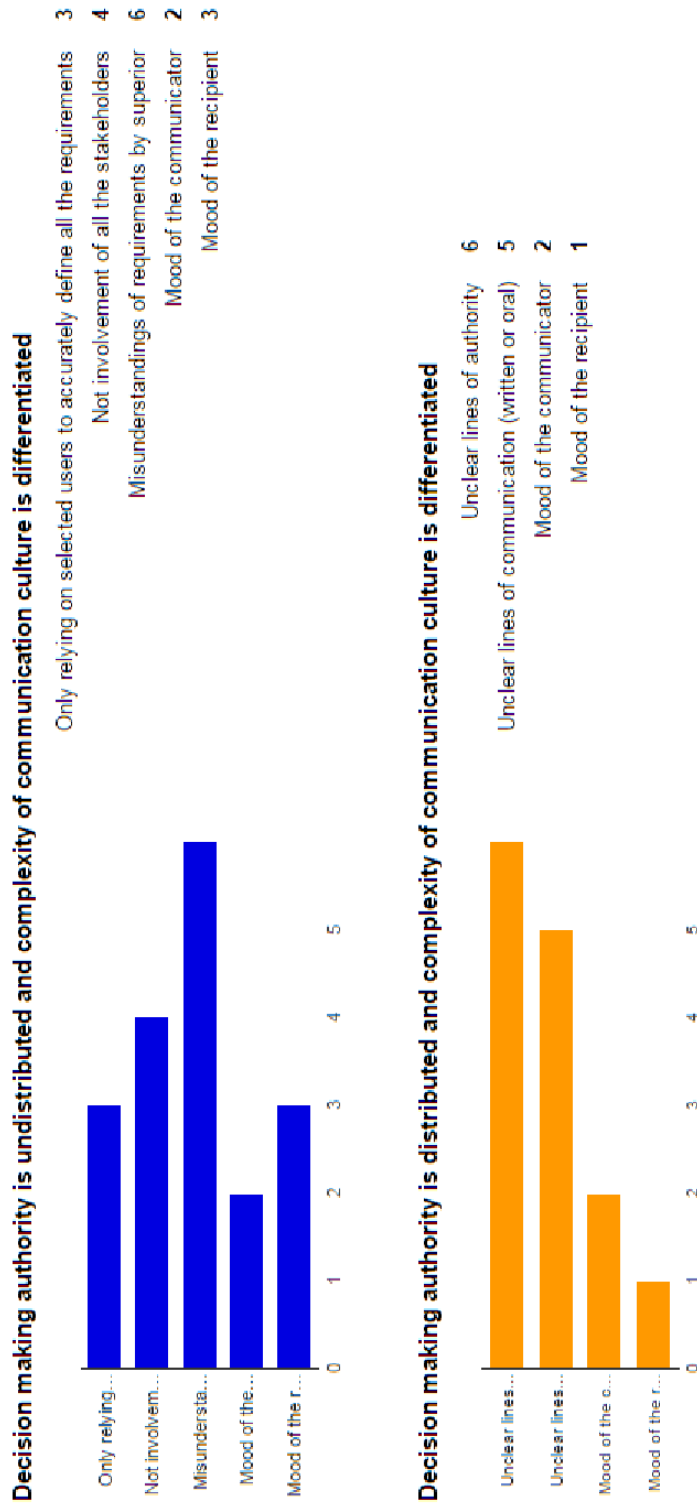
Figure 5.3: Communication as a Cause of Human Error (continued)
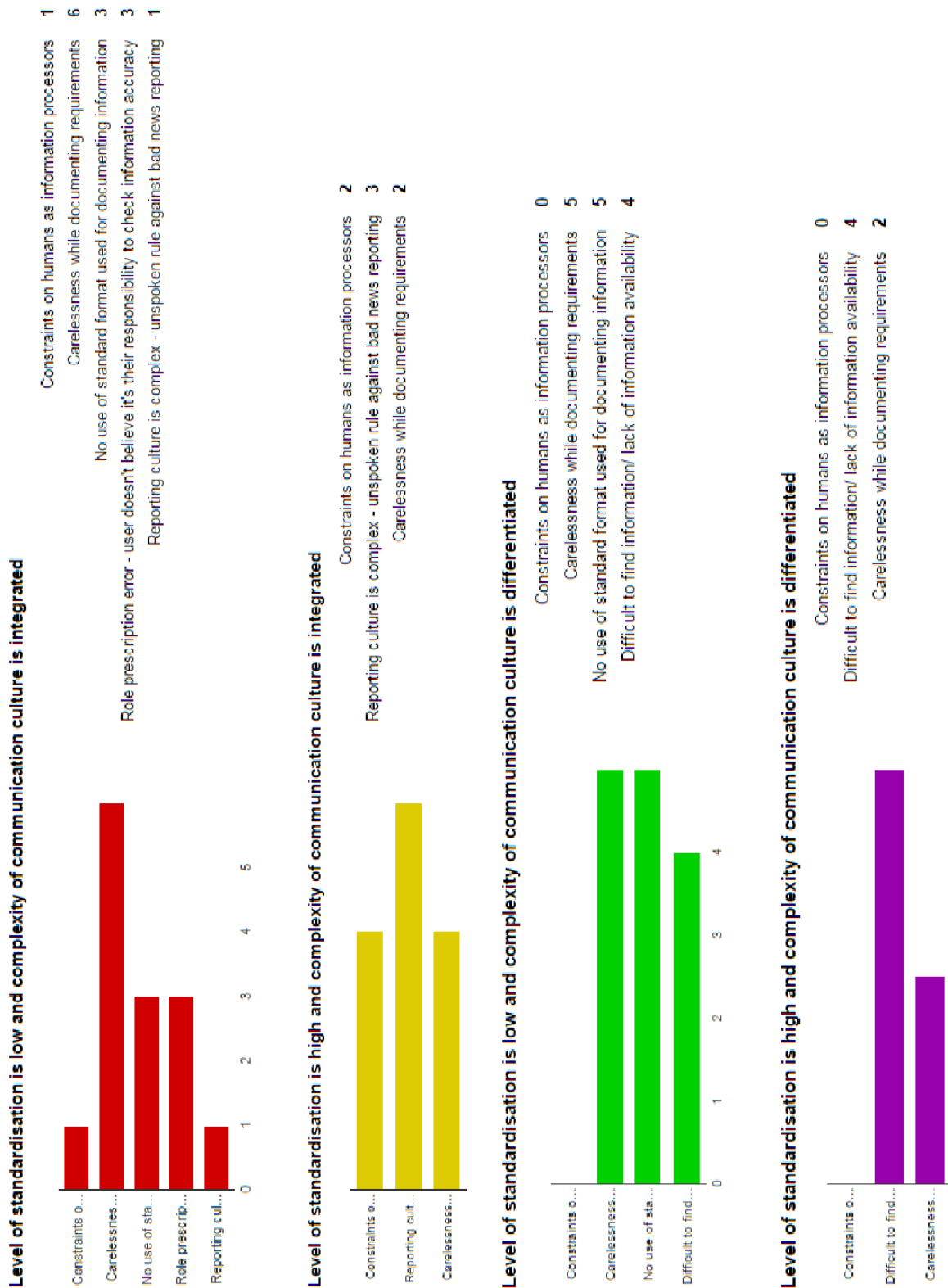
Figure 5.4: Information as a Cause of Human Error
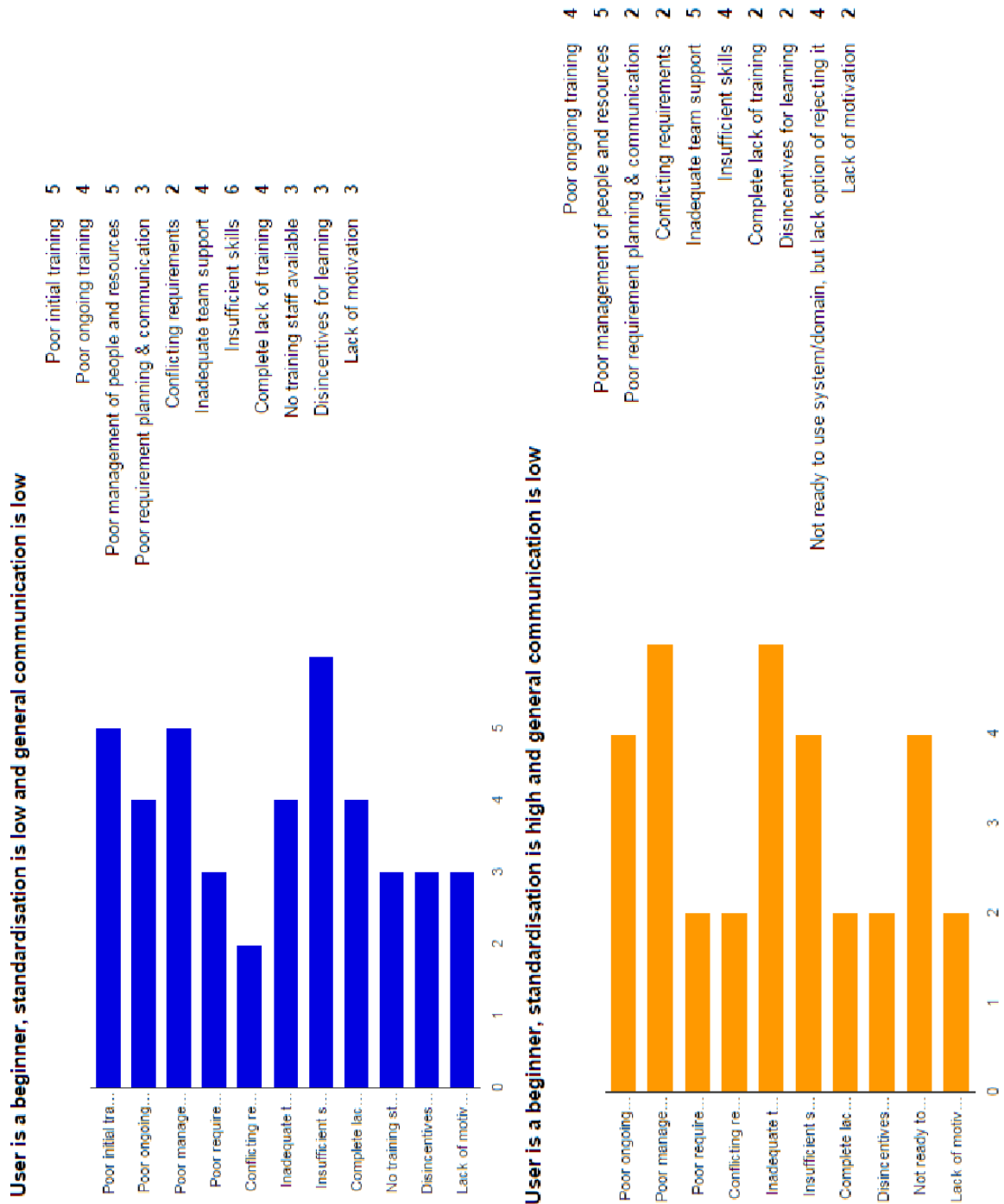
Figure 5.5: Training as a Cause of Human Error
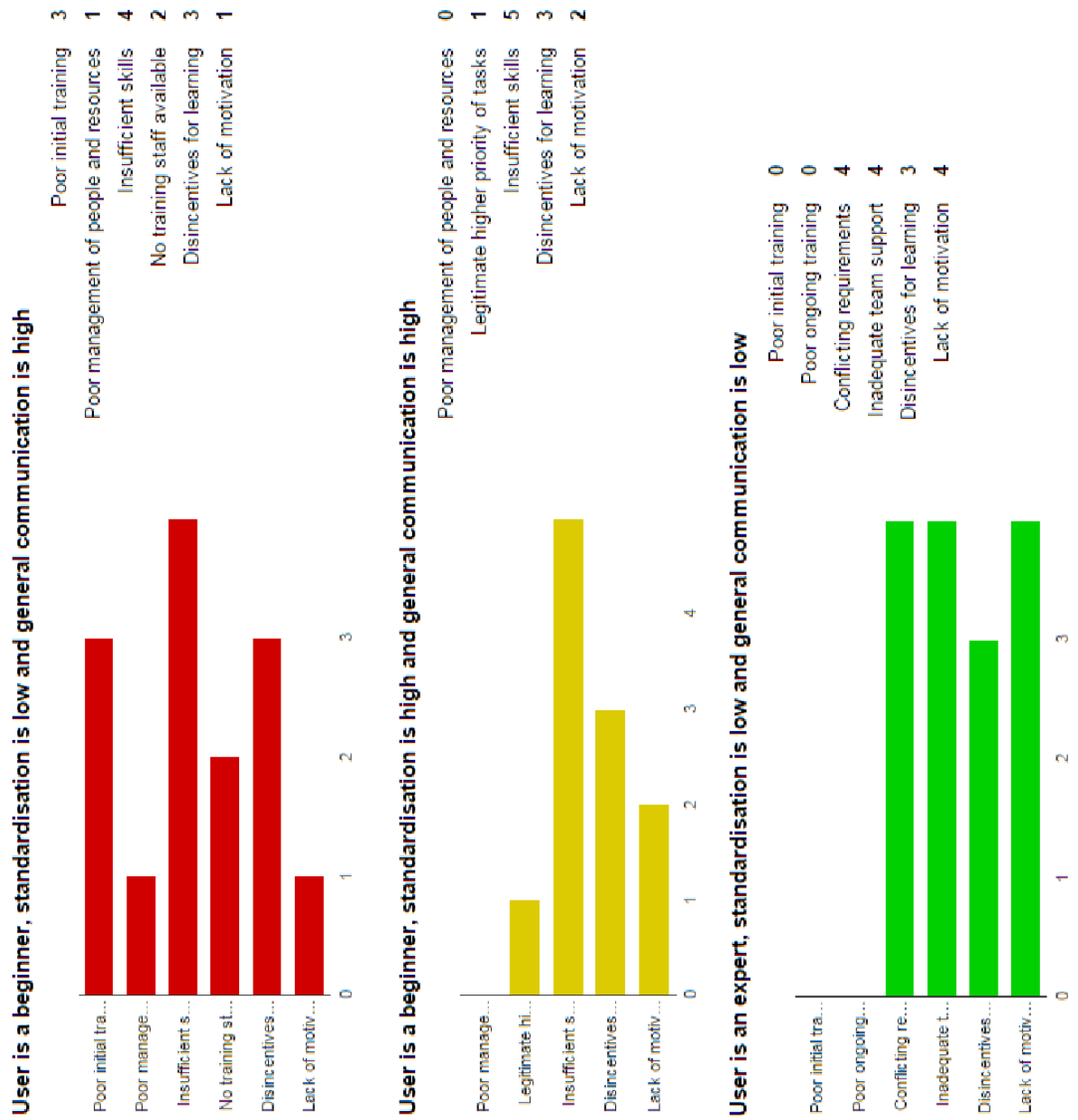
Figure 5.6: Training as a Cause of Human Error (continued)
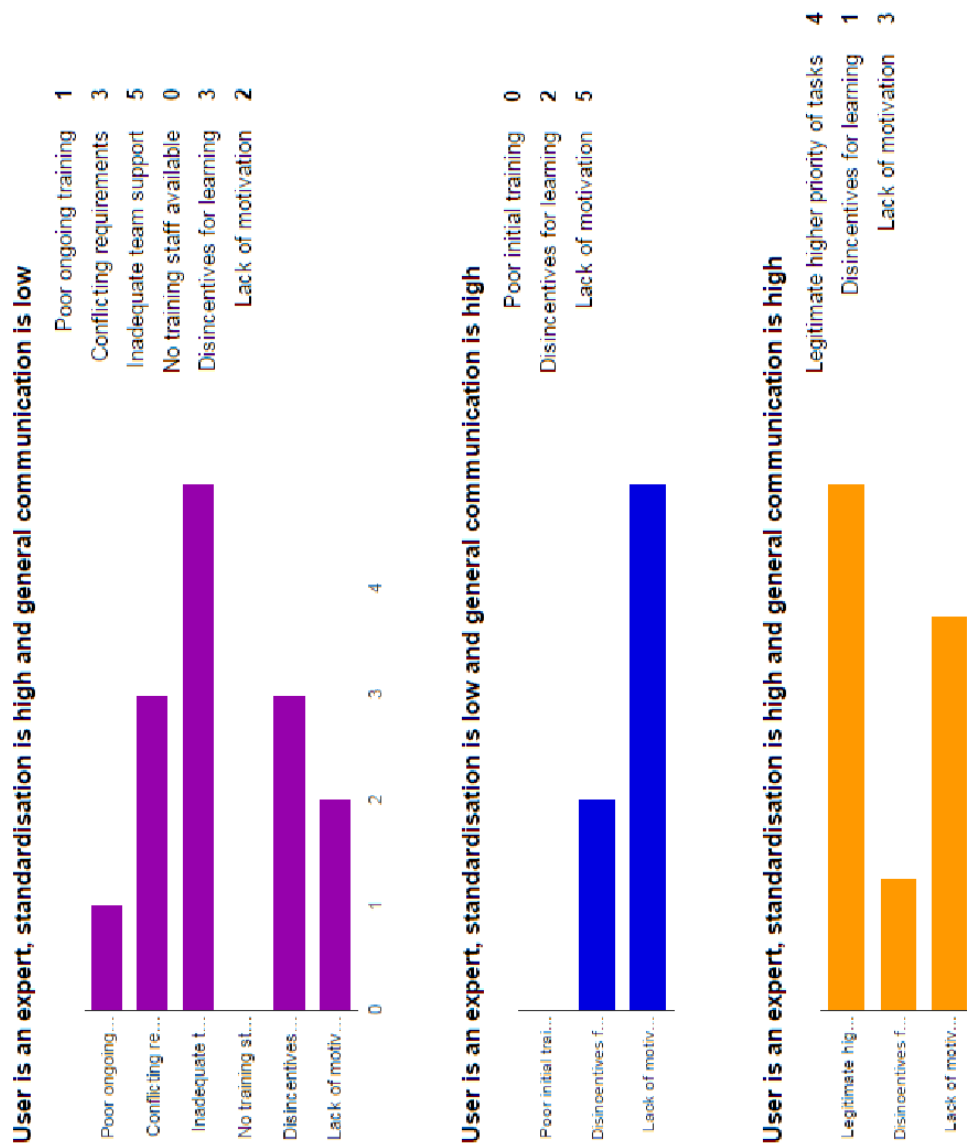
Figure 5.7: Training as a Cause of Human Error (continued)
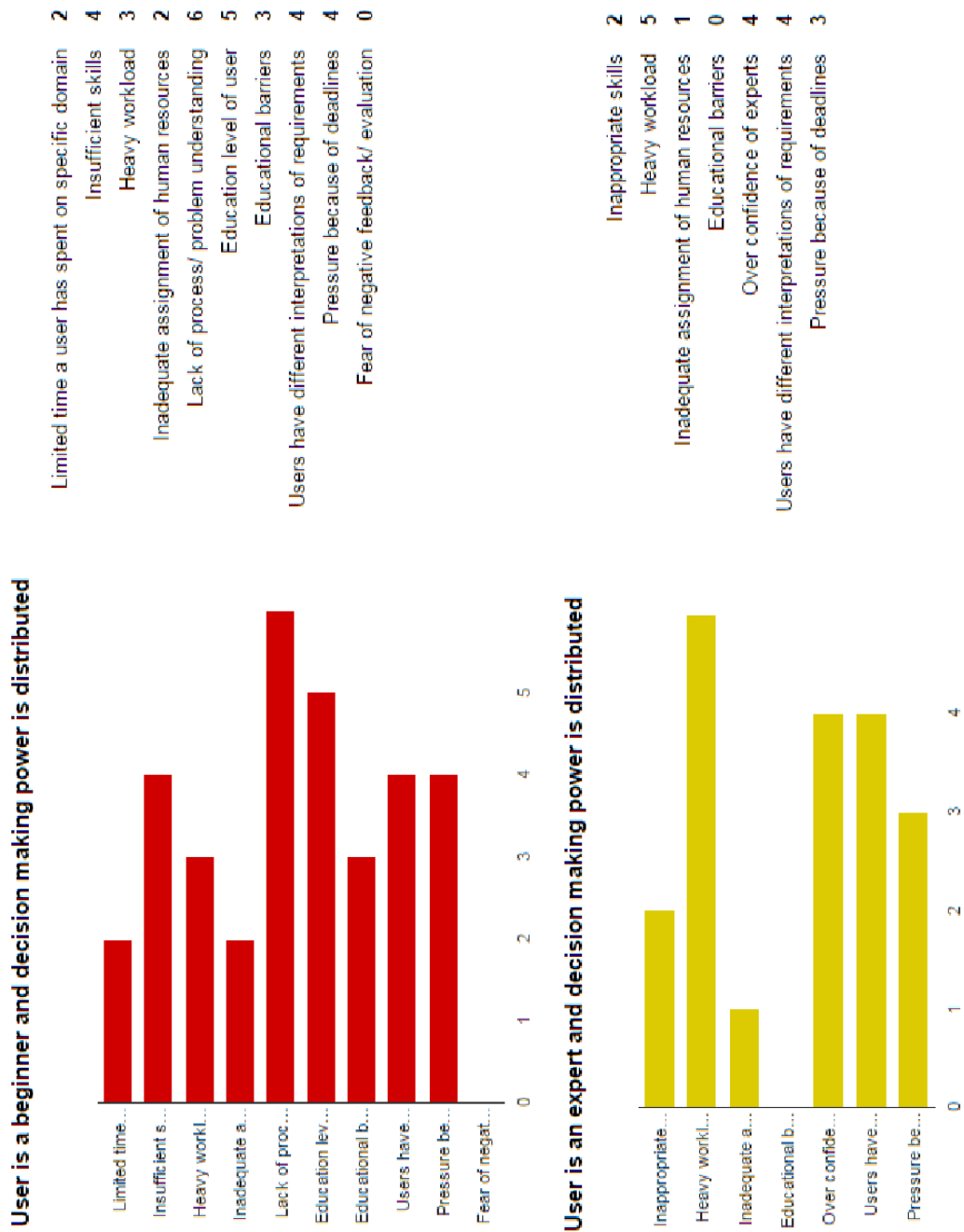
Figure 5.8: Experience as a Cause of Human Error
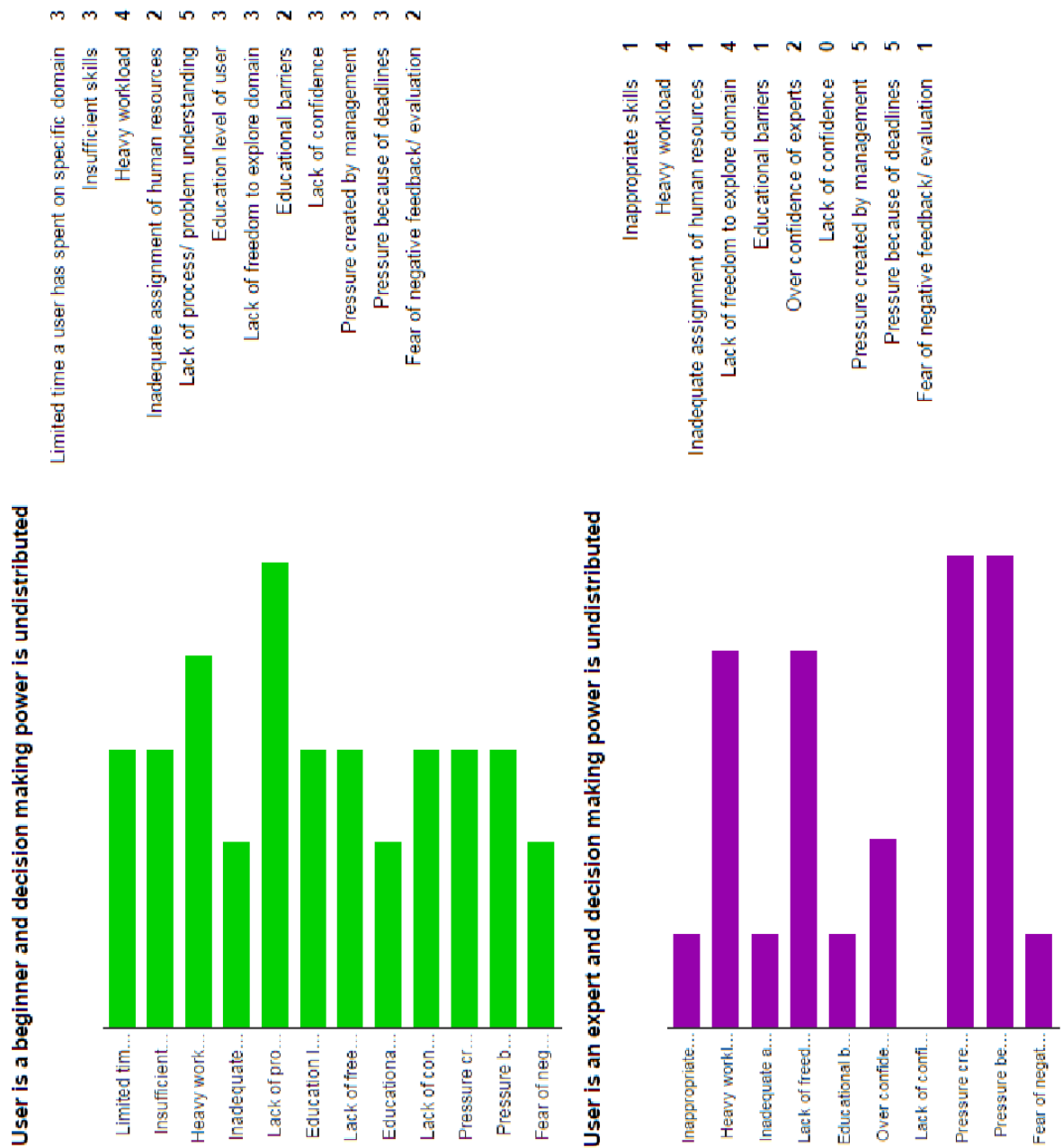
Figure 5.9: Experience as a Cause of Human Error (continued)
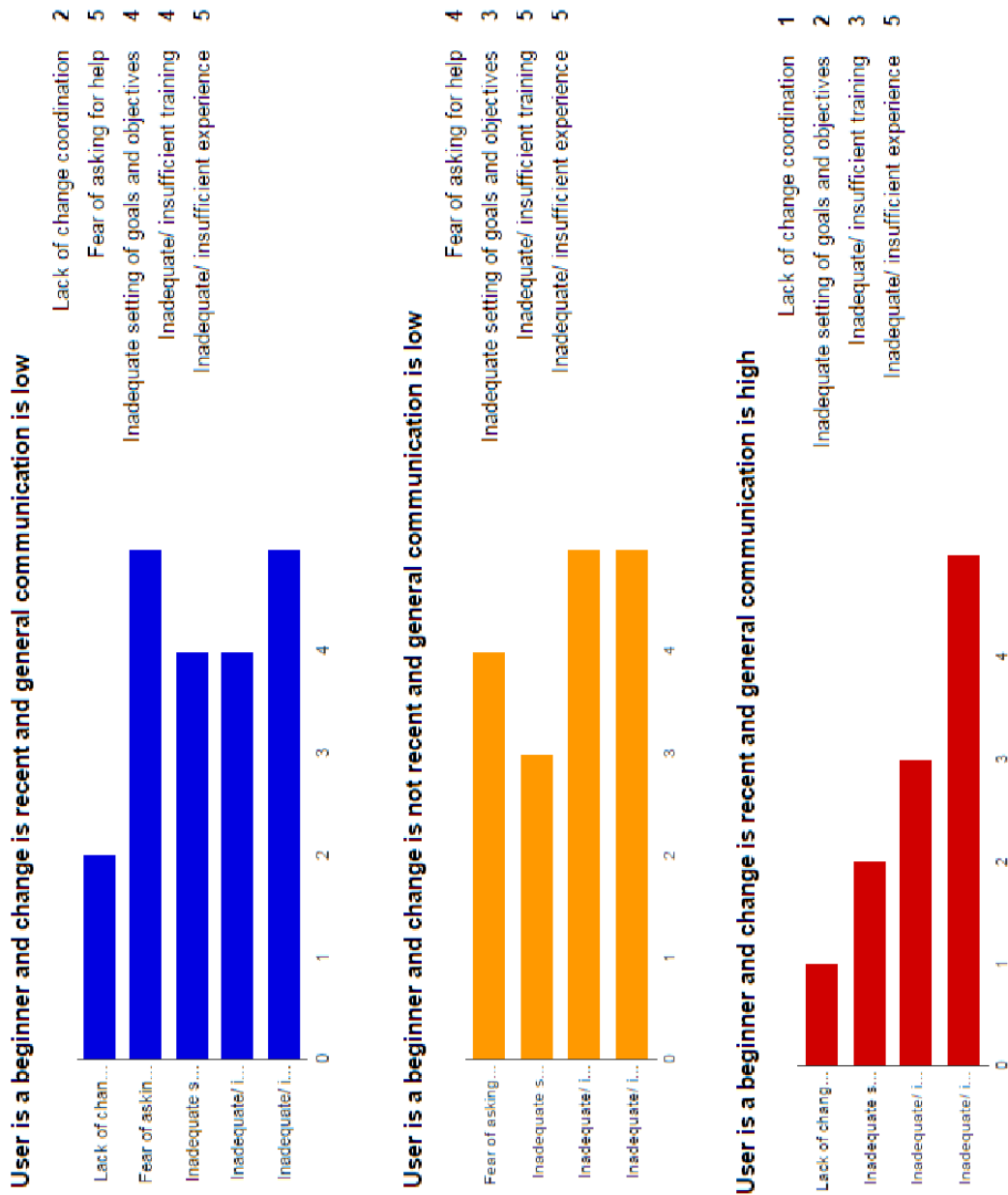
Figure 5.10: Uncertainty as a Cause of Human Error
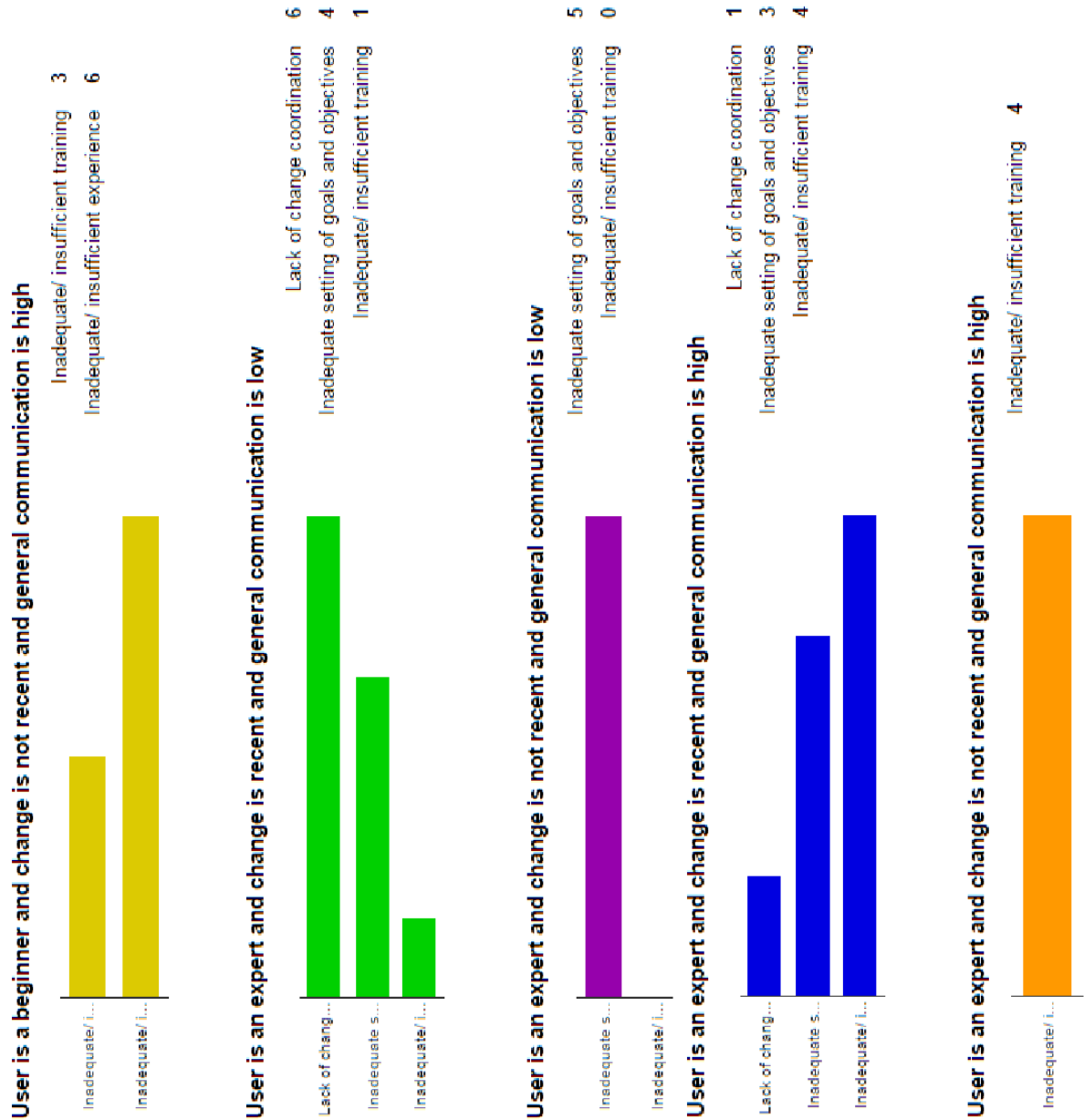
Figure 5.11: Uncertainty as a Cause of Human Error (continued)
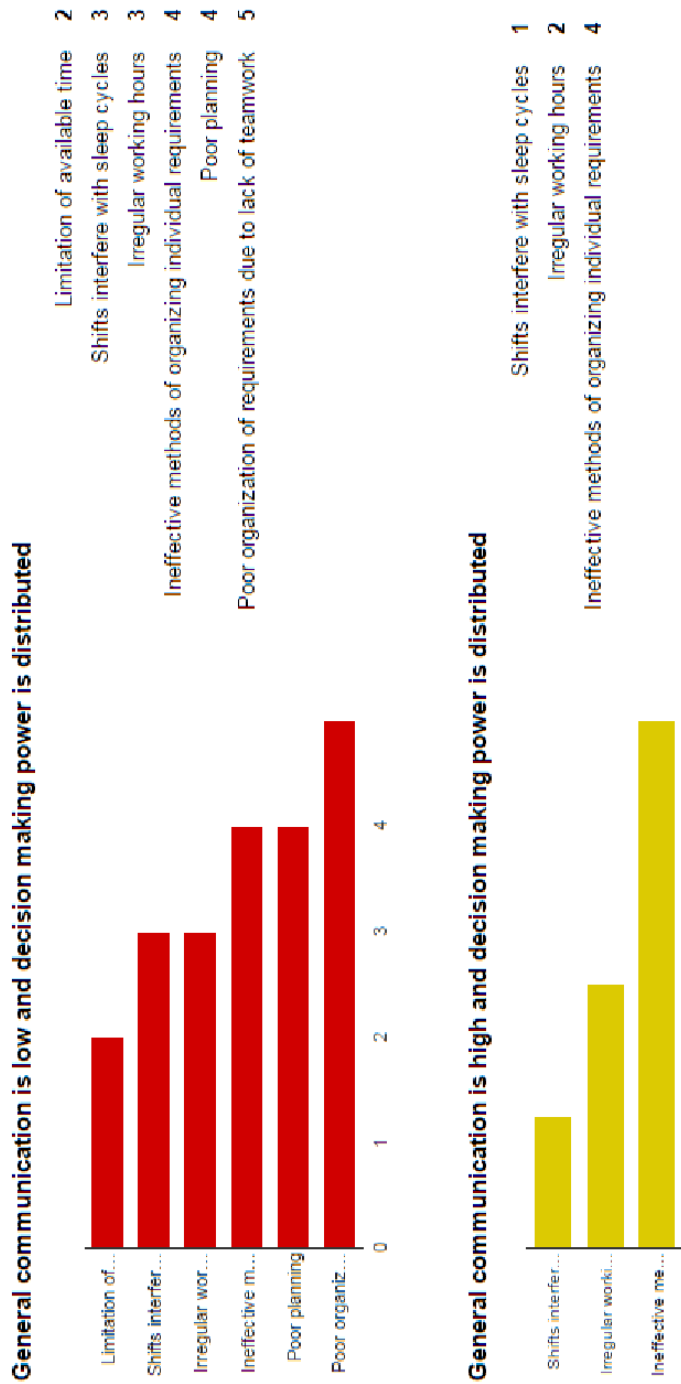
Figure 5.12: Time as a Cause of Human Error
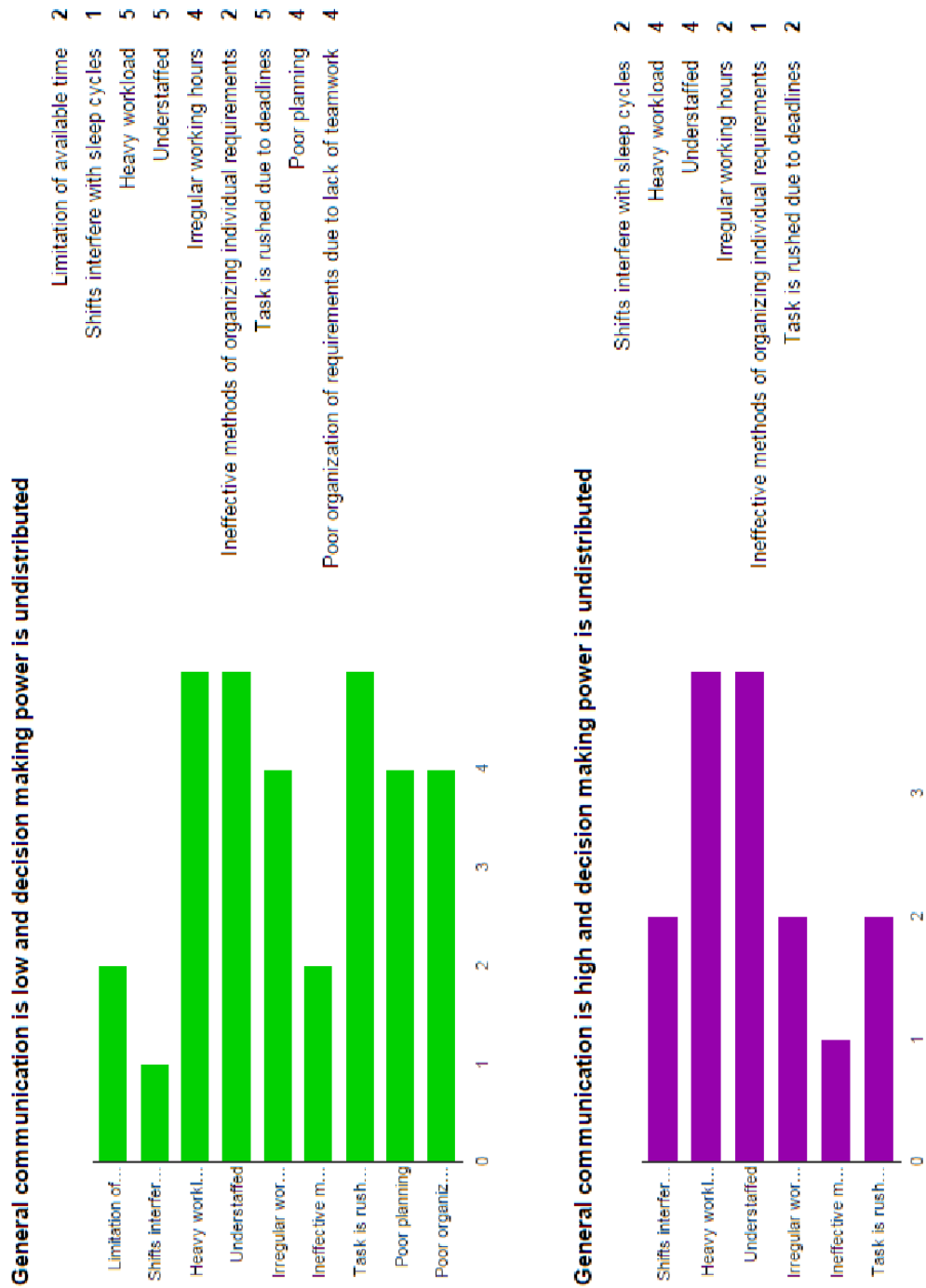
Figure 5.13: Time as a Cause of Human Error (continued)
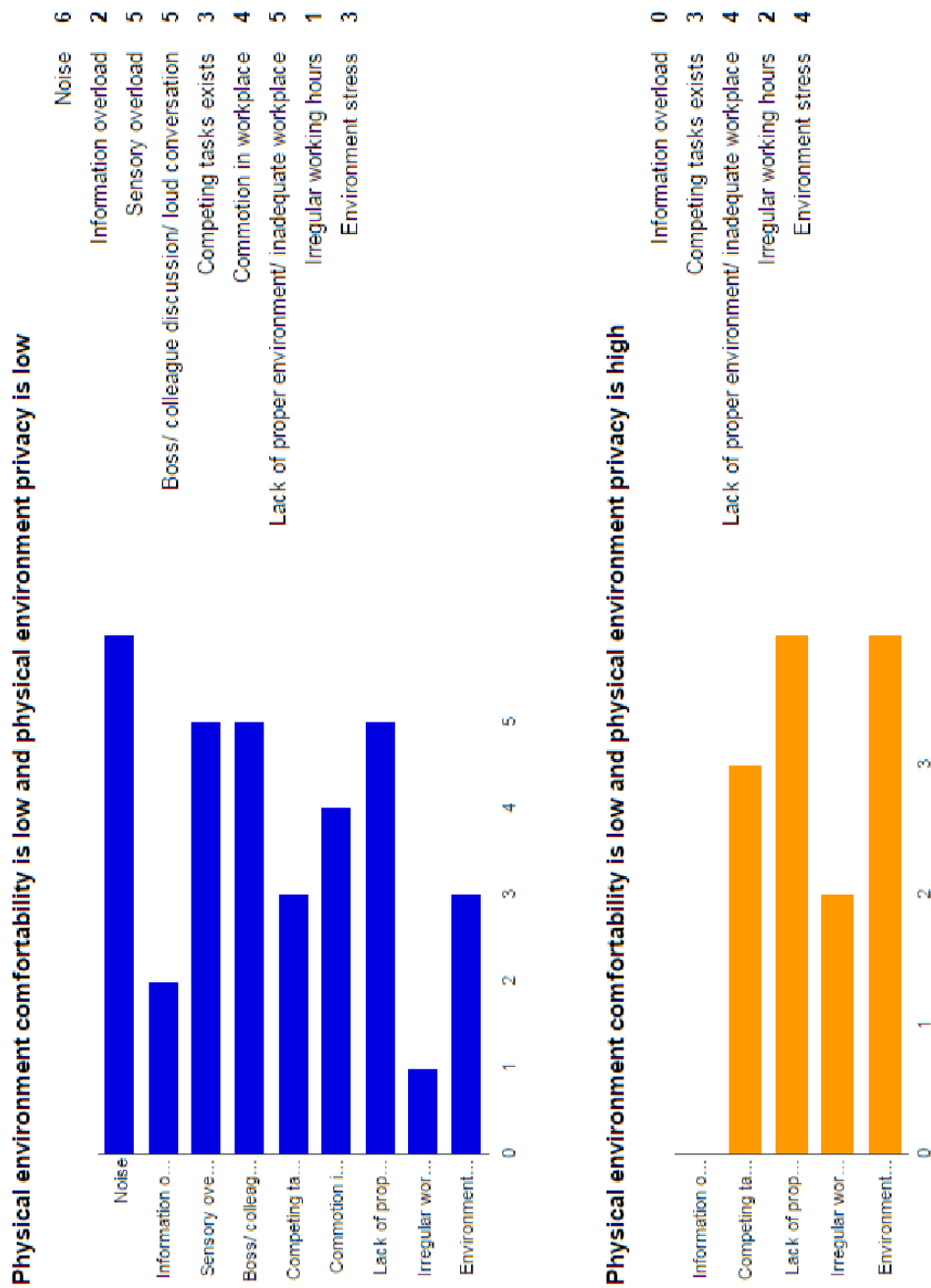
Figure 5.14: Attention as a Cause of Human Error
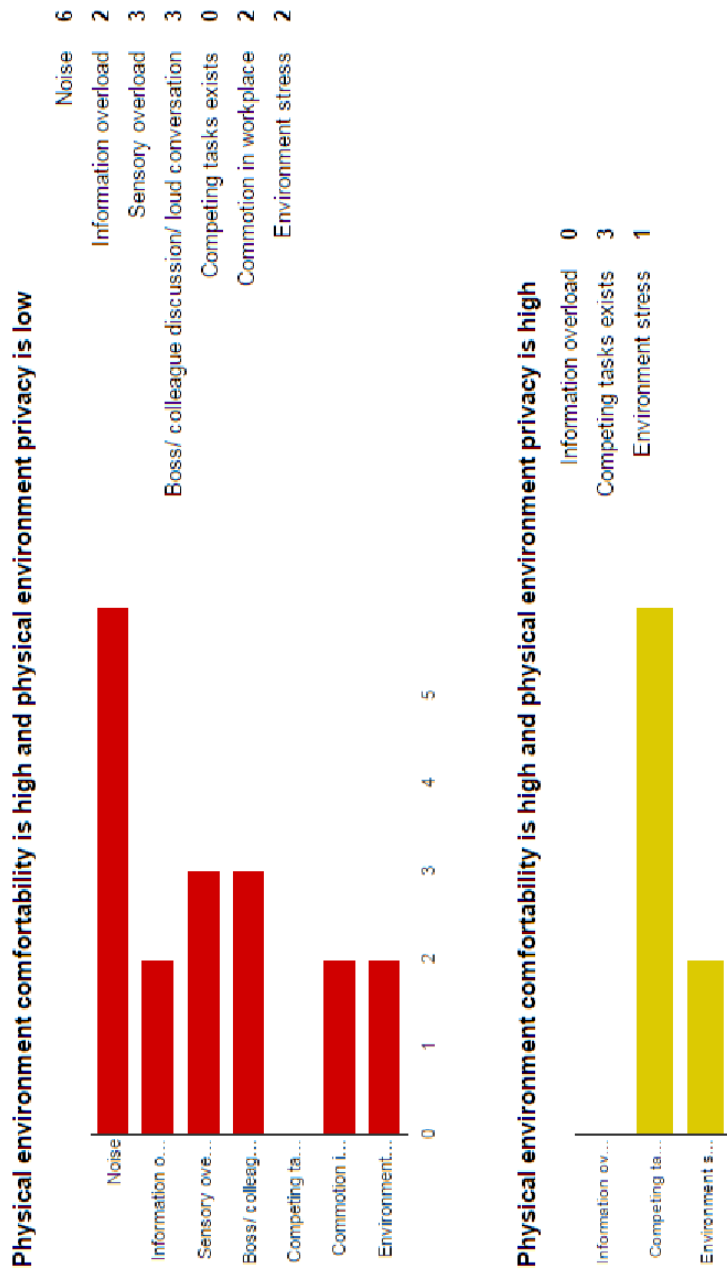
Figure 5.15: Attention as a Cause of Human Error (continued)
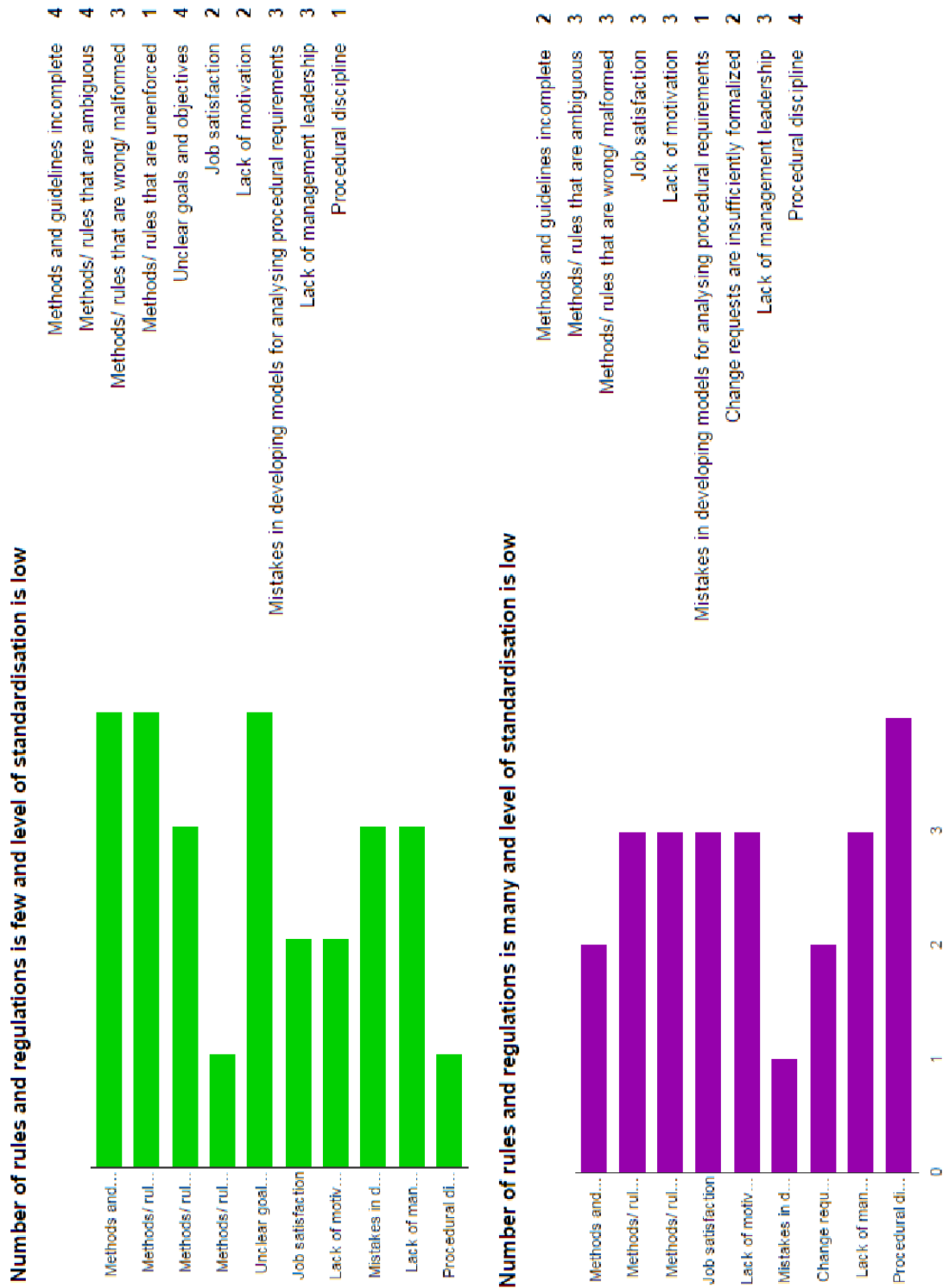
Figure 5.16: Procedure as a Cause of Human Error
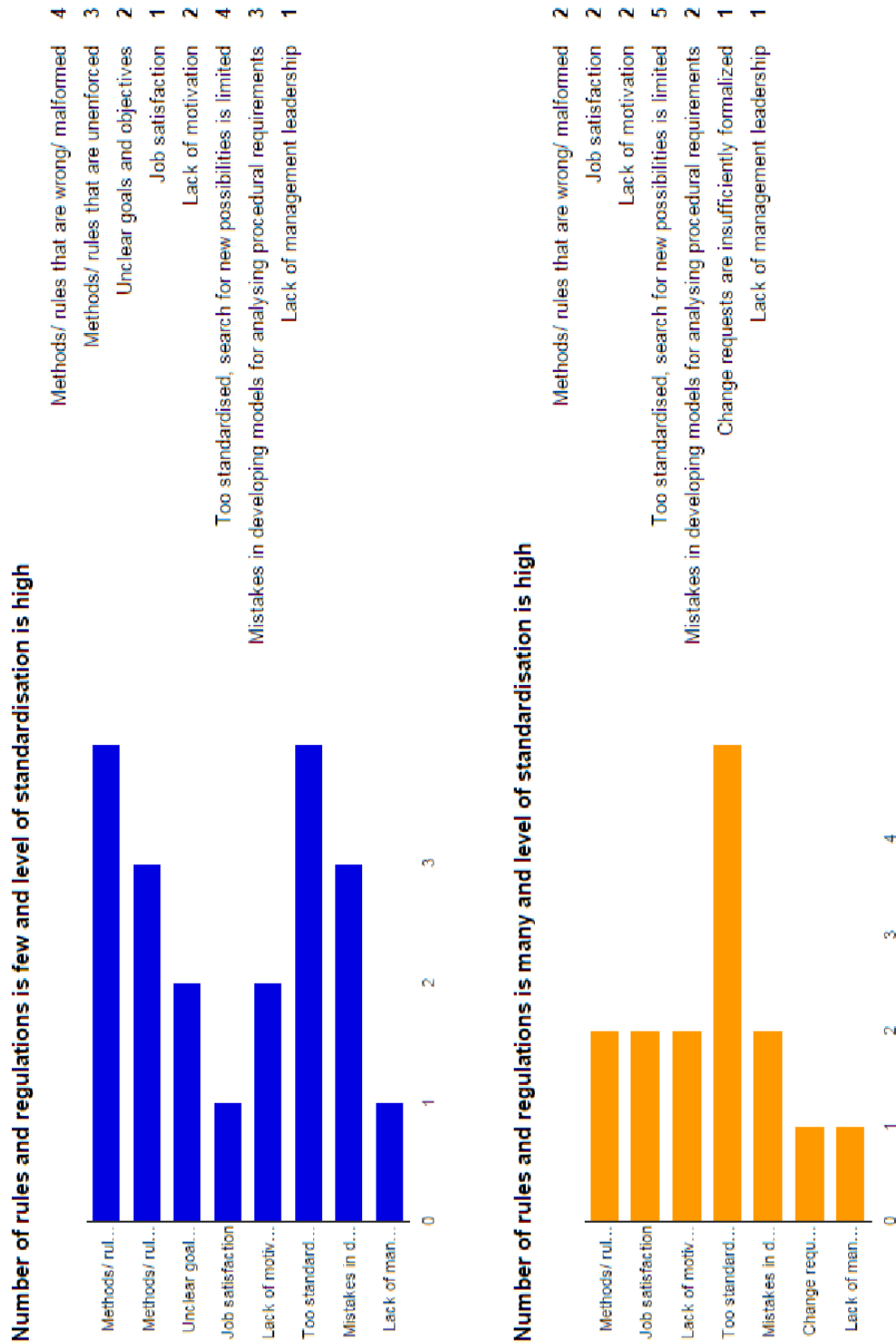
Figure 5.17: Procedure as a Cause of Human Error (continued)
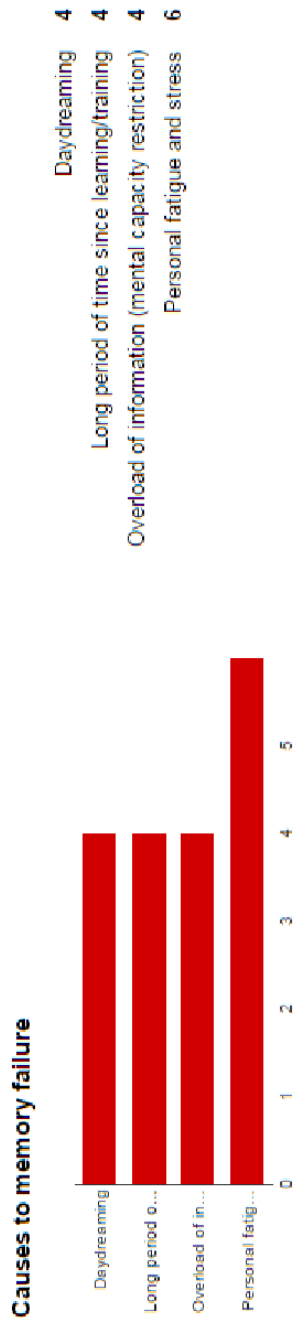
Figure 5.18: Memory as a Cause of Human Error

5.3.3   Analysis of Survey Feedback

The inclusion and exclusion of causes of human error due to data collection is a complex task. Even if a cause of human error only has 14.3% that agrees it is a relevant cause, an expert has still deemed it relevant. The cause of human error cannot simply be excluded from the model. Although, on the other hand, some causes have received a score of 100%.

There is consensus on a few causes of human error that not one expert deemed relevant. These are excluded from the final model. All of the remaining causes of human error are now listed from most to least relevant. Where causes with 100% relevance is first on the list, and causes with 14.3% will be at the bottom. This will mean that the likelihood that the given cause of human error at the top of the given, is more accurate than the one at the bottom.

5.4   Summary

The findings from this chapter is now used to create the final decision support model in Chapter 6.

Chapter 6

A Decision Support Model for IS Failures

6.1   Introduction

With all the factors identified to create a decision making model, these factors are put together in steps for practical use. Firstly the user of the decision making model should identify the human error occurring in their environment. The idea is to present a list of human errors and within that list the occurred human error is found. The human errors are presented in such a way that all are categorised under human error classifications. Human error classifications are linked to contextual factors and through the identification of the given contextual factors, causes of and solutions to failures are given.

6.2 Steps of the Model

Figure 6.1: Steps of the Decision Making Model

Step 1 A list of human errors are given and the user reads through the list until the occurred human error is identified.

Step 2 The human errors are categorised by human error classifications. Identify the linked classification.

Step 3 Each human error classification has linked context identifiers. Here the user must choose contextual factors relevant to their organisational environment based on the descriptions given.
Options are labelled alphabetically and each alphabetical code is connected to a numerical output.

Step 4 Given the output in Step 3, labelled 1 to 45, there is a list of possible causes and their solutions.

6.3 The Decision Support Model

An information sheet is given to each user listing the context indicators and their definitions as per Section 5.2.

Figure 6.2: The Decision Making Model

Figure 6.3: The Decision Making Model (continued)

Figure 6.4: The Decision Making Model (continued)

Figure 6.5: The Decision Making Model (continued)

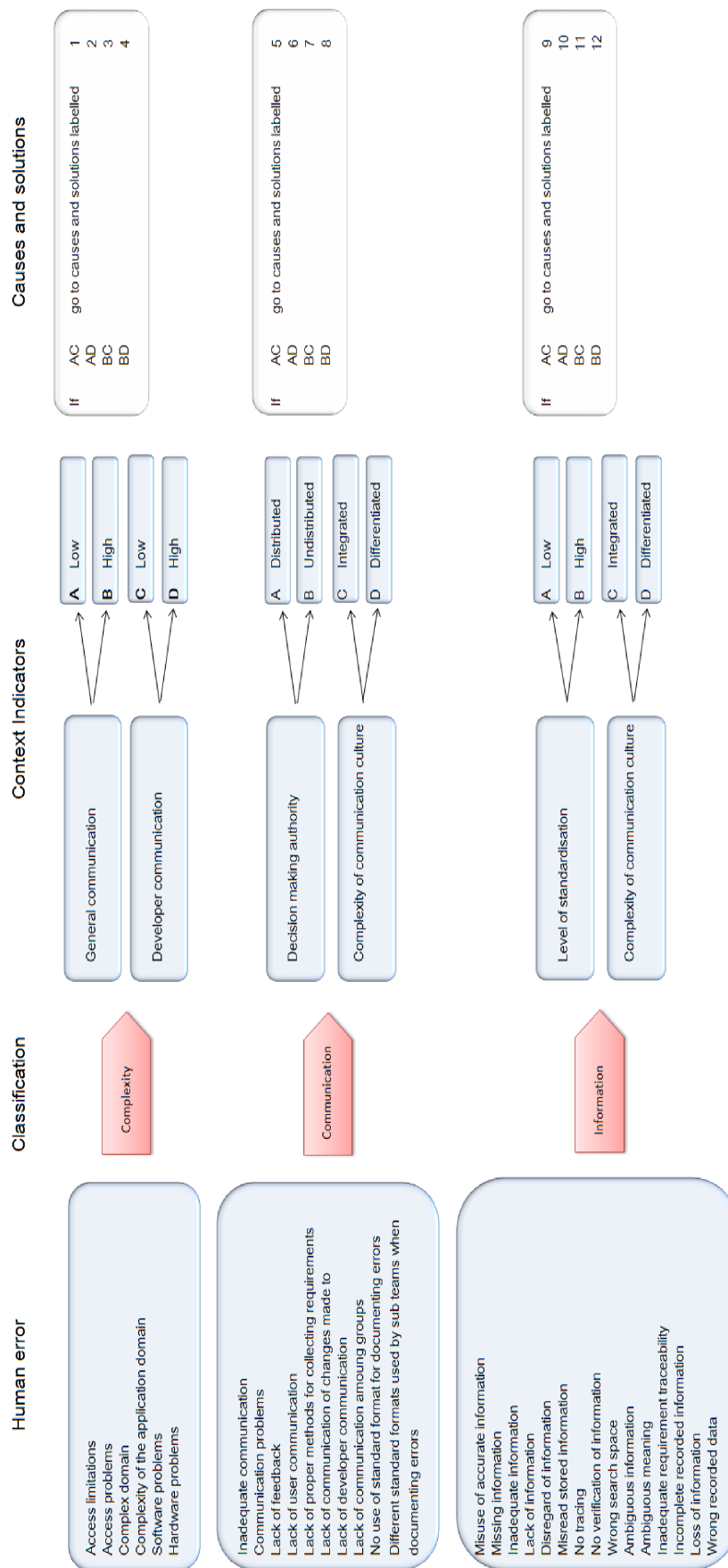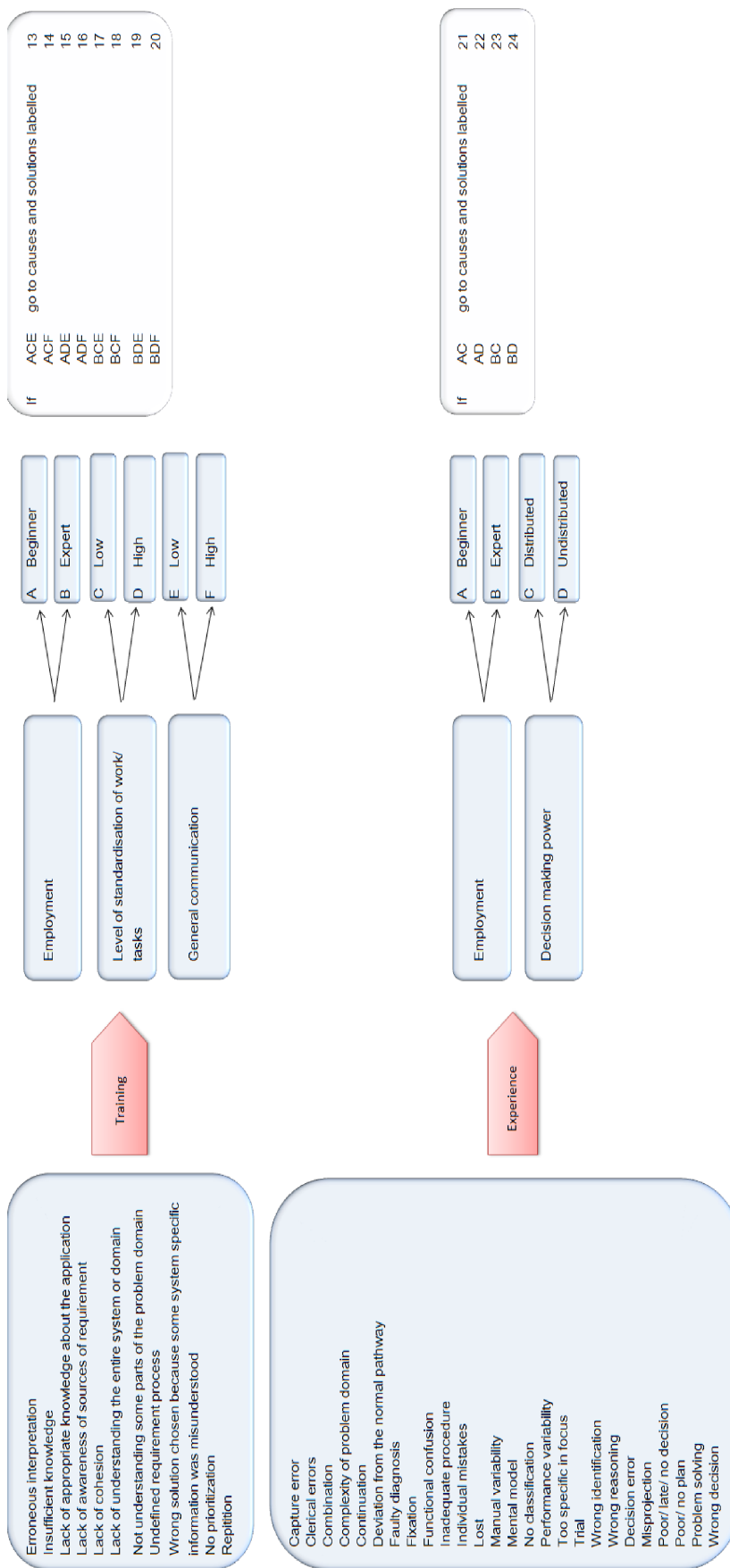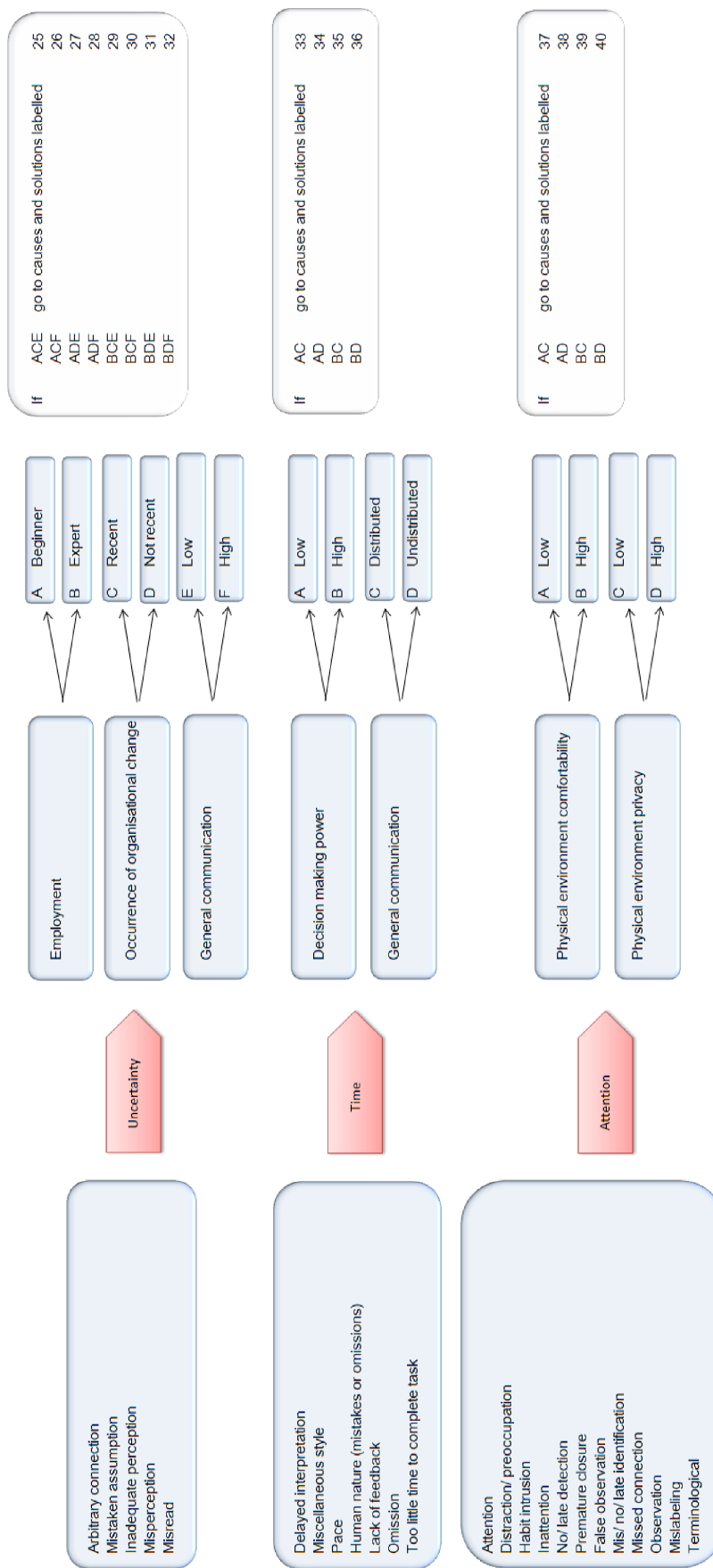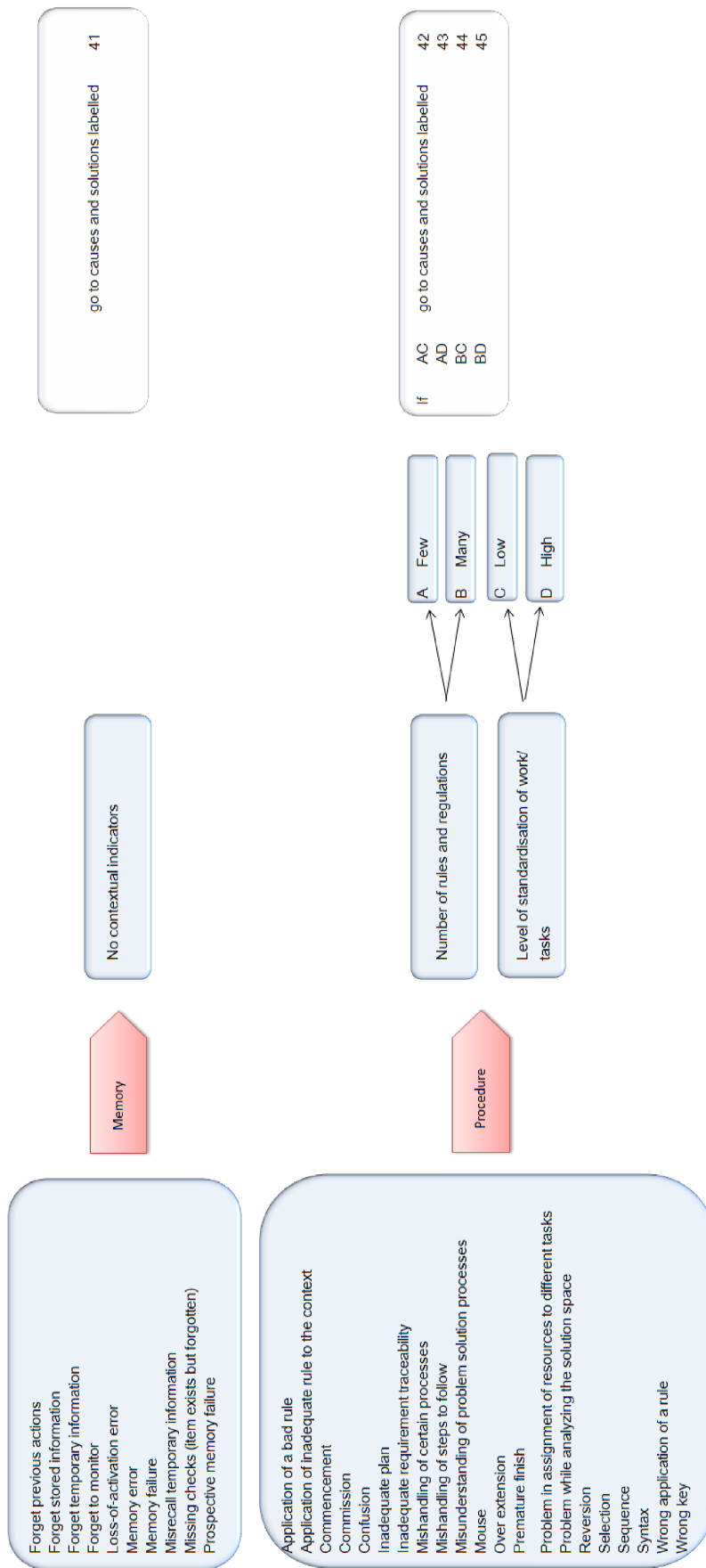|	Cause	Solution
1	The user needs are not well understood or interpreted by different stakeholders	Communication should be between users and developers, not management level employees who are not directly working with the IS.
	The lack of involvement of users at all times during requirement development	Implement incentives or a culture for motivation and give users a clear sight of the benefits that can be gained by actively being involved.
	Poor communication among developers and users exists	The design and development of systems should be done with users and developers collectively as a team. Where top management may have the correct vision, the users possess the practical knowledge the design of the system needs.
	There is a design impairment	The given system should be adapted according to requirements. A system should not be rigid in the sense that it cannot change or alter it's design to accommodate users effectively.
	There is a lack of post implementation support; in the form of a tool or person	Employ development teams or external companies who can provide post-implementation support. Support should be in the form of a tool with rapid response or a physical assistant.
2	There is a lack of involvement of users at all times during the development of the requirement	Implement incentives or a culture for motivation and give users a clear sight of the benefits that can be gained by actively being involved.
	The user needs are not well understood or interpreted by different stakeholders	Communication should be between users and developers, not management level employees who are not directly working with the IS.
3	There is poor communication among developers and users	The design and development of systems should be done with users and developers collectively as a team. Where top management may have the correct vision, the users possess the practical knowledge the design of the system needs.
	There is a lack of post implementation support; in the form of a tool or person	Employ development teams or external companies who can provide post-implementation support. Support should be in the form of a tool with rapid response or a physical assistant.
	There is a design impairment	The given system should be adapted according to requirements. A system should not be rigid in the sense that it cannot change or alter it's design to accommodate users effectively.
4	Hardware malfunction/ bugs/ unreliable	Implement a reporting system for hardware malfunction with immediate respond IT team and continuously implement hardware quality improvement through user feedback.
	Software malfunction/ bugs/ unreliable	Implement a reporting system for hardware malfunction with immediate respond IT team and continuously implement software quality improvement through user feedback.
5	Unclear lines of authority	There should be a clear hierarchy of authority and the organisational design should be clearly communicated to all users.
	Mood of the communicator	Discourage informal communication when user or manager could be distracted and busy when communicating important requirements. Encourage scheduling of meetings for such scenarios.
6	Unclear lines of authority	There should be a clear hierarchy of authority and the organisational design should be clearly communicated to all users.
	Unclear lines of communication (written or oral)	A clear hierarchy of reporting and feedback should be created. It should be clear who needs to know what.
	Mood of the communicator	Discourage informal communication when user or manager could be distracted and busy when communicating important requirements. Encourage scheduling of meetings for such scenarios.
	Mood of the recipient	Discourage informal communication when user or manager could be distracted and busy when communicating important requirements. Encourage scheduling of meetings for such scenarios.
7	Only relying on selected users to accurately define all the requirements	Implement responsibility sharing, by creating mutually dependent and beneficial teams and establish an environment for open communication.
	Fear of admitting mistakes	Create a positive connotation to mistakes where it is associated with learning and establish an approachable reporting system.
	Misunderstandings of requirements by superior	An "open door' policy should exist until requirements are clearly communicated and supervisors should "check in" on users to ensure requirements are continuously and correctly communicated. Face-to-face communication, in contrast to e-mailing and phone calls, is essential and ideal when interchanging requirements
	Lack of involvement due to internal factors (such as rivalry)	The social climate and situation should not interfere with necessary requirements, a mediator should be employed to resolve disputes where all parties are treated fairly.
8	Misunderstandings of requirements by superior	An "open door' policy should exist until requirements are clearly communicated and supervisors should "check in" on users to ensure requirements are continuously and correctly communicated. Face-to-face communication, in contrast to e-mailing and phone calls, is essential and ideal when interchanging requirements
	Not involvement of all the stakeholders	Feedback systems should be put in place and/ or a mediator should be employed between parties to ensure stakeholders are involved via the mediator.
	Only relying on selected users to accurately define all the requirements	Implement responsibility sharing, by creating mutually dependent and beneficial teams and establish an environment for open communication.
	Mood of the recipient	Discourage informal communication when user or manager could be distracted and busy when communicating important requirements. Encourage scheduling of meetings for such scenarios.
	Mood of the communicator	Discourage informal communication when user or manager could be distracted and busy when communicating important requirements. Encourage scheduling of meetings for such scenarios.

Figure 6.6: The Causes and Solutions

#	Causes	Solutions
9	Carelessness while documenting requirements	Inform users of the consequences of inaccurate info as to communicate the bigger picture and enforce timely check ups to ensure accurate information.
	No use of standard format used for documenting information	Create a standard format for documenting information for all users.
	Role prescription error - user doesn't believe it's their responsibility to check information accuracy	Communicate individual responsibility to all users.
	Constraints on humans as information processors	In order to lessen the effect of human constraint, a complete reliance on people should be avoided. Rather an adequate system that ensures that people cannot make mistakes should be the solution.
	Reporting culture is complex - unspoken rule against bad news reporting	A solution would be an anonymous reporting system, where users can post issues or problems and solutions can be given online.
10	Carelessness while documenting requirements	Inform users of the consequences of inaccurate info as to communicate the bigger picture and enforce timely check ups to ensure accurate information.
	No use of standard format used for documenting information	Create a standard format for documenting information for all users.
	Difficult to find information/ lack of information availability	Increase the ease of findability for relevant information; make the information openly available and easy to access, on the intranet or any other platform.
11	Reporting culture is complex - unspoken rule against bad news reporting	A solution would be an anonymous reporting system, where users can post issues or problems and solutions can be given online.
	Carelessness while documenting requirements	Inform users of the consequences of inaccurate info as to communicate the bigger picture and enforce timely check ups to ensure accurate information.
	Constraints on humans as information processors	In order to lessen the effect of human constraint, a complete reliance on people should be avoided. Rather an adequate system that ensures that people cannot make mistakes should be the solution.
12	Difficult to find information/ lack of information availability	Increase the ease of findability for relevant information; make the information openly available and easy to access, on the intranet or any other platform.
	Carelessness while documenting requirements	Inform users of the consequences of inaccurate info as to communicate the bigger picture and enforce timely check ups to ensure accurate information.
13	Insufficient skills	Periodically evaluate a user's fitness for duty or implement a trial period for the unskilled before permanent employment.
	Poor initial training	Ensure the skill level of the trainer is adequate and employ trainers with people skills who are helpful and approachable.
	Poor management of people and resources	Re-evaluate and adapt the current training programme and skill placement.
	Poor ongoing training	Increase user task familiarity with ongoing training.
	Inadequate team support	Create a supportive corporate culture.
	Complete lack of training	Ensure the permanent availability of training staff.
	Poor requirement planning & communication	Re-evaluate and adapt the current methods of training.
	No training staff available	Ensure the permanent availability of training staff.
	Disincentives for learning	Motivate staff and incentivise good performance of employees.
	Lack of motivation	Motivate staff and incentivise good performance of employees.
	Conflicting requirements	Encourage employees to ask questions as part of ongoing learning.
14	Insufficient skills	Periodically evaluate a user's fitness for duty or implement a trial period for the unskilled before permanent employment.
	Poor initial training	Ensure the skill level of the trainer is adequate and employ trainers with people skills who are helpful and approachable.
	Disincentives for learning	Motivate staff and incentivise good performance of employees.
	No training staff available	Ensure the permanent availability of training staff.
	Poor management of people and resources	Re-evaluate and adapt the current training programme and skill placement.
	Lack of motivation	Motivate staff and incentivise good performance of employees.
15	Poor management of people and resources	Re-evaluate and adapt the current training programme and skill placement.
	Inadequate team support	Create a supportive corporate culture.
	Poor ongoing training	Increase user task familiarity with ongoing training.
	Insufficient skills	Periodically evaluate a user's fitness for duty or implement a trial period for the unskilled before permanent employment.
	Not ready to use system/domain, but lack option of rejecting it	Test the readiness of an user of the system, if the user is not ready continue with in-work training.
	Poor requirement planning & communication	Re-evaluate and adapt the current methods of training.
	Conflicting requirements	Encourage employees to ask questions as part of ongoing learning.
	Complete lack of training	Ensure the permanent availability of training staff
	Disincentives for learning	Motivate staff and incentivise good performance of employees.
	Lack of motivation	Motivate staff and incentivise good performance of employees.

Figure 6.7: The Causes and Solutions (continued)

#	Causes	Solutions
16	Insufficient skills	Periodically evaluate a user's fitness for duty or implement a trial period for the unskilled before permanent employment.
	Disincentives for learning	Motivate staff and incentivise good performance of employees.
	Lack of motivation	Motivate staff and incentivise good performance of employees.
	Legitimate higher priority of tasks	Include prioritisation training, classify tasks according to importance and stress the importance of critical tasks.
17	Conflicting requirements	Encourage employees to ask questions as part of ongoing learning.
	Inadequate team support	Create a supportive corporate culture.
	Lack of motivation	Motivate staff and incentivise good performance of employees.
	Disincentives for learning	Motivate staff and incentivise good performance of employees.
18	Lack of motivation	Motivate staff and incentivise good performance of employees.
	Disincentives for learning	Motivate staff and incentivise good performance of employees.
19	Inadequate team support	Create a supportive corporate culture.
	Conflicting requirements	Encourage employees to ask questions as part of ongoing learning.
	Disincentives for learning	Motivate staff and incentivise good performance of employees.
	Lack of motivation	Motivate staff and incentivise good performance of employees.
	Poor ongoing training	Increase user task familiarity with ongoing training.
20	Legitimate higher priority of tasks	Include prioritisation training, classify tasks according to importance and stress the importance of critical tasks.
	Lack of motivation	Motivate staff and incentivise good performance of employees.
	Disincentives for learning	Motivate staff and incentivise good performance of employees.
21	Lack of process/ problem understanding	There is a lack of bigger picture and logic of the system, merely by communicating the bigger picture can understanding be gained.
	Education level of user	Different training should be applied for persons of different skill levels. Persons showing adequacy can be taken out of a training program earlier than others.
	Insufficient skills	Improve employment methods, prior skills and capabilities are vital to ensure a user's ability to operate an IS.
	Users have different interpretations of requirements	Clearly communicate the organisational vision and requirements to users and encourage management to be a part of managerial briefings.
	Pressure because of deadlines	Set additional and reasonable extensions if deviations from certain tasks occur.
	Heavy workload	Ensure the workload given to a user is fair and communicate the vision and goals to users so that they can prioritise their workload according to the bigger picture and it's importance. With a fair workload pressure can be eliminated.
	Educational barriers	Different training should be users for persons of different skill levels. Persons showing adequacy can be taken out of a training program earlier than others.
	Limited time a user has spent on specific domain	Patience with experience being built and to ensure a support system for users whom do not yet have full experience.
	Inadequate assignment of human resources	Improve the placement and assignment or users according to their skills and personality.
22	Lack of process/ problem understanding	There is a lack of bigger picture and logic of the system, merely by communicating the bigger picture can understanding be gained.
	Heavy workload	Ensure the workload given to a user is fair and communicate the vision and goals to users so that they can prioritise their workload according to the bigger picture and it's importance. With a fair workload pressure can be eliminated.
	Limited time a user has spent on specific domain	Patience with experience being built and to ensure a support system for users whom do not yet have full experience.
	Insufficient skills	Improve employment methods, prior skills and capabilities are vital to ensure a user's ability to operate an IS.
	Education level of user	Different training should be applied for persons of different skill levels. Persons showing adequacy can be taken out of a training program earlier than others.
	Lack of freedom to explore domain	Give users the freedom to explore the problem domain by encouraging to find alternative methods to solving problems.
	Lack of confidence	Establish a culture that encourages the sharing of ideas and mutually beneficial support in teams.
	Pressure created by management	Set additional and reasonable expectations if deviations from certain tasks occur.
	Pressure because of deadlines	Set additional and reasonable extensions if deviations from certain tasks occur.
	Inadequate assignment of human resources	Improve the placement and assignment or users according to their skills and personality.
	Educational barriers	Different training should be users for persons of different skill levels. Persons showing adequacy can be taken out of a training program earlier than others.
	Fear of negative feedback/ evaluation	Encourage creativity and mistakes, as people learn from mistakes. Mistakes should never have a negative connotation.

Figure 6.8: The Causes and Solutions (continued)

#	Causes	Solutions
23	Heavy workload Over confidence of experts Users have different interpretations of requirements Pressure because of deadlines Inappropriate skills Inadequate assignment of human resources	Ensure the workload given to a user is fair and communicate the vision and goals to users so that they can prioritise their workload according to the bigger picture and it's importance. With a fair workload pressure can be eliminated. Communicate responsibility of tasks. Clearly communicate the organisational vision and requirements to users and encourage management to be a part of managerial briefings. Set additional and reasonable extensions if deviations from certain tasks occur. Improve employment methods, prior skills and capabilities are vital to ensure a user's ability to operate an IS. Improve the placement and assignment or users according to their skills and personality.
24	Pressure created by management Pressure because of deadlines Heavy workload Lack of freedom to explore domain Over confidence of experts Inappropriate skills Inadequate assignment of human resources Educational barriers Fear of negative feedback/ evaluation	Set additional and reasonable expectations if deviations from certain tasks occur. Set additional and reasonable extensions if deviations from certain tasks occur. Ensure the workload given to a user is fair and communicate the vision and goals to users so that they can prioritise their workload according to the bigger picture and it's importance. With a fair workload pressure can be eliminated. Give users the freedom to explore the problem domain by encouraging to find alternative methods to solving problems. Communicate responsibility of tasks. Improve employment methods, prior skills and capabilities are vital to ensure a user's ability to operate an IS. Improve the placement and assignment or users according to their skills and personality. Different training should be users for persons of different skill levels. Persons showing adequacy can be taken out of a training program earlier than others. Encourage creativity and mistakes, as people learn from mistakes. Mistakes should never have a negative connotation.
25	Fear of asking for help Inadequate/ insufficient experience Inadequate setting of goals and objectives Inadequate/ insufficient training Lack of change coordination	Create an anonymous query system or forum with expert feedback. Delegate less power and authority until the user is proven worthy of decision making. Clearly communicate goals and objectives to users. Delegate less power and authority until adequate training is received. Communicate changes of tasks or requirements; eliminate resistance by ensuring current employees of their job security and value.
26	Inadequate/ insufficient experience Inadequate/ insufficient training Inadequate setting of goals and objectives Lack of change coordination	Delegate less power and authority until the user is proven worthy of decision making. Delegate less power and authority until adequate training is received. Clearly communicate goals and objectives to users. Communicate changes of tasks or requirements; eliminate resistance by ensuring current employees of their job security and value.
27	Inadequate/ insufficient training Inadequate/ insufficient experience Fear of asking for help Inadequate setting of goals and objectives	Delegate less power and authority until adequate training is received. Delegate less power and authority until the user is proven worthy of decision making. Create an anonymous query system or forum with expert feedback. Clearly communicate goals and objectives to users.
28	Inadequate/ insufficient experience Inadequate/ insufficient training	Delegate less power and authority until the user is proven worthy of decision making. Delegate less power and authority until adequate training is received.
29	Lack of change coordination Inadequate setting of goals and objectives Inadequate/ insufficient training	Communicate changes of tasks or requirements; eliminate resistance by ensuring current employees of their job security and value. Clearly communicate goals and objectives to users. Delegate less power and authority until adequate training is received.
30	Inadequate/ insufficient training Inadequate setting of goals and objectives Lack of change coordination	Delegate less power and authority until adequate training is received. Clearly communicate goals and objectives to users. Communicate changes of tasks or requirements; eliminate resistance by ensuring current employees of their job security and value.
31	Inadequate setting of goals and objectives	Clearly communicate goals and objectives to users.
32	Inadequate/ insufficient training	Delegate less power and authority until adequate training is received.

Figure 6.9: The Causes and Solutions (continued)

#	Causes	Solutions
33	Poor organization of requirements due to lack of teamwork Ineffective methods of organizing individual requirements Poor planning Shifts interfere with sleep cycles Irregular working hours Limitation of available time	Set realistic schedules for work to be completed. A solution is to take a personal interest in staff regarding for example children, illnesses or family issues to better understand and accommodate employees. Set realistic schedules for work to be completed. Improved scheduling accommodating human "clock". Improved scheduling, close monitoring of after hours work and limiting employees to suitable hours. Provide adequate time to users for completion of tasks; learn from past regarding time scheduling and schedule accordingly.
34	Heavy workload Understaffed Task is rushed due to deadlines Irregular working hours Poor planning Poor organization of requirements due to lack of teamwork Limitation of available time Ineffective methods of organizing individual requirements	Ensure the workload given to a user is fair and communicate the vision and goals to users so that they can prioritise their workload according to the bigger picture and it's importance. With a fair workload pressure can be eliminated. Employ more staff to be able to handle current workload, even temporary people can be employed. Set realistic schedules for work to be completed. Improved scheduling, close monitoring of after hours work and limiting employees to suitable hours. Set realistic schedules for work to be completed. Set realistic schedules for work to be completed. Provide adequate time to users for completion of tasks; learn from past regarding time scheduling and schedule accordingly. A solution is to take a personal interest in staff regarding for example children, illnesses or family issues to better understand and accommodate employees.
35	Heavy workload Understaffed Shifts interfere with sleep cycles Irregular working hours Task is rushed due to deadlines Ineffective methods of organizing individual requirements	Ensure the workload given to a user is fair and communicate the vision and goals to users so that they can prioritise their workload according to the bigger picture and it's importance. With a fair workload pressure can be eliminated. Employ more staff to be able to handle current workload, even temporary people can be employed. Improved scheduling accommodating human "clock". Improved scheduling, close monitoring of after hours work and limiting employees to suitable hours. Set realistic schedules for work to be completed. A solution is to take a personal interest in staff regarding for example children, illnesses or family issues to better understand and accommodate employees.
36	Ineffective methods of organizing individual requirements Irregular working hours Shifts interfere with sleep cycles	A solution is to take a personal interest in staff regarding for example children, illnesses or family issues to better understand and accommodate employees. Improved scheduling, close monitoring of after hours work and limiting employees to suitable hours. Improved scheduling accommodating human "clock".
37	Noise Sensory overload Boss/ colleague discussion/ loud conversation Lack of proper environment/ inadequate workplace Commotion in workplace Competing tasks exists Environment stress Information overload Irregular working hours	Adapt or change conditions under which users work to address the cause of the disruption. Adapt or change conditions under which users work to address the cause of the disruption. Ensure the availability of social areas and boardrooms for informal meetings so that it can be done privately without distracting colleagues. Adapt or change conditions under which users work to address the cause of the disruption. Adapt or change conditions under which users work to address the cause of the disruption. Communicate the importance of tasks and the level of prioritisation it should receive. Adapt or change conditions under which users work to address the cause of the disruption. Communicate the importance of tasks and the level of prioritisation it should receive. Improved scheduling, close monitoring of after hours work and limiting employees to suitable hours.
38	Lack of proper environment/ inadequate workplace Environment stress Competing tasks exists Irregular working hours	Adapt or change conditions under which users work to address the cause of the disruption. Adapt or change conditions under which users work to address the cause of the disruption. Communicate the importance of tasks and the level of prioritisation it should receive. Improved scheduling, close monitoring of after hours work and limiting employees to suitable hours.
39	Noise Sensory overload Boss/ colleague discussion/ loud conversation Information overload Commotion in workplace Environment stress	Adapt or change conditions under which users work to address the cause of the disruption. Adapt or change conditions under which users work to address the cause of the disruption. Ensure the availability of social areas and boardrooms for informal meetings so that it can be done privately without distracting colleagues. Communicate the importance of tasks and the level of prioritisation it should receive. Adapt or change conditions under which users work to address the cause of the disruption. Adapt or change conditions under which users work to address the cause of the disruption.

Figure 6.10: The Causes and Solutions (continued)

#	Cause	Solution
40	Competing tasks exists	Communicate the importance of tasks and the level of prioritisation it should receive.
	Environment stress	Adapt or change conditions under which users work to address the cause of the disruption.
41	Personal fatigue and stress	Encourage breaks to increase focus as people have a limited attention span and re-evaluate workload planning.
	Daydreaming	Ensure that the work and the workplace is not monotonous and encourage breaks to increase focus as people have a limited attention span.
	Long period of time since learning/training	Implement adequate ongoing support tools.
	Overload of information (mental capacity restriction)	Increase the availability of information and therefore decreasing need to memorize data, knowledge or actions. Users can now rather focus at one thing at a time.
42	Methods and guidelines incomplete	Implement adequate monitoring systems.
	Methods/ rules that are ambiguous	Rules and methods should be clearly communicated and a manual to reference methods and rules should be available.
	Unclear goals and objectives	Communicate the bigger picture and objectives or visions of what the users are working towards or what their role is in the organisation.
	Methods/ rules that are wrong/ malformed	Rules and methods should be clearly communicated and create obvious means of reversing unintended actions or errors.
	Mistakes in developing models for analysing procedural requirements	Edit or adjust the currently developed model and procedures.
	Lack of management leadership	Encourage the involvement of management.
	Job satisfaction	Increase employee motivation.
	Lack of motivation	Increase employee motivation.
	Methods/ rules that are unenforced	Rules and methods should be clearly communicated and a manual to reference methods and rules should be available.
	Procedural discipline	Motivate, train and monitor the implementation of procedures.
43	Methods/ rules that are wrong/ malformed	Rules and methods should be clearly communicated and create obvious means of reversing unintended actions or errors.
	Too standardised, search for new possibilities is limited	Encourage the use of creativity in abnormal or unique situations.
	Methods/ rules that are unenforced	Rules and methods should be clearly communicated and a manual to reference methods and rules should be available.
	Mistakes in developing models for analysing procedural requirements	Edit or adjust the currently developed model and procedures.
	Unclear goals and objectives	Communicate the bigger picture and objectives or visions of what the users are working towards or what their role is in the organisation.
	Lack of motivation	Increase employee motivation.
	Job satisfaction	Increase employee motivation.
	Lack of management leadership	Encourage the involvement of management.
44	Procedural discipline	Motivate, train and monitor the implementation of procedures.
	Methods/ rules that are ambiguous	Rules and methods should be clearly communicated and a manual to reference methods and rules should be available.
	Methods/ rules that are wrong/ malformed	Rules and methods should be clearly communicated and create obvious means of reversing unintended actions or errors.
	Job satisfaction	Increase employee motivation.
	Lack of motivation	Increase employee motivation.
	Lack of management leadership	Encourage the involvement of management.
	Methods and guidelines incomplete	Implement adequate monitoring systems.
	Change requests are insufficiently formalized	Edit or adjust the currently developed model and procedures.
	Mistakes in developing models for analysing procedural requirements	Edit or adjust the currently developed model and procedures.
45	Too standardised, search for new possibilities is limited	Encourage the use of creativity in abnormal or unique situations.
	Methods/ rules that are wrong/ malformed	Rules and methods should be clearly communicated and create obvious means of reversing unintended actions or errors.
	Job satisfaction	Increase employee motivation.
	Lack of motivation	Increase employee motivation.
	Mistakes in developing models for analysing procedural requirements	Edit or adjust the currently developed model and procedures.
	Change requests are insufficiently formalized	Edit or adjust the currently developed model and procedures.
	Lack of management leadership	Encourage the involvement of management.

Figure 6.11: The Causes and Solutions (continued)

When following the structure of the model from left to right, a human error has to occur that a manager or supervisor has to identify. The error can then be found in the list labelled "human error", from the identification of the error it can be filtered down into a "classification" that leads to "context indicators". There are two or more "context indicators" connected to each "classification", these "context indicators" have options to be chosen to identify the relevant existing context. After a combination of the real world contexts are chosen the next step will be to go to the "causes and solutions" where a number is identified. This number is connected to a list of possible causes and solutions to aid in solving or potentially avoiding human errors.

6.4   The Need for Expert Validation

There is an assumption that science is not as scientific as we expect (Nanda *et al.*, 2000). Findings that may appear to be valid under certain conditions or disciplines may not be valid if assessed under different disciplines (Nanda *et al.*, 2000). Factors that have been identified and connected in forming the model are according to certain literature related knowledge. Since there is a lack of interdisciplinary validation it causes a constraint to the general applicability of the model.

Chapter 7 addresses the problem of finding scientific justification.

Chapter 7

Validation of the Model

The objective of this chapter is to validate the decision support model with the goal of identifying human errors that cause IS failure and find solutions to these occurrences of failure. The validation of the model is to ensure that it meets industry needs and that it is practical and operational. The chapter starts with introducing the background of the validation process and is followed by the validation of the decision support model itself.

7.1 Introduction

There exists consensus about the need for validation of research studies in order that results can be used effectively. Without validation the research questions cannot be truthfully answered and the model cannot be generalised for use in the real world. A lack of validity is a major constraint to the solving of complex problems and leads to poor decision making (Nanda *et al.*, 2000).

Decision Support Systems (DSS) are increasingly being used in environmental decision making and problem solving, and are therefore not only useful, but necessary (Moisil, 2000). The importance of DSS support the need for its validation.

A DSS is validated by considering how relevant and useful a decision model is for its pre-determined purpose (Moisil 2000; Finlay and Wilson 1991). An important focus during the process of DSS validation is to have a specific description of the following:

- Who will use the system?

- What is the type of problems that will be addressed?

The validity of the system is therefore restricted to a certain environment and the problem area, which is referred to as an industry need (Moisil, 2000).

A simple definition of the process of validation is checking the appropriateness of a model to create an acceptable representation in order to address real world problems (Finlay and Wilson, 1991).

7.2   Decision Support System Validation

There are two types of validation, internal and external validation. Internal validation refers to how well the study was conducted in terms of operational definitions and research design. External validation refers to the extent to which research results can be generalised and how widely it can be applied in real world situations.

7.2.1   Internal Validation

The greatest part of the model is validated by using existing research and a combination of valid models to create the new model. The missing link of validation is the link between the context indicators and the causes of error.

Content validity in Chapter 5 is done to create this connection, it refers to how well a model measures the behaviour for which it is intended. A panel of experts who is familiar with the work that is being measured, judges the content of the constructed model via survey response. This establishes to which extent they believe the content is true, or untrue. Multiple experts are used and the feedback is compared to establish a certain level of agreement.

7.2.2   External Validation

The goal of external validation is generalisation to the world at large. The decision support model has only been validated by existing scientific literature and the opinions of experts through surveys. Now an expert is chosen for external validation through the implementation of face validity. Face validity is a means of establishing content validity (Sarvela and McDermott, 1993). An article that assesses validation of decision support models, the life cycle of the model includes its development, validation by means of face validation and ultimately user and field test validation (Borenstein, 1998). In order to perfect a decision support model environmental application, user and field test validation, is necessary, though this takes years (Wierzbicki *et al.*, 2000).

By using this technique, face validation, the model is assessed and analysed for accuracy and relevance. Feedback is collected based on an expert's

opinion regarding a particular given construct. The expert decides whether the decision support model appropriately assesses the construct (Adams and Lawrence, 2014). This is useful when the opinions and judgements of experts and practitioners are necessary.

7.3   Face Validity

The expert chosen for validation associates with operational efficiency and fits the criteria regarding knowledge and experience of the research topic. Face validity needs but one person to review the research for it to to be credible (Sarvela and McDermott, 1993). As the sample population is only one person, the model can not necessarily be generalisable to all situations and industries. Even so, a larger group of experts cannot ensure generalisability (Hasson *et al.*, 2000). Representativeness is assessed on the quality of the expert(s) related to credibility, fittingness and confirmability (Nanda *et al.* 2000; Powell 2003; Yousuf 2007; Hasson *et al.* 2000) .

The expert is approached by means of an interview in order to validate the model. The steps explaining the process followed is:

Step 1 The expert has been identified as a person in charge of operational efficiency at a large company (large according to employee numbers, financial assets and income). The expert is a person in position to use the model in real-world situations.

Step 2 Communicating the model and the need for validation to the expert to ensure a clear and comprehensive understanding of the research problem.

Step 3 Receiving feedback through a face-to-face interview where the decision support model is presented.

Step 4 Analysing feedback to create a meaningful understanding of the decision support model.

7.4   Feedback

Where suggestions are not made, the expert has analysed and agreed with the decision support model. Suggestions were also made that merely confirmed what is already part of the model, which is positive, as practical situations confirm the research. The expert believes the model to be understandable by intended users in practice.

Feedback suggestions are captured under two sections. *Suggested Adjustments to the Model* is the specific inputs given in relation to the structure of the model itself. *Additional Suggestions* are those factors outside of the model that influence the logic and implementation of the model from a wider perspective.

7.4.1   Suggested Adjustments to the Model

It is suggested that *systems* should be added to the model as a human error classification. The model placed system problems or malfunction under the *complexity* classification. Complexity should be defined as those human errors that occur when the interface is not user friendly, when there are no help options or when it is difficult to navigate. The system itself is the tool, where human errors can occur due to software lags or tools incapable for the tasks at hand.

Human errors under the *communication* classification uses the term "requirements". Feedback suggests that an improved and simpler word should be used, namely "word" or "task" as the word "requirements" holds a wider definition which is more developer based.

The *communication* classification could be more specific by splitting the human errors in two groups as to distinguish between peer-to-peer and management communication. It is in the expert's opinion that communication between managers and users is more important than peer-to-peer communication. However, it is agreed that both should still be classified under the concept of communication.

The expert also pointed out that causes of failure linked to the classifications *training* and *experience* can be very much entwined. This is true, as for example a number of the causes of failure present under *training* are also present under experience.

An important suggestion is the addition of "technology" as a human error under the classifications *attention* and *time*. Technology entails all social media or web browsing that is not work related. Social media or web browsing serves not only as a distraction, but consumes more time than comprehended.

The suggested adjustments are made to the model. Edits are indicated through the use of red.
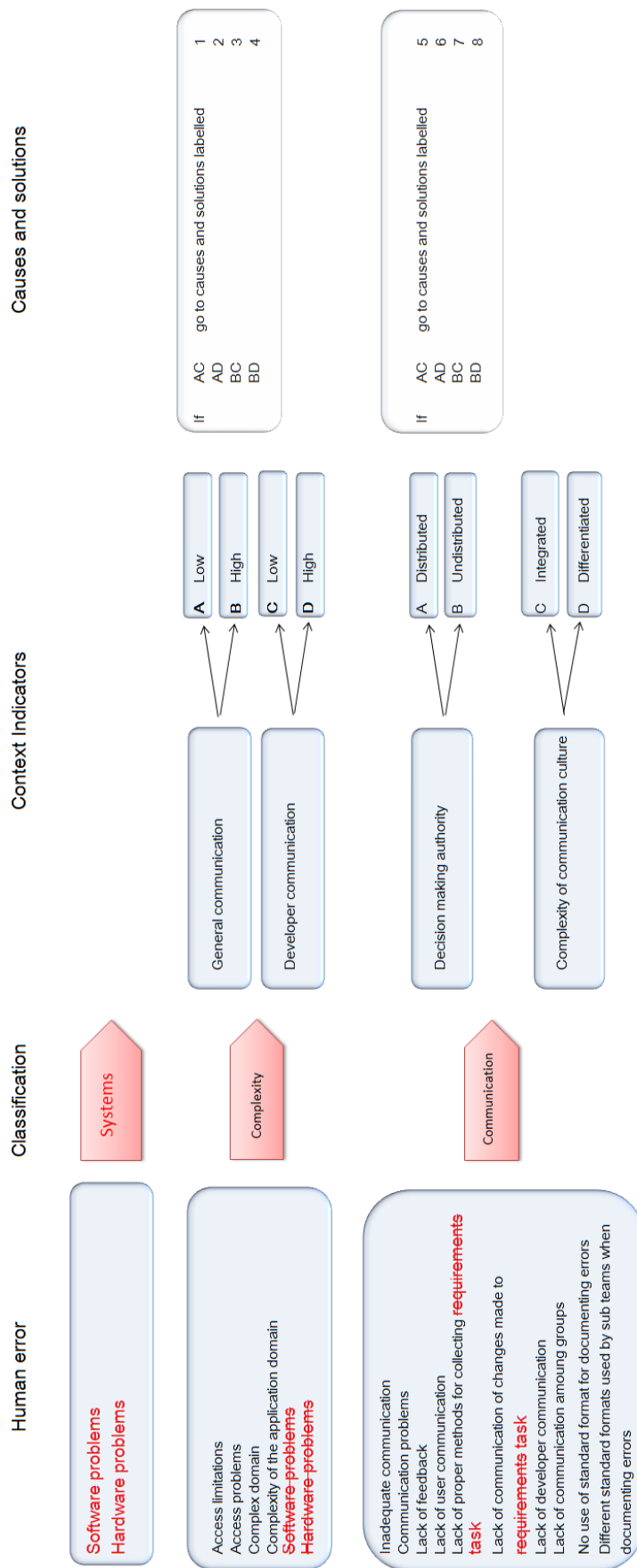
Figure 7.1: The Adjusted Decision Making Model
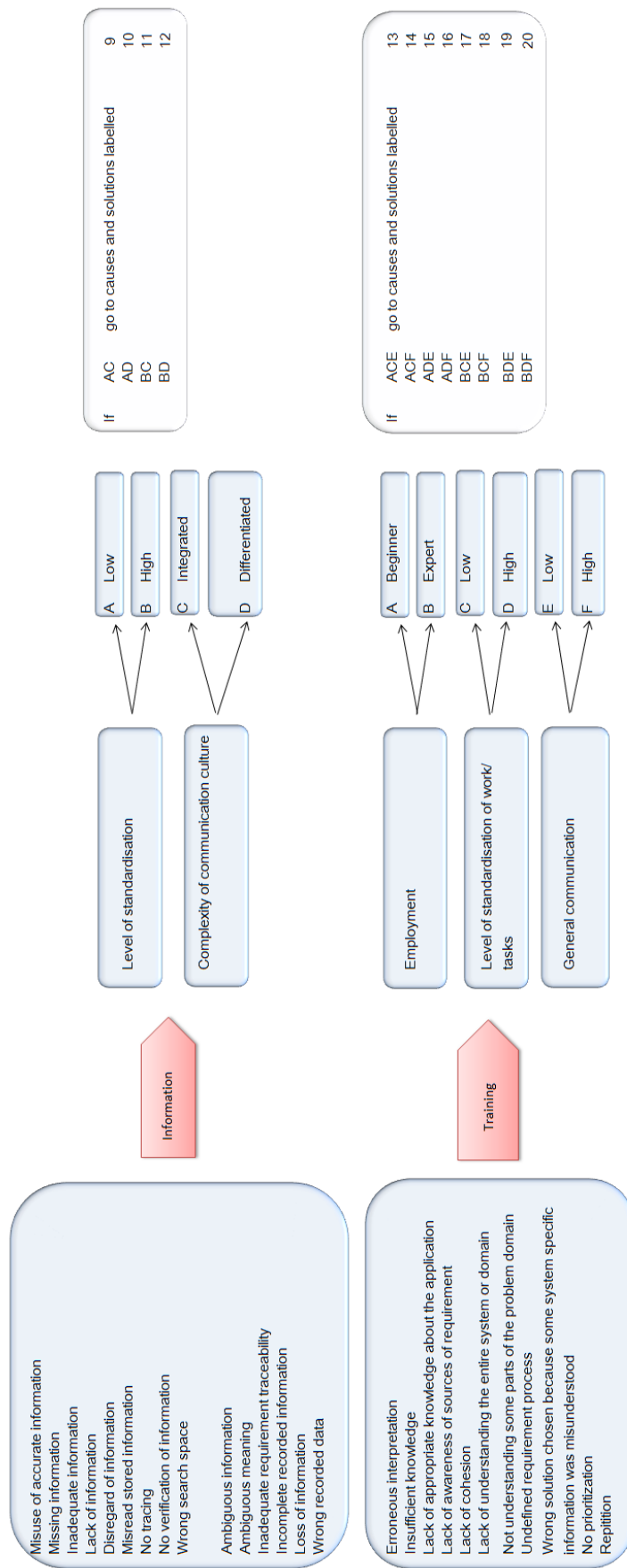
Figure 7.2: The Adjusted Decision Making Model
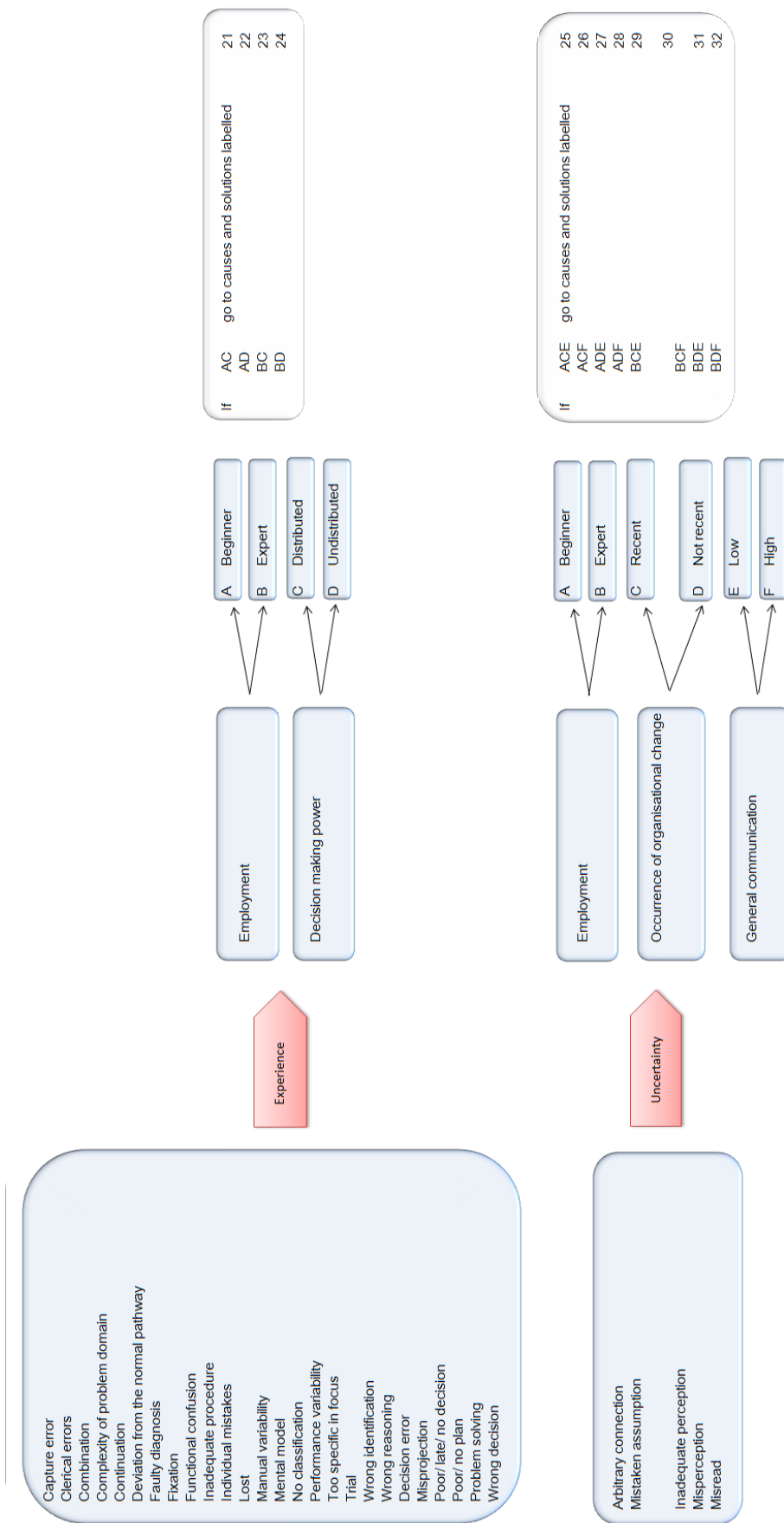
Figure 7.3: The Adjusted Decision Making Model
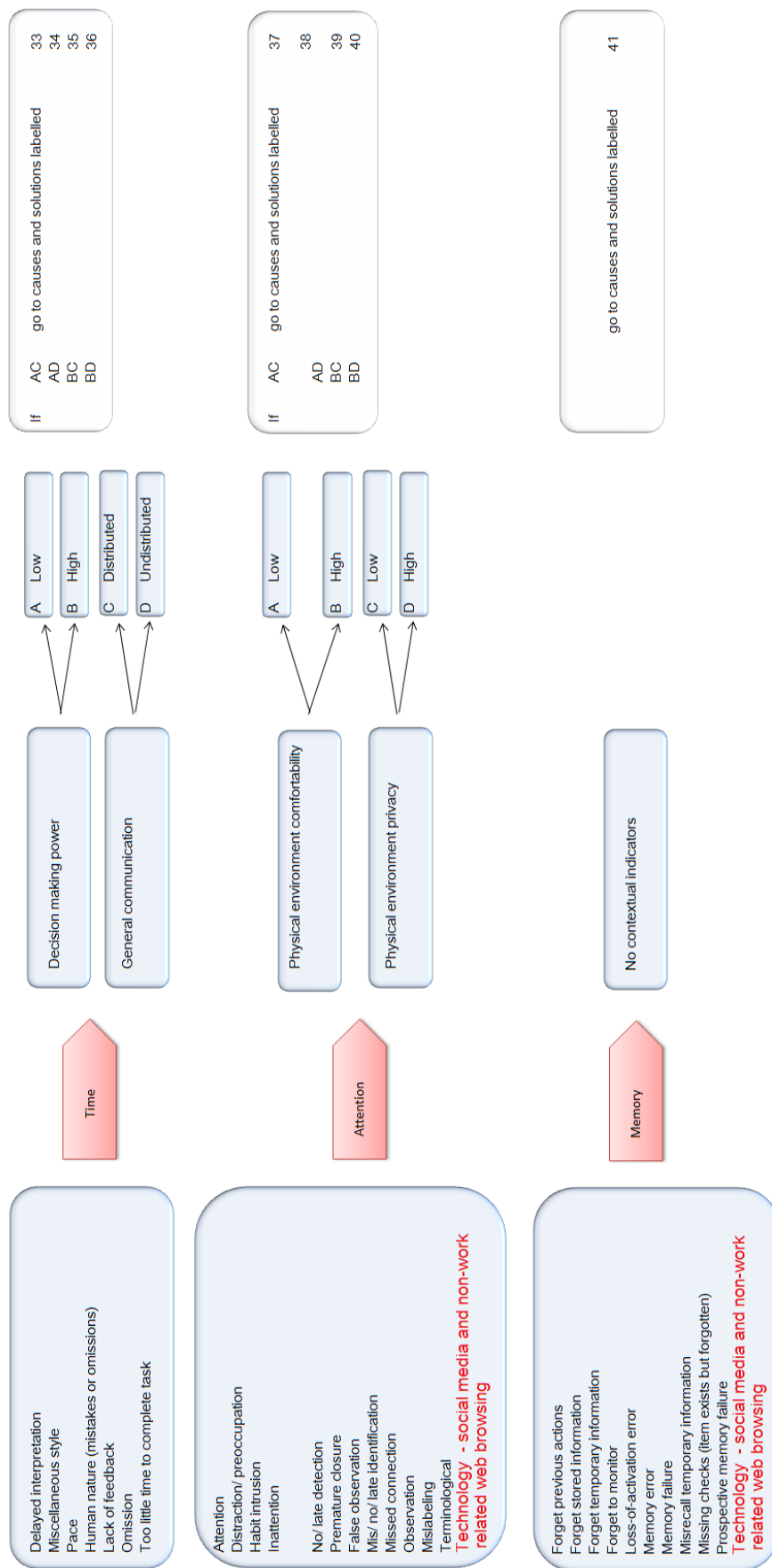
Figure 7.4: The Adjusted Decision Making Model
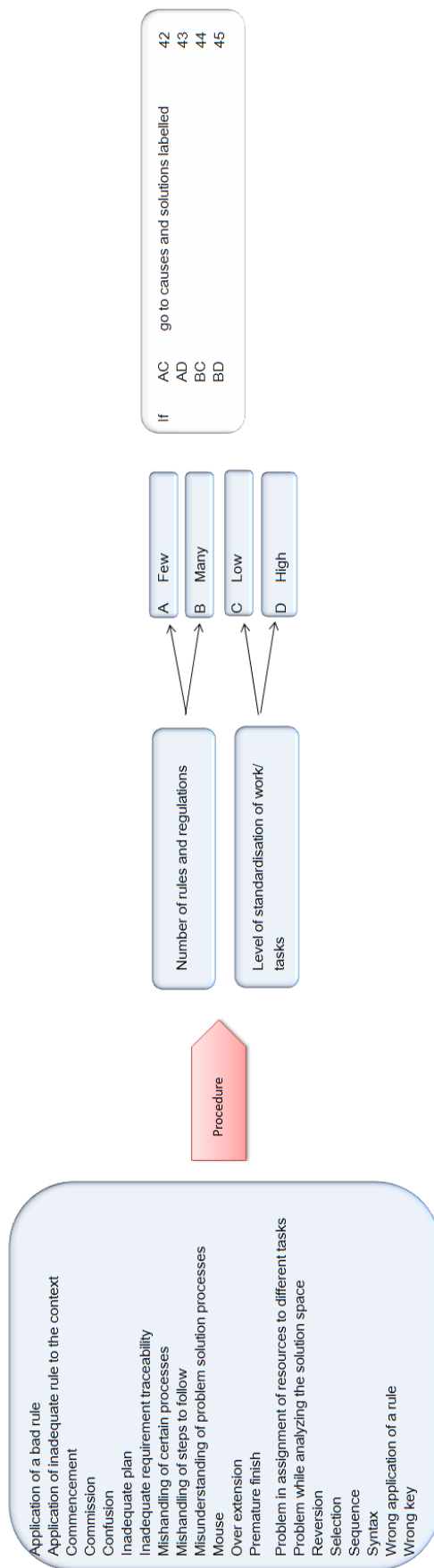
Figure 7.5: The Adjusted Decision Making Model

7.4.2 Additional Suggestions

It is suggested that a user may have more than one human error or symptom and that the model must take this into account. The model does this by having causes and solutions that repeat themselves under different situations. The expert believes this to be accurate and very inclusive of all possibilities. From an implementation perspective it is a strong indicator of accuracy if the user of the decision support model sees a repeated cause of failure .

Another proposal is the implementation of the decision support model in a specific environment, where it can be adapted in time to fit the situation. Human errors that regularly occur can be captured and the model can be edited and adapted to easily identify the failures in a specific organisation or department.

As the model's aim is to be generalisable, the expert believes adaption after implementation can serve specific environments.

7.4.3 Conclusion

The expert's opinion validates the decision support model and its usability in practice. Small changes to the structure of the model are suggested, though the expert believes the model is accurate and implementable. Refinement to specific situations can be achieved through implementation.

Chapter 8

Conclusions and Recommendations

This chapter's aim is to summarise the research findings. The contributions of the research are discussed, along with the conclusion and the limitations. Lastly recommendations are made for further research.

8.1   Summary of the Research Results

The research results are summarised in terms of the research questions.

8.1.1   Possible Organisational Contexts and Conditions

In order to address the problem, organisational contexts and conditions need to be identified and understood. Through the study of literature and content analysis an answer to the research question is obtained.

In response to the question – *What are the possible organisational contexts and conditions in which IS can exist where human error is possible?* – a list of eleven context indicators are identified. The short list of context indicators is as follows (the detailed list which includes definitions can be found in Section 4.2.3):

1. Decision making power

2. Decision making authority

3. Number of rules and regulations

4. Level of standardisation of work/tasks

5. Complexity in terms of communication culture

6. General communication

7. Developer communication

8. Occurrence of organisational change

9. Physical environment comfortability

10. Physical environment privacy

11. Employment

8.1.2   Human Error Classifications

In response to the research question – *What are the most likely human errors leading to IS inefficiencies and can they be classified in groups to simplify identification and can they be linked to the identified contexts and conditions?* – the short list of human error classifications is as follows (the detailed list which includes definitions can be found in Section 4.4.2):

1. Complexity

2. Communication

3. Information

4. Training

5. Experience

6. Uncertainty

7. Time

8. Attention

9. Memory

10. Procedure

The list of human errors linked to each classification can be seen in Appendix C.

To answer the second part of the question, these classifications are linked to the identified contexts and conditions in Table 8.1.

Human Error Classification	Context Indicators
Complexity	General Communication
	Developer Communication
Communication	Decision Making Authority
	Complexity of communication culture
Information	Level of standardisation
	Complexity of Communication Culture
Training	Employment
	Level of Standardisation of work/tasks
	General Communication
Experience	Employment
	Decision Making Power
Uncertainty	Employment
	Occurrence of Organisational Change
	General Communication
Time	Decision Making Power
	General Communication
Attention	Physical Environment Comfortability
	Physical Environment Privacy
Memory	No Contextual Indicators

Table 8.1: The linked classifications and contextual indicators

8.1.3 Causes of Human Error Leading to IS inefficiencies

To answer the third research question – *What are the most likely causes and related solutions to human error in IS and can they be linked to the context identifiers?* – according to the research, there are 45 causes found each relevant to human errors and each has a linked solution. The extensive and final list can be found in Section 6.3 labelled 1 to 45, as well as each link to the context identifiers connected through survey validation.

8.1.4 Building a Reliable Decision Making Model

The last research question – *With the answers from questions one to three, what will a reliable decision making model look like?* – is answered in Chapter 6. The entire model can be found in Chapter 6 along with instructions on how to use the model. The model is validated in Chapter 7.

8.2 Contribution of the Research

The research contributes to the problem of human error in both theory and practice.

8.2.1 Theoretical Contributions

The theoretical contributions are as follows:

1. An extensive list of human errors is established for identification of IS failure.

2. Human errors are classified in easily identifiable groups.

3. Contexts and conditions where human errors in IS can occur are established.

4. An extensive list of causes and their solutions is established.

5. A decision support model is built to help find root causes of human error related failures in IS. The model aims at finding the links between human errors, their classifications, contextual indicators and the causes of failure.

8.2.2 Practical Contributions

The practical contributions are as follows:

1. Support exists in the form of a decision making aid, to not only find human errors, but to solve or avoid these errors.

2. There is potential for decision making to be simplified and for time to be saved when the model is used.

3. The model supports the ongoing operations linked to IS, as it attempts to minimise the occurrence of ongoing errors through finding the root cause of these human errors.

8.3 Conclusions

For the success of the decision support model users and the provider of the model should work together in order to reach its full potential. Having the appropriate people involved who can ensure continuous improvement of the

model, is more important than having a perfect model.

The generalisability of the model is strengthened through implementation by users, as active participation is the route to realising the full value of the model. By actively monitoring real-world findings, the model can be adapted and accuracy can be improved to create the most value for the user. Commitment and open communication between the user and the provider of the decision support model are critical to success.

Continuous improvement and performance measurement are the paths forward for the model. Validation has proved the model to not only be implementable, but beneficial. Implementation can lead to the reduction of human errors that are costly to an organisation. Preventative measures can be put in place when an organisation is aware of the causes of human error, in order to increase efficiency.

It is necessary to provide a means to implement the decision support model in a structured and executable form.

8.4   Limitations

The limitation of the research is its lack of generalisability to all industries or organisations. The model is greatly based on literature related research, where the literature itself validates the model, as it is created through the combination of existing and proven models or research. Linking causes and solutions to context indicators is validated through surveys completed by experts, who are in daily contact with human error. The decision support model is then validated by an expert. The research is therefore partially based on existing literature and in part based on real-world related expertise.

The model aims at being generalisable and at investigating the problem in the broadest sense possible. The adaptions or differences needed in the model are potentially marginal, even so the model cannot be generalised across all situations or organisations. Content validity is inevitably based on judgement and there are no completely objective methods of ensuring a model's representativeness (Polit and Beck, 2008). Even though the research is validated by a credible expert, there is a need for more variations to be taken into account.

8.5 Recommendations and Future research

Recommendations for future research are made in order to expand on the new contributions made in this research and address the limitations.

1. The decision making model itself can be tried and tested by a wider spectrum of credible experts. The greater the amount of expert feedback received, the greater the level of generalisability across all possible situations.

2. The implementation of the model in real-world situations is recommended to refine the model for each situation. It is suggested that the model be adapted according to a specific organisation or department. The given model can be used and edited over time, as and when human errors occur. The basic decision support model is then modified according to each situation, creating a customised version for each organisation or situation.

3. It is recommended that a dashboard is created for the decision support model for ease of use and implementation. The possibility of a dashboard simplifies the use and understanding of the model.

Appendices

Appendix A

Human Errors per Journal Article

Journal article 1: The role of errors in learning computer software
Attention
Memory error
Observe
Observation
Observation
Sequence
Syntax
Wrong key
Arbitrary connection
Missed connection
Mistaken assumption
Mental model
Over extension
Wrong search space
Too specific in focus
Misunderstands task
Terminology
Combination
Fixation
Miscellaneous style
Pace
Premature closure

Journal article 2: Comparison of human performance by knowledge domain: Types, frequency, and sequencing of errors made while interacting with an information system
Attention
Commencement
Terminological
Problem solving

114

Commission
Omission
Continuation
Repetition
Premature finish
Mouse
Lost
Trial

Journal article 3: Application of human error theories for the process improvement of Requirements Engineering

Loss of information
Wrong recorded data
Disregard of information
No application of a good rule
Omission
Inadequate perception
Erroneous interpretation
Lack of cohesion
Capture error
No classification
Repitition
Wrong application of a rule
Application of a bad rule
Application of inadequate rule to the context
Deviation from the normal pathway
Confusion
Reversion
Incomplete recorded information
Ambiguous meaning
Inadequate means of communication
Lack of feedback
No prioritization
No tracing
No verification of information
Wrong decision
Loss-of-activation error

Journal article 4: Applications of integrated human error identification techniques on the chemical cylinder change task

Manual variability
Functional confusion

Habit intrusion
Distraction/ preoccupation
Omission
Timing
Sequence
Selection
Information Communication
No/ late detection
Misread
Misperception
Mis/ no/ late identification
Forget to monitor
Prospective memory failure
Forget previous actions
Forget temporary information
Misrecall temporary information
Forget stored information
Misread stored information
Misprojection
Poor/ late/ no decision
Poor/ no plan

Journal article 5: A systematic literature review to identify and classify software requirement errors

Inadequate project communications
Changes in the requirements not communicated
Communication and transcription error
Missing checks (item exists but forgotten)
Mishandling of steps to follow
Lack of understanding of the system
Lack of domain knowledge or lack of system knowledge
Communication problems
Individual mistakes
Lack of domain knowledge
Misunderstanding of problem solution processes
Carelessness while documenting requirements
Mishandling of certain processes
Poor communication between users and developers, and between members of the development teams
Lack of communication between sub teams; and inadequate requirement development processes
Communication errors between development teams
Lack of user communication

Complexity of problem domain
Problem in assignment of resources to different tasks
Inadequate requirement traceability
Problem while analysing the solution space
Communication issues between users and developers
Complexity of the application domain
Inadequate requirement traceability
Undefined requirement process
Poor communication and interactions among users and developers thorough the requirement development process
Lack of domain knowledge or lack of specific task knowledge
Clerical errors
Mistaken assumptions about the problem space
Different technical standards followed by sub-teams
Lack of proper environment
Complex domain
Lack of domain knowledge
Lack of communication
Lack of appropriate knowledge about the application and lack of awareness of sources of requirements
Lack of domain knowledge
Human nature (mistakes or omissions)
Communication problems
Simple omission
Wrong solution chosen because some system specific
Information was misunderstood
Not understanding some parts of the problem domain

Journal article 6: The Application of the Root Causes of Human Error Analysis Method Based on HAZOP Analysis in Using Process of Weapon
False observation
Wrong identification
Faulty diagnosis
Wrong reasoning
Decision error
Delayed interpretation
Inadequate plan
Priority error
Memory failure
Distraction
Performance variability
Inattention

Equipment failure
Inadequate procedure
Access limitations
Ambiguous information
Access problems
Mislabeling
Communication failure
Missing information
Insufficient knowledge

Appendix B

Categorised Human Error

The journal articles are numbered as follows:

1. The role of errors in learning computer software

2. Comparison of human performance by knowledge domain: Types, frequency, and sequencing of errors made while interacting with an information system

3. Application of human error theories for the process improvement of Requirements Engineering

4. Applications of integrated human error identification techniques on the chemical cylinder change task

5. A systematic literature review to identify and classify software requirement errors

6. The Application of the Root Causes of Human Error Analysis Method Based on HAZOP Analysis in Using Process of Weapon

Classification	Human Errors and paper numbers
Complexity	Complexity of the application domain [5]
	Lack of proper environment [5]
	Complex domain [5]
	Equipment failure [6]
	Access limitations [6]
	Access problems [6]
Communication	Misunderstands task [1]
	Inadequate means of communication [3]
	Information Communication [4]
	Inadequate project communications [5]
	Changes in the requirements not communicated [5]
	Communication and transcription error [5]
	Communication problems [5]
	Poor communication between users and developers, and between members of the development teams [5]
	Lack of communication between sub teams; and inadequate requirement development processes [5]
	Communication errors between development teams [5]
	Lack of user communication [5]
	Communication issues between users and developers [5]
	Poor communication and interactions among users and developers thorough the requirement development process [5]
	Lack of communication [5]
	Communication problems [5]
	Communication failure [6]
Information	Wrong search space [1]
	Loss of information [3]
	Wrong recorded data [3]
	Disregard of information [3]
	No application of a good rule [3]
	Incomplete recorded information [3]
	Ambiguous meaning [3]
	No tracing [3]
	No verification of information [3]
	Misread stored information [4]
	Carelessness while documenting requirements [5]
	Inadequate requirement traceability [5]
	Ambiguous information [6]
	Missing information [6]
Training	Repetition [2]
	Erroneous interpretation [3]
	Lack of cohesion [3]

Classification	Human Errors and paper numbers
	Repetition [3]
	No prioritization [3]
	Lack of understanding of the system [5]
	Lack of domain knowledge or lack of system knowledge [5]
	Lack of domain knowledge [5]
	Undefined requirement process [5]
	Lack of domain knowledge or lack of specific task knowledge [5]
	Different technical standards followed by sub-teams [5]
	Lack of domain knowledge [5]
	Lack of appropriate knowledge about the application and lack of awareness of sources of requirements [5]
	Lack of domain knowledge [5]
	Wrong solution chosen because some system specific information was misunderstood [5]
	Not understanding some parts of the problem domain [5]
	Priority error [6]
	Insufficient knowledge [6]
Experience	Mental model [1]
	Too specific in focus [1]
	Combination [1]
	Fixation [1]
	Problem solving [2]
	Continuation [2]
	Lost [2]
	Trial [2]
	Capture error [3]
	No classification [3]
	Deviation from the normal pathway [3]
	Wrong decision [3]
	Manual variability [4]
	Functional confusion [4]
	Timing [4]
	Misprojection [4]
	Poor/ late/ no decision [4]
	Poor/ no plan [4]
	Individual mistakes [5]
	Complexity of problem domain [5]
	Clerical errors [5]
	Wrong identification [6]
	Faulty diagnosis [6]
	Wrong reasoning [6]

Classification	Human Errors and paper numbers
	Decision error [6]
	Performance variability [6]
	Inadequate procedure [6]
Uncertainty	Arbitrary connection [1]
	Mistaken assumption [1]
	Inadequate perception [3]
	Misread [4]
	Misperception [4]
	Mistaken assumptions about the problem space [5]
Time	Miscellaneous style [1]
	Pace [1]
	Omission [2]
	Omission [3]
	Lack of feedback [3]
	Omission [4]
	Human nature (mistakes or omissions) [5]
	Simple omission [5]
	Delayed interpretation [6]
Attention	Attention [1]
	Observe [1]
	Observation [1]
	Missed connection [1]
	Terminology [1]
	Premature closure [1]
	Attention [2]
	Terminological [2]
	Habit intrusion [4]
	Distraction/ preoccupation [4]
	No/ late detection [4]
	Mis/ no/ late identification [4]
	False observation [6]
	Distraction [6]
	Inattention [6]
	Mislabeling [6]
Memory	Memory error [1]
	Loss-of-activation error [3]
	Forget to monitor [4]
	Prospective memory failure [4]
	Forget previous actions [4]
	Forget temporary information [4]
	Misrecall temporary information [4]
	Forget stored information [4]

Classification	Human Errors and paper numbers
Procedure	Missing checks (item exists but forgotten) [5]
	Memory failure [6]
	Sequence [1]
	Syntax [1]
	Wrong key [1]
	Over extension [1]
	Commencement [2]
	Commission [2]
	Premature finish [2]
	Mouse [2]
	Wrong application of a rule [3]
	Application of a bad rule [3]
	Application of inadequate rule to the context [3]
	Confusion [3]
	Reversion [3]
	Sequence [4]
	Selection [4]
	Mishandling of steps to follow [5]
	Misunderstanding of problem solution processes [5]
	Mishandling of certain processes [5]
	Problem in assignment of resources to different tasks [5]
	Problem while analysing the solution space [5]
	Inadequate requirement traceability [5]
	Inadequate plan [6]

Appendix C

Causes of Failure per Journal Article

Journal article 1: Application of human error theories for the process improvement of Requirements Engineering
Misunderstandings of requirements by superior
Lack of involvement due to internal factors like rivalry
Carelessness while documenting requirements
No use of standard format used for documenting information
Role prescription - user doesn't believe it s their responsibility to check information accuracy
Poor initial training
Poor ongoing training
Poor requirement planning and communication
People have different interpretations of requirements
Methods/ rules that are ambiguous
Methods/ rules that are wrong/ malformed
Methods/ rules that are unenforced
Change requests insufficiently formalised

Journal article 2: Applications of integrated human error identification techniques on the chemical cylinder change task
Poor initial training
Limited time a user has spent on specific domain
Education level of user
Limitation of available time
Shifts interfere with sleep cycles
Understaffed
Sensory overload
Lack of proper environment/ inadequate workplace
Personal fatigue and stress

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Overload of information (mental capacity restriction)
Methods/ rules that are ambiguous

Journal article 3: A systematic literature review to identify and classify software requirement errors
Poor communication among developers and users
User needs not well-understood or interpreted by different stakeholders
Lack of involvement of users at all times during requirement development
Hardware malfunction/ bugs/ clumsy/ unreliable
Software malfunction/ bugs/ clumsy/ unreliable
Only relying on selected users to accurately define all the requirements
Unclear lines of authority
Unclear lines of communication (written or oral)
Not involvement of all the stakeholders
Lack of involvement due to internal factors like rivalry
Constraints on humans as information processors
Ease of finding information/ lack of information availability
Poor management of people and resources
Conflicting requirements by lack of communication
Insufficient skills
Complete lack of training
Not ready to use system, but lack option of rejecting it
Lack of motivation
Inappropriate skills
Heavy workload
Inadequate assignment of human resources
Lack of process/ problem understanding
Lack of change coordination
Inadequate setting of goals and objectives
Inadequate/ insufficient training
Inadequate/ insufficient experience
Ineffective method of organizing individual requirements
Poor planning
Poor organization of requirements
Too standardized, search for new possibilities is limited
Mistakes in developing models for analysing procedural requirements
Lack of management leadership

Journal article 4: The Application of the Root Causes of Human Error Analysis Method Based on HAZOP Analysis in Using Process of Weapon
Design impairment

Lack of involvement due to internal factors like rivalry
Poor initial training
Poor ongoing training
Legitimate higher priority
Inadequate team support
Insufficient skills
Insufficient skills
Pressure created by management
Fear of asking for help
Irregular working hours
Noise
Temporary incapacitation
Boss/ colleague discussion/ loud conversation
Competing tasks exists
Lack of proper environment/ inadequate workplace
Irregular working hours
Daydreaming
Long period of time since learning/training
Methods and guidelines incomplete
Unclear goals and objectives

Journal article 5: The Reluctance to Report Bad News on Troubled Software

Mood of the communicator
Mood of the recipient
Disincentives for learning
Limited time a user has spent on specific domain
Education level of user
Educational barriers
Over confidence of experts
Lack of confidence
Fear of negative feedback/ evaluation
Job satisfaction

Journal article 6: Understanding Adverse Events: Human factors

Lack of involvement due to internal factors like rivalry
Pressure because of deadlines
Overload of information (mental capacity restriction)
Methods and guidelines incomplete
Methods/ rules that are ambiguous

Journal article 7: Development and Application of a Human Error

Identification Tool for Air Traffic Control
Insufficient skills
Environment stress
Overload of information (mental capacity restriction)

Journal article 8: A Taxonomy of Error Types for Failure Analysis and Risk Assessment
Lack of post implementation support (tool or assistant)
Unclear lines of authority
Unclear lines of communication (written or oral)
Fear of admitting mistakes
No use of standard format used for documenting information
Reporting culture, unspoken rule against bad news reporting
No training staff available
Lack of feedom to explore (problem) domain
Over confidence of experts
Lack of change coordination
Heavy workload
Task is rushed due to deadlines
Information overload
Sensory overload
Commotion in workplace
Lack of proper environment/ inadequate workplace
Environment stress
Personal fatigue and stress
Overload of information (mental capacity restriction)
Methods/ rules that are wrong/ malformed
Methods/ rules that are unenforced
Lack of motivation
Procedural discipline

Appendix D

Categorised Causes of Human Error

The journal articles are numbered as follows:

1. Application of human error theories for the process improvement of Requirements Engineering

2. Applications of integrated human error identification techniques on the chemical cylinder change task

3. A systematic literature review to identify and classify software requirement errors

4. The Application of the Root Causes of Human Error Analysis Method Based on HAZOP Analysis in Using Process of Weapon

5. The Reluctance to Report Bad News on Troubled Software

6. Understanding Adverse Events: Human factors

7. Development and Application of a Human Error Identification Tool for Air Traffic Control

8. A Taxonomy of Error Types for Failure Analysis and Risk Assessment

Classification	Causes of Human Error and paper numbers
Complexity	Poor communication among developers and users [3]
	Design impairment [4]
	Lack of post implementation support (tool or assistant) [8]
	User needs not well-understood or interpreted by different stakeholders [3]
	Lack of involvement of users at all times during requirement development [3]
	Hardware malfunction/ bugs/ clumsy/ unreliable [3]
	Hardware malfunction/ bugs/ clumsy/ unreliable [3]
Communication	Only relying on selected users to accurately define all the requirements [3]
	Unclear lines of authority [3; 8]
	Unclear lines of communication (written or oral) [3; 8]
	Not involvement of all the stakeholders [3]
	Misunderstandings of requirements by superior [1]
	Mood of the communicator [5]
	Mood of the recipient [5]
	Fear of admitting mistakes [8]
	Lack of involvement due to internal factors like rivalry [1; 3; 4; 6]
Information	Constraints on humans as information processors [3]
	Carelessness while documenting requirements [1]
	No use of standard format used for documenting information [1; 8]
	Ease of finding information/ lack of information availability [3]
	Role prescription - user doesn't believe it s their responsibility to check information accuracy [1]
	Reporting culture, unspoken rule against bad news reporting [8]
Training	Poor initial training [1; 2; 4]
	Poor ongoing training [1; 4]
	Poor management of people and resources [3]
	Poor requirement planning and communication [1]
	Conflicting requirements by lack of communication [3]
	Legitimate higher priority [4]
	Inadequate team support [4]
	Insufficient skills [3; 4]
	Complete lack of training [3]
	No training staff available [8]
	Disincentives for learning [5]
	Not ready to use system, but lack option of rejecting it [3]
	Lack of motivation [3]

Classification	Causes of Human Error and paper numbers
Experience	Limited time a user has spent on specific domain [2; 5]
	Insufficient skills [4; 7]
	Inappropriate skills [3]
	Heavy workload [3]
	Inadequate assignment of human resources [3]
	Lack of process/ problem understanding [3]
	Education level of user [2; 5]
	Lack of freedom to explore domain [8]
	Educational barriers [5]
	Over confidence of experts [5; 8]
	People have different interpretations of requirements [1]
	Lack of confidence [5]
	Pressure created by management [4]
	Pressure because of deadlines [6]
	Fear of negative feedback/ evaluation [5]
Uncertainty	Lack of change coordination [3; 8]
	Fear of asking for help [4]
	Inadequate setting of goals and objectives [3]
	Inadequate/ insufficient training [3]
	Inadequate/ insufficient experience [3]
Time	Limitation of available time [2]
	Shifts interfere with sleep cycles [2]
	Heavy workload [8]
	Understaffed [2]
	Irregular working hours [4]
	Ineffective method of organizing individual requirements [3]
	Task is rushed due to deadlines [3; 8]
	Poor planning [3]
	Poor organization of requirements [3]
Attention	Noise [4]
	Temporary incapacitation [4]
	Information overload [8]
	Sensory overload [2; 8]
	Boss/ colleague discussion/ loud conversation [4]
	Competing tasks exists [4]
	Commotion in workplace [8]
	Lack of proper environment/ inadequate workplace [2; 4; 8]
	Irregular working hours [4]
	Environment stress [7; 8]

Classification	Causes of Human Error and paper numbers
Memory	Daydreaming [4]
	Long period of time since learning/training [4]
	Personal fatigue and stress [2; 8]
	Overload of information (mental capacity restriction) [2; 6; 7; 8]
Procedure	Methods and guidelines incomplete [4; 6]
	Methods/ rules that are ambiguous [1; 2; 6]
	Methods/ rules that are wrong/ malformed [1; 3; 8]
	Methods/ rules that are unenforced [1; 8]
	Unclear goals and objectives [4]
	Job satisfaction [5]
	Lack of motivation [3; 8]
	Too standardized, search for new possibilities is limited [3]
	Mistakes in developing models for analysing procedural requirements [3]
	Change requests insufficiently formalized [1]
	Lack of management leadership [3]
	Procedural discipline [8]

Appendix E

Survey Analysis

E.1   Survey Questions

Causes of human error that lead to information systems failure

All questions present a given circumstance with causes of human error linked to each.

Please tick ALL of the boxes where you agree (that it is indeed a cause of human error connected to the given circumstance) Where you disagree simply leave the box un-ticked.

1 COMPLEXITY AS A CAUSE OF HUMAN ERROR
Definitions:
General communication - is the level of communication between users of the same information system. Where if there are high levels of communication between users it is classified as high or where there is little communication between users it is classified as low.

Developer communication - is the level of communication between users and the developers of the information system. Where if there is high levels of communication between users and developers it is classified as high or where there is little communication between users and developers it is classified as low.

General communication is low and developer communication is low

- Poor communication among developers and users exists

- There is a design impairment

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- The user needs are not well understood or interpreted by different stake-holders

- The lack of involvement of users at all times during requirement development

- There is a lack of post implementation support; in the form of a tool or person

General communication is high and developer communication is high

- Hardware malfunction/ bugs/ unreliable

- Software malfunction/ bugs/ unreliable

General communication is low and developer communication is high

- The user needs are not well understood or interpreted by different stake-holders

- There is a lack of involvement of users at all times during the development of the requirement

General communication is high and developer communication is low

- There is poor communication among developers and users

- There is a design impairment

- There is a lack of post implementation support; in the form of a tool or person

2 COMMUNICATION AS A CAUSE OF HUMAN ERROR

Definitions:

Decision making authority - is the extent to which the authority (authority is a person's right to act or make decisions due to their position) to make decisions is distributed. Where many people can make decisions an organisation is distributed or where few people, say only top management, can make decisions an organisation is undistributed.

Complexity of communication culture - is the level to which an organisation is coordinated and shares a common corporate culture. Where a highly coordinated organisation is integrated or where low levels of coordination exists an organisation is differentiated.

Decision making authority is undistributed and complexity of communication culture is integrated

- Only relying on selected users to accurately define all the requirements

- Misunderstandings of requirements by superior

- Mood of the communicator

- Mood of the recipient

- Fear of admitting mistakes

- Lack of involvement due to internal factors (such as rivalry)

Decision making authority is distributed and complexity of communication culture is integrated

- There are unclear lines of authority

- Mood of the communicator

- Mood of the recipient

Decision making authority is undistributed and complexity of communication culture is differentiated

- Only relying on selected users to accurately define all the requirements

- Not involvement of all the stakeholders

- Misunderstandings of requirements by superior

- Mood of the communicator

- Mood of the recipient

Decision making authority is distributed and complexity of communication culture is differentiated

- Unclear lines of authority

- Unclear lines of communication (written or oral)

- Mood of the communicator

- Mood of the recipient

3 INFORMATION AS A CAUSE OF HUMAN ERROR

Definitions:

Level of standardisation - of work/tasks is the extent to which human discretion is allowed and the level of pre-set expected behaviour. Where there is little pre-set expected behaviour standardisation is low or where there is many pre-set expected behaviours standardisation is high.

Complexity of communication - culture is the level to which an organisation is coordinated and shares a common corporate culture. Where a highly coordinated organisation is integrated or where low levels of coordination exists an organisation is differentiated.

Level of standardisation is low and complexity of communication culture is integrated

- Constraints on humans as information processors

- Carelessness while documenting requirements

- No use of standard format used for documenting information

- Role prescription error - user doesn't believe it's their responsibility to check information accuracy

- Reporting culture is complex - unspoken rule against bad news reporting

Level of standardisation is high and complexity of communication culture is integrated

- Constraints on humans as information processors

- Reporting culture is complex - unspoken rule against bad news reporting

- Carelessness while documenting requirements

Level of standardisation is low and complexity of communication culture is differentiated

- Constraints on humans as information processors

- Carelessness while documenting requirements

- No use of standard format used for documenting information

- Difficult to find information/ lack of information availability

Level of standardisation is high and complexity of communication culture is differentiated

- Constraints on humans as information processors

- Difficult to find information/ lack of information availability

- Carelessness while documenting requirements

4 TRAINING AS A CAUSE OF HUMAN ERROR

Definitions:

Employment - defines the user's ability to use or operate a certain information system. Where a domain is the technology employed by an organisation, users can be classified as either beginners or experts. A beginner is an individual who has the prerequisite knowledge assumed by the domain or experts and an expert is an individual with specialised knowledge of the domain.

Level of standardisation of work/tasks - is the extent to which human discretion is allowed and the level of pre-set expected behaviour. Where there is little pre-set expected behaviour standardisation is low or where there is many pre-set expected behaviours standardisation is high.

General communication - is the level of communication between users of the same IS. Where if there are high levels of communication between users it is classified as high or where there is little communication between users it is classified as low.

User is a beginner, standardisation is low and general communication is low

- Poor initial training

- Poor ongoing training

- Poor management of people and resources

- Poor requirement planning and communication

- Conflicting requirements

- Inadequate team support

- Insufficient skills

- Complete lack of training

- No training staff available

- Disincentives for learning

- Lack of motivation

User is a beginner, standardisation is high and general communication is low

- Poor ongoing training

- Poor management of people and resources

- Poor requirement planning and communication

- Conflicting requirements

- Inadequate team support

- Insufficient skills

- Complete lack of training

- Disincentives for learning

- Not ready to use system/domain, but lack option of rejecting it

- Lack of motivation

User is a beginner, standardisation is low and general communication is high

- Poor initial training

- Poor management of people and resources

- Insufficient skills

- No training staff available

- Disincentives for learning

- Lack of motivation

User is a beginner, standardisation is high and general communication is high

- Poor management of people and resources

- Legitimate higher priority of tasks

- Insufficient skills

- Disincentives for learning

- Lack of motivation

User is an expert, standardisation is low and general communication is low

- Poor initial training

- Poor ongoing training

- Conflicting requirements

- Inadequate team support

- Disincentives for learning

- Lack of motivation

User is an expert, standardisation is high and general communication is low

- Poor ongoing training

- Conflicting requirements

- Inadequate team support

- No training staff available

- Disincentives for learning

- Lack of motivation

User is an expert, standardisation is low and general communication is high

- Poor initial training

- Disincentives for learning

- Lack of motivation

User is an expert, standardisation is high and general communication is high

- Legitimate higher priority of tasks

- Disincentives for learning

- Lack of motivation

5 EXPERIENCE AS A CAUSE OF HUMAN ERROR

Definitions:

Employment - defines the user's ability to use or operate a certain information system. Where a domain is the technology employed by an organisation, users can be classified as either beginners or experts. A beginner is an individual who has the prerequisite knowledge assumed by the domain or experts and an expert is an individual with specialised knowledge of the domain.

Decision making power - is the extent to which the power (power is any individual's ability to influence decisions) to make decisions is distributed. Where many people can influence decisions an organisation is distributed or where few people, say only top management, can influence decisions an organisation is undistributed.

User is a beginner and decision making power is distributed

- Limited time a user has spent on specific domain

- Insufficient skills

- Heavy workload

- Inadequate assignment of human resources

- Lack of process/ problem understanding

- Education level of user

- Educational barriers

- Users have different interpretations of requirements

- Pressure because of deadlines

- Fear of negative feedback/ evaluation

User is an expert and decision making power is distributed

- Inappropriate skills

- Heavy workload

- Inadequate assignment of human resources

- Educational barriers

- Over confidence of experts

- Users have different interpretations of requirements

- Pressure because of deadlines

User is a beginner and decision making power is undistributed

- Limited time a user has spent on specific domain

- Insufficient skills

- Heavy workload

- Inadequate assignment of human resources

- Lack of process/ problem understanding

- Education level of user

- Lack of freedom to explore domain

- Educational barriers

- Lack of confidence

- Pressure created by management

- Pressure because of deadlines

- Fear of negative feedback/ evaluation

User is an expert and decision making power is undistributed

- Inappropriate skills

- Heavy workload

- Inadequate assignment of human resources

- Lack of freedom to explore domain

- Educational barriers

- Over confidence of experts

- Lack of confidence

- Pressure created by management

- Pressure because of deadlines

- Fear of negative feedback/ evaluation

6 UNCERTAINTY AS A CAUSE OF HUMAN ERROR

Definitions:

Employment - defines the user's ability to use or operate a certain information system. Where a domain is the technology employed by an organisation, users can be classified as either beginners or experts. A beginner is an individual who has the prerequisite knowledge assumed by the domain or experts and an expert is an individual with specialised knowledge of the domain.

Occurrence of organisational change - is when change to the organisation or organisational structure is present it is still an ongoing process or if change is not present it has already occurred and been finalised.

General communication - is the level of communication between users of the same information system. Where if there are high levels of communication between users it is classified as high or where there is little communication between users it is classified as low.

User is a beginner and change is recent and general communication is low

- Lack of change coordination

- Fear of asking for help

- Inadequate setting of goals and objectives

- Inadequate/ insufficient training

- Inadequate/ insufficient experience

User is a beginner and change is not recent and general communication is low

- Fear of asking for help

- Inadequate setting of goals and objectives

- Inadequate/ insufficient training

- Inadequate/ insufficient experience

User is a beginner and change is recent and general communication is high

- Lack of change coordination

- Inadequate setting of goals and objectives

- Inadequate/ insufficient training

- Inadequate/ insufficient experience

User is a beginner and change is not recent and general communication is high

- Inadequate/ insufficient training

- Inadequate/ insufficient experience

User is an expert and change is recent and general communication is low

- Lack of change coordination

- Inadequate setting of goals and objectives

- Inadequate/ insufficient training

User is an expert and change is not recent and general communication is low

- Inadequate setting of goals and objectives

- Inadequate/ insufficient training

User is an expert and change is recent and general communication is high

- Lack of change coordination

- Inadequate setting of goals and objectives

- Inadequate/ insufficient training

User is an expert and change is not recent and general communication is high

- Inadequate/ insufficient training

7 TIME AS A CAUSE OF HUMAN ERROR

Definitions:

Decision making power - is the extent to which the power (power is any individual's ability to influence decisions) to make decisions is distributed. Where many people can influence decisions an organisation is distributed or where few people, say only top management, can influence decisions an organisation is undistributed.

General communication - is the level of communication between users of the same information system. Where if there are high levels of communication between users it is classified as high or where there is little communication between users it is classified as low.

General communication is low and decision making power is distributed

- Limitation of available time

- Shifts interfere with sleep cycles

- Irregular working hours

- Ineffective methods of organizing individual requirements

- Poor planning

- Poor organization of requirements due to lack of teamwork

General communication is high and decision making power is distributed

- Shifts interfere with sleep cycles

- Irregular working hours

- Ineffective methods of organizing individual requirements

General communication is low and decision making power is undistributed

- Limitation of available time

- Shifts interfere with sleep cycles

- Heavy workload

- Understaffed

- Irregular working hours

- Ineffective methods of organizing individual requirements

- Task is rushed due to deadlines

- Poor planning

- Poor organization of requirements due to lack of teamwork

General communication is high and decision making power is undistributed

- Shifts interfere with sleep cycles

- Heavy workload

- Understaffed

- Irregular working hours

- Ineffective methods of organizing individual requirements

- Task is rushed due to deadlines

8 ATTENTION AS A CAUSE OF HUMAN ERROR

Definitions:

Physical environment comfortability - is the extent to which the physical environment makes a user comfortable for example temperature and lighting. Where a user is uncomfortable the classification is low or where the user is comfortable the classification is high.

Physical environment privacy - is the extent to which the physical environment creates private and undisturbed work ethic. Where a physical environment with an open seating plan and open policy would give low levels of privacy or where a physical environment with closed office spaces would give high levels of privacy.

Physical environment comfortability is low and physical environment privacy is low

- Noise

- Temporary incapacitation

- Information overload

- Sensory overload

- Boss/ colleague discussion/ loud conversation

- Competing tasks exists

- Commotion in workplace

- Lack of proper environment/ inadequate workplace

- Irregular working hours

- Environment stress

Physical environment comfortability is low and physical environment privacy is high

- Temporary incapacitation

- Information overload

- Competing tasks exists

- Lack of proper environment/ inadequate workplace

- Irregular working hours

- Environment stress

Physical environment comfortability is high and physical environment privacy is low

- Noise

- Temporary incapacitation

- Information overload

- Sensory overload

- Boss/ colleague discussion/ loud conversation

- Competing tasks exists

- Commotion in workplace

- Environment stress

Physical environment comfortability is high and physical environment privacy is high

- Temporary incapacitation

- Information overload

- Competing tasks exists

- Environment stress

9 PROCEDURE AS A CAUSE OF HUMAN ERROR

Definitions:

Number of rules and regulations - is the extent to which the rules and regulations are preprogrammed and the input towards job execution. Where the rules and regulations are highly preprogrammed the rules are many or where the rules and regulations are minimally preprogrammed the rules are few.

Level of standardisation of work/tasks - is the extent to which human discretion is allowed and the level of pre-set expected behaviour. Where there is little pre-set expected behaviour standardisation is low or where there are many pre-set expected behaviours standardisation is high.

Number of rules and regulations is few and level of standardisation is low

- Methods and guidelines incomplete

- Methods/ rules that are ambiguous

- Methods/ rules that are wrong/ malformed

- Methods/ rules that are unenforced

- Unclear goals and objectives

- Job satisfaction

- Lack of motivation

- Mistakes in developing models for analysing procedural requirements

- Lack of management leadership

- Procedural discipline

Number of rules and regulations is many and level of standardisation is low

- Methods and guidelines incomplete

- Methods/ rules that are ambiguous

- Methods/ rules that are wrong/ malformed

- Job satisfaction

- Lack of motivation

- Mistakes in developing models for analysing procedural requirements

- Change requests are insufficiently formalised

- Lack of management leadership

- Procedural discipline

Number of rules and regulations is few and level of standardisation is high

- Methods/ rules that are wrong/ malformed

- Methods/ rules that are unenforced

- Unclear goals and objectives

- Job satisfaction

- Lack of motivation

- Too standardised, search for new possibilities is limited

- Mistakes in developing models for analysing procedural requirements

- Lack of management leadership

Number of rules and regulations is many and level of standardisation is high

- Methods/ rules that are wrong/ malformed

- Job satisfaction

- Lack of motivation

- Too standardised, search for new possibilities is limited

- Mistakes in developing models for analysing procedural requirements

- Change requests are insufficiently formalized

- Lack of management leadership

10 MEMORY AS A CAUSE OF HUMAN ERROR Errors surrounding memory is seen as specifically individual related, therefore the context or physical environment an individual finds them self in would not have an effect on errors caused by memory failure. Please do however indicate if you agree that the following are causes of memory failures by ticking the box.

Causes to memory failure

- Daydreaming

- Long period of time since learning/training

- Overload of information (mental capacity restriction)

- Personal fatigue and stress

Thank you

Appendix F

Research Ethics Committee Approval

Approval Notice
New Application

17-Nov-2015
Van Deventer, Lienke L

Proposal #: SU-HSD-001239
Title: **A Decision Support Model to Identify Causes of Human Error Creating Information Systems Failure**

Dear Ms Lienke Van Deventer,

Your **New Application** received on **19-Oct-2015**, was reviewed
Please note the following information about your approved research proposal:

 Proposal Approval Period: **13-Nov-2015** -**12-Nov-2016**

General comments:
The researcher is reminded to obtain permission from the participating organisation/institution for access to their information/data and/or employees. Proof of permission should be kept on record.

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your **proposal number** (**SU-HSD-001239**) on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 218089183.

 Included Documents:
 DESC Report - Ficker, Tanya
 REC: Humanities New Application

Sincerely,

Clarissa Graham
REC Coordinator

Figure F.1: Approval Notice

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