Ollscoil na hÉireann, Corcaigh

National University of Ireland, Cork

University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

An Exploration of Decision Making Oscillations in Dynamic and Undynamic Environments

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for the degree of

Doctor of Philosophy

University College Cork

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2021

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Declaration

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at the University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism.

List of Research Outputs

Aspects of this thesis have been peer-reviewed and published in the Journal of Decision systems as shown below:

Michael O'Driscoll, Gaye Kiely & John McAvoy (2019) The data-driven pilot and the risk of personal sensitivity to a negative outcome, Journal of Decision Systems, 28:2, 101-119, DOI: 10.1080/12460125.2019.1620574

Acknowledgements

The writing of this page marks the culmination of a research journey which I could not have completed alone. As such it is only right to thank all the people who played such an important role in this journey.

I would like to thank my supervisors, Dr Gaye Kiely and Dr John McAvoy. Thank you for your guidance, enthusiasm, patience, and the good humour that this work was conducted in. It was a pleasure working with you both over the years.

Thank you to Professor Joseph Feller for allowing me to conduct this research in such a supportive department. I would also like to thank all BIS staff who offered me support and advice on research, teaching, and anything else down through the years.

To my colleagues Conor, Ian, Steve, Yvonne, and Wendy thank you for your support and advice throughout this process but mostly for the good fun along the way. It made every day working in UCC enjoyable. I would also like to thank all my past colleagues of the PhD lab.

To my parents, Ann & Eamonn, and brother Denis, thank you for your continued enthusiasm for all my endeavours. I will always be grateful for the support and advice you've given me throughout the years and would not be in this position without it. Thank you Orla for your encouragement, positivity, fun, lifts in the rain, and all those coffees.

Abstract

The rapidly changing nature of information and use of information systems within organisations has seen the emergence of a gradual mistrust of human decision-making approaches. This is evident today with both researchers and practitioners advocating for an increased use of data-driven decision making**.** Although the advantages of using a data-driven approach have been well-documented, there has been scant research on the interplay between a data-driven approach and more human-centric decision making from an information systems perspective. To that end, this research study seeks to explore oscillations in decision-making approaches while having access to information systems in dynamic and undynamic environments. Data was gathered across four case study locations, in two distinct environments. The first of these was classified as a dynamic environment and two case studies were investigated involving aircraft pilots and an air traffic controller. The second was classified as an undynamic environment, with two further case studies investigated involving a pharmacist and national grid controller.

The output of this study makes a number of contributions to IS theory and practise. Firstly, this study extends cognitive continuum theory to the information systems domain. In doing so, this study validates that decision makers will oscillate between an intuitive, system-aided judgement, and data-driven approach to decision making. Secondly, two distinct mechanisms are identified and once activated these mechanisms will oscillate a decision makers decision-making approach. These mechanisms are referred to as the personal sensitivity to a negative outcome mechanism and the process loafing mechanism. Thirdly, this research has validated that the environment a decision maker operates is a factor in the decision-making approach used. However, it was also found that the personal sensitivity to a negative outcome mechanism will override the environment a decision maker is in once activated. Fourthly, this study highlights the need for organisations to consider decision making approaches when implementing new policies, procedures, and information systems.

Chapter 1 will now provide a high level overview of each chapter in this research thesis.

Chapter 1: Research Overview

The chapter begins by providing rationale for studying the research topic in section 1.1. The research objective and research questions are introduced in section 1.2. The thesis roadmap discussed in Section 1.3 provides the reader with a high-level overview of the thesis as a whole, and the chapter concludes in section 1.4.The next section will provide a background to this research.

1.1 Rationale for Study

Decision making has been and continues to be a well-researched area. The importance of decision making can be seen in Mintzberg (1973) classical view of the manager. In this seminal work, Mintzberg (1973) found that the manager was the individual who was the “nerve centre of the organisation” and the individual who gathers, processes, and disseminates information across the organisation (Mallia, 1992). Theories on modes of cognition have traditionally focused upon the dual processes of intuition and analysis (Evans, 1996, Epstein, 1994, Khatri et al., 2018). Intuition is described as automatic, effortless, and rapid while analysis is more rule based, deliberate, and slower (Dane and Pratt, 2007, Dhami and Thomson, 2012). Historically, the high performing manger described by Mintzberg (1973) primarily relied upon using an intuitive decision making approach (Sadler-Smith, 2019). These intuitive and expert decision makers have also been observed outside of the business world in domains such as the medical field, manufacturing, and sport (Simon, 1987, Bin, 2004, Davenport, 2014). This highlights the importance of decision making across a range of domains as core to human activity. Historically, there has been mistrust in the use of information systems to aid decision making with the expert and intuitive manager more favoured by organisations (Davenport, 2013).

This view has changed as the nature and volume of information, and managers’ behaviour in seeking and using information, has undergone massive transformations in the past 20 years (Van Knippenberg et al., 2015). During this period there has been the emergence of improved electronics, the internet, business intelligence, and data analytics (Van Knippenberg et al., 2015, Davenport, 2013). Today as decision making has become increasingly assisted and automated by information systems, traditional managerial decision making has radically altered since the era of Mintzberg (Carillo, 2017). Mobile technology and internet of things are now offering organisations the ability to support highly mobile, location-aware, person-centred, and context-relevant operations and transactions (Chen et al., 2012). The widespread adoption of these technologies has led to increasing datasets and organisations are now seeking to hire managers who use a data-driven approach to decision making to maximise these datasets potential (Brynjolfsson and McElheran, 2016). The data-driven manager has been identified as a manager who uses data to be more effective at real-time decision making, responding to change, and understanding customers (Akhtar et al., 2019). In addition, using a data-driven approach allows a manager to see patterns and make decisions using information systems which was previously thought to be invisible (Barton and Court, 2012, Akhtar et al., 2019). The increasing popularity of using a data-driven decision making approach can be seen with employees being hired specifically for their expertise with statistics or trained to develop these skills for use with analytics (Bohler et al., 2017). This type of manager counters the type of manager that Mintzberg (1973) described.

There is a growing view that as the amount of data organisations collect increases, the importance placed on human decision-making approaches will be decreased (McAfee, 2013). This approach has not been without criticism with a situation developing that instead of having the statistics as a servant to expert choice, the expert becomes a servant of the statistical machine (Ayres, 2007). Domains such as the medical profession have also raised concerns, with research in the medical field showing that surgeons should trust their intuition far more than the systems they use in the operating theatre as switching on a particular analytical information system can switch off the decision makers intuition whilst in the operating theatre (Sutton et al., 2015). This is a view shared by Simon (1987) who observed that research into decision making has had “less impact on decision making that is loosely structured, intuitive, and qualitative” (pp.57). This debate offers an interesting avenue of research. As decision making becomes increasingly automated and assisted by information systems, how does this interplay with human intuition?

In addition to differing decision-making approaches available to a decision maker, research has shown that the decisions people make are often susceptible to the demands exerted on them by the environment (Porcelli and Delgado, 2009). Research conducted by Karimi et al. (2004) found that managerial tasks are affected by rapid changes in the decision-makers operating environment. Environments which are dynamic have been found to have increased time pressure, complexity, instability, and potential for information overload while undynamic environments have the opposite characteristics (Driskell and Salas, 1991, Khatri and Ng, 2000, Maitland and Sammartino, 2015). The rapidly changing characteristics of a dynamic environment have been found to negatively affect the decision making process (Khatri and Ng, 2000). In addition, dynamic environments such as those that CEOs, aircraft pilots, medical professionals, emergency services, and air traffic controllers operate in require large amounts of complex information to be processed in a short period of time. This is a phenomenon identified by Simon (1957) who reported that managers at the time were beginning to work under conditions of information overload moving away from information scarcity which had impacted managerial decision making previously. This phenomenon has not altered and is more pronounced today with the abundance of data available to individuals resulting in increasing competition for the attention of individuals, groups, and organisations. A key concern for organisations is the amount of data that decision makers are required to interact with to make decisions in dynamic environments (Colbert et al., 2016). The environment an individual operates in can impact on the most appropriate decision-making approach for that environment. Intuition has been shown to be best suited to decision makers in unstructured environments, whilst, in contrast to this, analytical decision-making systems are more applicable to structured environments (Dane and Pratt 2007). As undynamic environments are slower and more structured, this favours a more methodical decision-making approach. This contradicts current information systems practitioner and academic trends that advocate individuals using a data-driven approach to decision making across all environments. Is it valid to recommend a singular decision-making approach when existing research has found that the environment may alter an individual's decision-making approach?

This is a valid question as research in non-IS domains has shown that individuals may move between decision-making approaches (Custers, 2013, Dhami and Thomson, 2012). When individuals make decisions there are many obstacles and challenges which can inhibit the use a single decision making approach (Dhami and Thomson, 2012). These risks are highlighted by King (1985) who discussed individuals solely using information systems for their decision-making approach:

"It is so easy to lose sight of reality – to believe that the computer models numerical forecasts are real and that they describe future outcomes that will, in fact, come to pass (...). The computer model's forecasts are based solely on those predictions about the future that we are able to quantify. Those things that are not readily quantifiable are usually omitted, and in being omitted there is a danger that they may be ignored. (p. xi).

Outside of the IS domain, alternative decision-making approaches have been found to be more applicable to specific scenarios and no one specific decision-making system is applicable to all scenarios (Dhami and Thomson, 2012). The ability to utilise multiple decision-making approaches has been shown to be advantageous with Simon (1987) advising that successful managers use a combination of intuition and analysis**.** One theory that explores combinations of decision making approach is Cognitive Continuum Theory (CCT). CCT aims to improve decision making by defining the characteristics of a task and assigning the optimum decision-making approach to a specific task (Hamm, 1988). CCT proposes that decision makers use: an intuitive decision-making approach, an analytical decision-making approach, or a combination of both, referred to as quasirationality, when making a decision (Dhami and Thomson, 2012). CCT seeks to avoid reliance on one decision-making approach and aims to allow the decision maker to adopt the correct decision-making approach for a specific scenario. CCT has been applied in various domains including management, the medical profession, and engineering (Custers, 2013).

However, CCT has yet to be applied to the information systems domain, although there have been calls to expand the theory to this domain (Dhami and Thomson, 2012). This represents a gap in our existing knowledge of how or if a manager will oscillate between differing decision-making approaches when using an information system. As decision making oscillations have been found in differing domains it is important to discover if this phenomenon exists while the decision maker has access to an information system. This is vital as current academic and practitioner consensus favours the use of data-driven decision making. Yet, it has been found that there are risks for individuals who rely solely on information systems such as system misunderstandings and data overload (Krasnow Waterman and Bruening, 2014).

In addition, the need to understand how decision makers approach problems and arrive at a particular decision in a given environment is of great importance. It has been proposed that the decision-making approach and psychological processes adapt to the environment in which they function (Dhami et al., 2004). Prior research has found that the decision-making approach used by an individual is susceptible to the demands exerted on them by the environment (Porcelli and Delgado, 2009). This is especially true in dynamic environments which have limited time, high pressure, and complexity such as the aviation or management field. Pilots for example are required to operate in highly dynamic environments under conditions of high risk, time pressure, and uncertainty (Sarter and Schroeder 2001). These risks are highlighted further by the Federal Aviation Authority (FAA) who state that from October 2016 to September 2017, 247 individuals died in 209 general aviation accidents where the loss of control in pilot's decision making was the number one cause of accidents (Federal Aviation Authority, 2018). This highlights the vital importance of furthering our understanding of decision makers in dynamic and undynamic environments while having access to information systems.

This section has presented the rational for pursuing this research study. It discussed how high performing individuals have traditionally relied on intuitive decision making. This has changed in the past decade as individuals have increasing access to highly sophisticated information systems which are producing large quantities of data. The increased use of these systems has seen the data-driven individual being much sought after by organisations (Brynjolfsson and McElheran, 2016). In contrast to the focus on the data-driven individual in the Information Systems domain, research from other domains has found that individuals may move between differing decision making approaches rather than rely on a singular approach (Dhami and Thomson, 2012, Parker-Tomlin et al., 2017). It has also been found that the environment may alter an individual's decision-making approach (Maitland and Sammartino, 2015). This is a promising research avenue from an information systems perspective. Research in this area could lead to improved decision making by further understanding decision making for individuals having access to information systems in differing environments. This section has discussed the rationale for pursuing this research study. The next section will provide the reader with the research objective and research questions which will inform this research study.

1.2 Research Objective

This research objective aims to further understand modern decision-making processes in both dynamic and undynamic environments as outlined in Section 1.1. As such the research objective of this study is to:

To explore oscillations in decision-making approaches while having access to information systems in dynamic and undynamic environments.

To achieve the stated research objective, two exploratory research questions have been formulated. Exploratory research questions are suitable for this study due to the lack of research surrounding the research objective from an information systems perspective (Dhami and Thomson, 2012, Robson, 2002).

Research Question 1:

How do decision-making approaches oscillate while having access to information systems?

Research question 1 has been formulated to understand how decision-making approaches oscillate while having access to information systems. Mintzsberg classical view of the manager was one of being the "nerve centre of the organisation", and one who gathers, processes, and disseminates information across the organisation (Mallia, 1992). Historically managers of this type primarily relied upon using an intuitive decision making approach (Sadler-Smith, 2019). Today, the managerial information gathering, processing, and disseminating process as described by Mintzberg has undergone enormous changes. Organisations now prefer a manager who uses scenarios and simulations (data analytics) that provide immediate guidance on the best actions to take when disruptions occur (LaValle et al., 2011). The data-driven manager has been identified as a manager who uses data to be more effective at making real-time decision making, responding to change, and understanding customers (Akhtar et al., 2019). The data-driven manager can also identify emerging trends in a business environment and contribute to developing strategies to remain competitive (Rejikumar et al., 2020). In addition, using a data-driven approach allows a manager to see patterns and make decisions on data which was previously thought to be invisible using information systems (Barton and Court, 2012, Akhtar et al., 2019). Despite the noted advantages of the data-driven manager research from engineering, medical, and management domains have found that individuals will oscillate between differing decision-making approaches. Despite calls to do so, there has not been research conducted on how decision-maker oscillate between differing decision-making approaches when using information systems (Dhami and Thomson, 2012). This research question will allow the researcher to answer how modes of cognition oscillate when using information systems. This is vital to understand as misalignment between decision-making approach and task has been found to be detrimental in task performance (Dhami and Mumpower, 2018).

Research Question 2:

How does the dynamic or undynamic environment impact on the oscillation of decision-making approaches while having access to information systems?

This research question is formulated to gain further insights into whether the environment a manager works in will oscillate a managers decision-making approach. It has been established in this chapter that academic scholars and practitioners have placed an increasing emphasis on managers using a data-driven approach to decision making. What is not clear though is if environmental changes may oscillate a decision makers decision-making approach while having access to information systems. Existing research has found that the environment a decision maker operates in can have profound implications for a managers decision making (Goll and Rasheed, 1997, Elbanna, 2015). In addition, environmental uncertainty and complexity has been shown to increase the difficulty in decision making (Maitland and Sammartino, 2015). Issues such as these have been highlighted as a stumbling block in managers adopting a data-driven approach with managers today regularly required to make decisions under conditions of information overload due to the environment they operate in (Persson, 2018). Challenges relating to information can become more pronounced in dynamic environments which have increasing time constraints, complexity, high risk, and instability(Maitland and Sammartino, 2015). In contrast, undynamic environments have been found to have lowered time constraints, risk, and are more stable (Melville and Ramirez, 2008). In addition to environmental challenges, existing research has found that differing decision-making approaches are more suited to specific environments than others (Dane and Pratt 2007). The second research question will allow the researcher to identify how decision-making approaches oscillate when using information systems in dynamic and undynamic environments.

The next section will provide a high-level overview of the research thesis. Table 1 provides the title and a brief overview of the purpose of each chapter. Each of the chapters are expanded upon and discussed in more detail in the next section. The section ends with Figure 1 which provides a thesis roadmap. This roadmap shows the different phases of research and the interconnected relationship between each of the chapters.

1.3 Thesis Roadmap

This section will provided a high level overview of each of the remaining chapters of this thesis. Chapter 2 provides the theoretical background of the research study. This chapter gives a thorough and in-depth review of existing literature. This chapter builds upon Chapter 1 by using the research objective as a guide for exploring existing literature relating to the research topic. The chapter concludes by identifying a potential gap in existing research that can be explored by the researcher.

Chapter 3 introduces the methodological positions adopted by the researcher for this thesis. This chapter gives an overview of various research paradigms, research methods, research strategy, the data collection method, and data analysis techniques. The positivist, interpretivist, and critical realist research paradigms are discussed in detail. The research objective and questions are found to be most aligned with the critical realist paradigm.

Chapter 4 introduces the first two case studies which are both classified as being within a dynamic environment. The first case study focuses on aircraft pilots who operate a training simulation of a Boeing 737 series aircraft. The case study takes place at an international flight training academy for pilots approved by the European Aviation Safety Agency (EASA). The second case study of this chapter takes place in a live air-traffic control tower. This air-traffic control tower handles over two million passengers annually. Both case study locations were classified as being within a dynamic environment. In both case studies, the unit of analysis is the key decision maker.

Chapter 5 introduces two additional case studies which are both classified as being within an undynamic environment. The first case study focuses upon a pharmacist who works in a public pharmacy. The pharmacist is required to interact with patients who require urgent assistance, co-workers who are seeking advice, and also interact with a health information system. The second case study took place at the national grid-control room. The control room is responsible for the safe and reliable distribution of power for one half of the country. As with Chapter 4, the unit of analysis in both case studies of Chapter 5 is the key decision maker.

Chapter 6 compares and contrasts the dynamic environment discussed in chapter 4 with the undynamic environment discussed in chapter 5. The four individual case studies are compared and contrasted from the perspective of the environment. Three decision-making approaches are identified across all four case studies and these are compared and contrasted. The chapter also introduces two new findings which were not previously accounted for in the literature. The chapter concludes with a theoretical model summarising the chapter being presented.

Chapter 7 presents the conclusions and further discussion of the thesis findings which are outlined in previous chapters. The chapter provides a conclusion for the research questions which are introduced in Chapter 1.

Chapter	Title	Content
1	Introduction	Provides an overview of the research topic. Discusses the research objective, questions, and provides a research roadmap. This section introduces the rest of the thesis.
2	Theoretical Background	An overview of current and existing literature surrounding the research topic. The theoretical background provides a guide for the researcher to investigate.
3	Research Strategy	This section discusses the research paradigm most suitable to the research, the research method selected, and the data analysis phase.
4	Dynamic Environment	Investigates two case studies, a pilot and air-traffic controller, and if their decision making oscillates in a dynamic environment.
5	Undynamic Environment	Investigates two case studies, a pharmacist and national grid control manager, and if their decision making oscillates in a undynamic environment.
6	Cross Comparison of Case Studies	This section compares and contrasts chapter 4 and 5. This section will also present any new findings that have emerged.
7	Discussion	This section provides a summarized overview of the research study. Theoretical implications, practical implications, future research, and limitations are discussed.

Table 1: Outline of the Dissertation

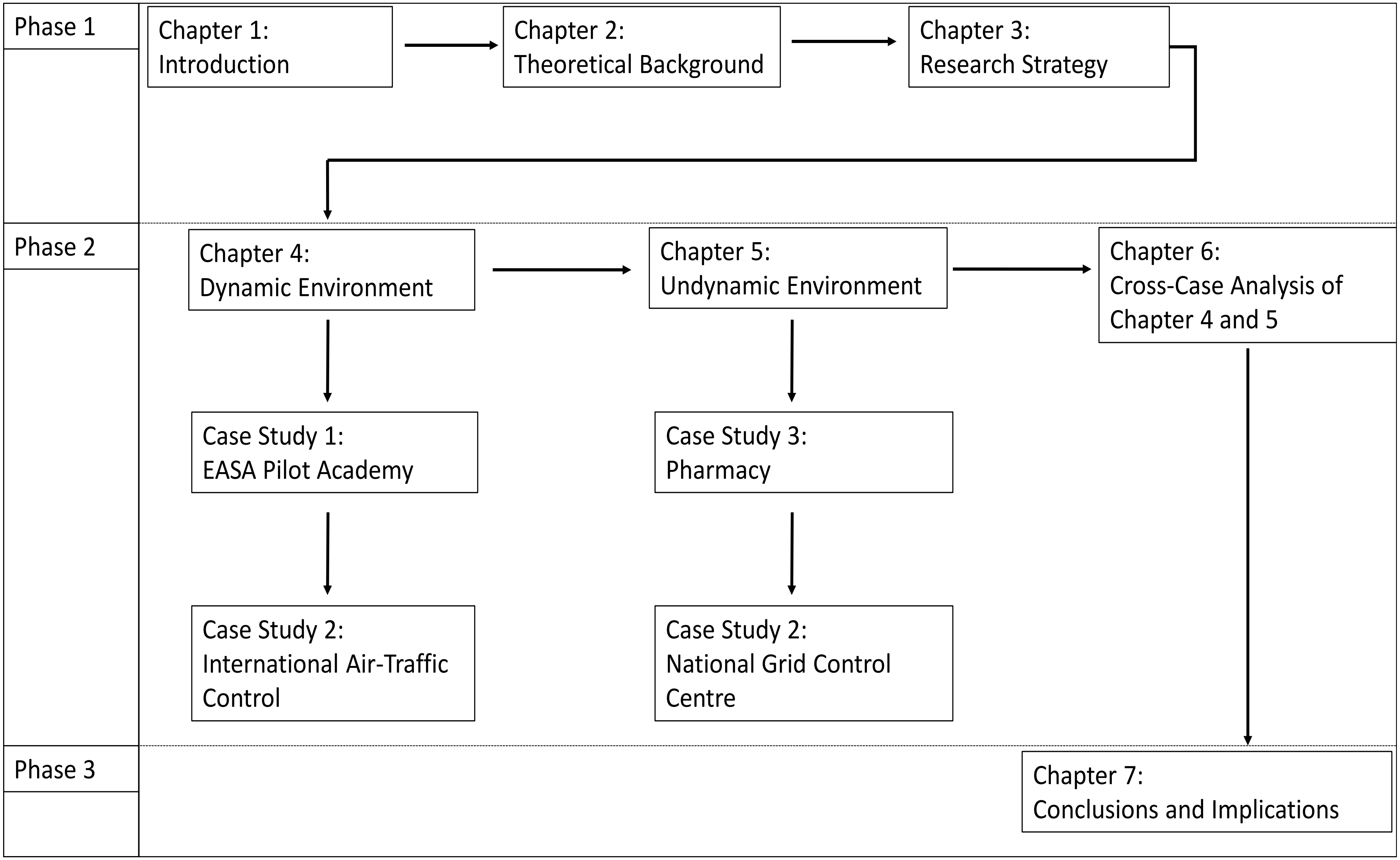

Figure 1 - Thesis Roadmap

Theoretical and practical contributions, future research, and limitations of the study are also presented and discussed by the researcher. A roadmap showing the relationship between sections is shown in Figure 1. The next section will conclude this chapter by giving the reader an overview of the research objective and questions.

1.4 Conclusion

This chapter has provided a high-level overview of the entire thesis by discussing the research background, research objective, and research questions. This chapter also provided an overview of the structure of the thesis and the relationships between each individual chapter. This is shown in Table 1 which provided the overall title and the content of each chapter. This was elaborated upon and discussed in more detail within the chapter. Figure 1 provides a graphical representation of the flow and relationships between each chapter. In summary, Chapter 1 - 3 provided the foundation of the thesis: introduction, literature review, and the research strategy. Chapter 4 and 5 build upon these foundations by detailing four case studies, two of which are categorised as being within a dynamic environment and two of which are categorised as being within an undynamic environment. Chapter 6 compare and contrast the dynamic environment and undynamic to further explore how decision-makers oscillate between differing modes of cognition when using information systems. Chapter 7 concludes the thesis by providing an in-depth discussion surrounding the theoretical and practical contributions of this study. Chapter 2 follows next which gives the theoretical background to the study.

Chapter 2: Theoretical Background

The past decade has seen a gradual mistrust of the human decision-making approaches with both researchers and practitioners advocating an increased use of data-driven decision-making to lower decision-making risk. This chapter explores how an emphasis on using a data-driven approach has come about and the impact this has had on individual decision-making.

Section 2.1 provides an overview of how the literature review was conducted. Section 2.2 introduces Simon (1978) theory of bounded rationality which highlights and explains the limitations and constraints under which human decision-making approaches are placed. Bounded rationality is important today as we have moved from a world of information scarcity to a world of information overload. Intuition and analysis, two individual's primary mode of decision making, are introduced in Section 2.3 In order to explore how intuition and analysis are used by individuals, the characteristics of both are deconstructed and discussed throughout Section 2.3 The vast amounts of data being created has resulted in the rise of information systems being used to support decision making. The differing types of business intelligence and data analytics and their application in different domains is discussed in Section 2.4. The use of business intelligence in different domains has raised questions on the relationship between an individual's decision-making approach and the use of a data-driven approach (discussed in Section 2.5). Cognitive Continuum Theory (CCT) is introduced in section 2.6 which explores how individuals will shift between differing decision-making approaches. As organisations now place an emphasis on the use of data analytics, how do these systems interact with individual decision making? The characteristics of CCT are broken down further in Sections 2.7 and 2.8. Section 2.7 discusses the impact task properties will have on the optimum decision-making approach used by an individual. It is proposed that if the properties of a task match the decision-making approach used by the individual, a successful task outcome is more likely. Section 2.8 focuses on how the environment in which a decision maker operates in affects the decision-making approach used.

Section 2.9 concludes the chapter with the resulting research objective and questions from the literature review discussed.

2.1 Conducting the Literature Review

To explore existing literature surrounding decision making a comprehensive literature review was conducted. The literature review conducted subscribes to the recommendations by Webster and Watson. A concept-centric approach (Figure 4) was conducted to ensure that the literature review did not become a subjective process. Creating a concept-centric literature review removes the possibility of the literature becoming a cherry picked set of references to support the authors viewpoint (Klopper and Lubbe, 2012). Adopting a concept-centric approach to the literature review also helps to clarify the concepts for the reader (Stendal et al., 2016).

A broad search strategy was conducted to find high-quality, peer-reviewed articles by searching inter-disciplinary databases (Science Direct, EBSCO, JSTOR, and Web of Knowledge). Adopting an inter-disciplinary search strategy is recommended as information systems an interdisciplinary field straddling other disciplines (Webster and Watson, 2002).Searches were preformed to find high-quality papers relating to the topic and papers were removed if:

1. The content of the paper did not relate to the phenomenon of interest.
2. No new contributions were presented in the paper.
3. The paper was dated pre 1960 as the focus was upon papers relating decision making and information systems due to the nature of this study.

The initial search returned 600 papers but once papers were reviewed based on the above criteria, the author was left with 250 high-quality, peer-reviewed journal papers. These papers were from varying fields and included management, information systems, aviation, sport, engineering, and the medical domain. From reviewing these papers, it was found that human decision-making has focused upon intuition and analysis. It was also found that increasing amounts of data have resulted in the automation of human decision-making approaches via the use of Business Intelligence (BI) and data analytics. The use of BI was discussed in a range of fields including financial trading, healthcare, sport, and aviation. The subsequent sections will now discuss the output of this endeavour.

2.2 Bounded Rationality

Individuals, regardless of their profession, are required to make decisions in uncertain situations under constraints of time, knowledge, and resources (Roehrich, Grosvold, & Hoejmose, 2014). Classical models of decision making have tended to ignore outside factors and treated human decision makers as knowing all possible permutations ahead of a decision (Simon, 1978). The concept of bounded rationality counters classic models and contains three parts:

(1) The need to search for decision alternatives

(2) The replacement of optimisation by targets and satisficing goals

(3) Mechanisms of learning and adaption (Simon, 1978).

Taking these into account, bounded rationality differs greatly from classical models of decision making. With regards to the selection of alternatives in decision making, classic models called for the decision maker to have knowledge of all alternatives before making a decision (Gigerenzer and Selten, 2001). This created two problems; the first being that the decision maker may not have access to all the information regarding alternatives. The second is the time required to make decisions. For example, high pressure, time-critical situations such as those pilots or air traffic controllers encounter would not allow time for the requirement to search for all the alternatives. It can therefore be stated that the environment has a great impact on a decision maker (Shapiro and Spence, 1997). Environments of time pressure are common in many professions such as financial traders, aviation, and healthcare professionals and as such would impact on their decision made.

Due to decision makers being constrained by factors of time and information, there will come a point when the decision maker needs to stop the search for alternatives (Parnell, 2017). Stigler (1961) describes this as the *stopping rule*, which is the point at which the costs for further search begin to exceed the benefits that a continued search could bring. This is one of the key differentiators between unbounded rationality and bounded rationale decision making. The latter model limits information search that is terminated by a stopping rule. Unbounded rationality encompasses decision making that has factored in the constraints of time, knowledge, money and computational capacities of the decision maker (K. Roehrich et al., 2014). Gigerenzer and Selten (2001) also state that real decision makers need to search for information and this process cannot go on forever. This argument can be held true even in well-structured environments which are governed by rules(Shapiro and Spence, 1997) . The game of chess is a great example of this. In chess, although the optimal move is available to the decision maker at every turn, not every move available can be made in a reasonable amount of time (Gigerenzer and Selten, 2001).

Simon proposes an alternative to simply stopping the search of alternatives, known as satisficing. A decision maker needs to find a relative level of aspiration exploring how good an alternative they wish to find is. As soon as an alternative is found that meets this level of aspiration, the search for alternatives is stopped (Simon, 1978, Parnell, 2017). Decision makers, "must use approximate methods to handle most tasks" (Simon 1990 p. 6). Incomplete information, for example, can be seen in market trading when making decisions (De Long et al., 1990). Stock market traders are described as acting on the basis of imperfect information and consequently cause prices to deviate from their equilibrium values. Although the method of satisficing reduces the amount of data to process and the speed of decision making, there can be a large amount of work to do in complex decisions at the beginning of the process. Custers (2013) describes satisficing as a form of adaptive behaviour which seeks an acceptable, but not necessarily the best, solution for a complex problem. In other words, satisficing is not fully analytical or intuitive. Analytic or intuitive decision making have been viewed as differing methods, but there is now a growing body of literature which now supports the view that this is in fact a false dichotomy (Dhami and Thomson, 2012). Research has been conducted which shows modes of cognition that lie in-between both intuition and analysis (Parker-Tomlin et al., 2017). This is referred to Cognitive Continuum Theory and will be discussed in Section 2.6. This section has discussed bounded rationality and the limitations of human decision making. The next section will discuss intuition and analysis decision-making approaches.

2.3 Intuition and Analysis

Theories on modes of cognition have traditionally focused on the dual processes of intuition and analysis (Evans, 1996, Epstein, 1994). Our judgment and decision making is partitioned into two main categories labelled as intuition and analysis (Stanovich and West, 2000).

Intuition has been referred to as System 1 or pattern recognition and governs much of our behaviour on a daily basis (Kahneman, 2011, Chase and Simon, 1973).Intuition is characterised as being automatic, effortless, involuntary, using associative processing, and requiring experience (Dhami and Thomson, 2012, Kahneman and Klein, 2009). Analysis decision making has been referred to as System 2, rational, or evaluative decision-making (Kahneman, 2011, Greeno and Simon, 1988, Evans, 2003). Analysis decision-making derives its name from its characteristics which are it's slower, rule based, deliberate, dominated by serial processing, and requires greater cognitive effort (Dane and Pratt, 2007, Kahneman, 2011). Analysis decision making is also described as being controlled, voluntary, and effortful (Kahneman and Klein, 2009). This study will refer to System 1 or pattern recognition as intuition and System 2, rational, or evaluative decision-making as analysis (Khatri et al., 2018).

Daniel Kahneman who is highly influential in the domain of decision making has found that intuition and analysis support each other in making decisions. Kahneman describes intuition as being able to rapidly propose answers to problems for decision makers that arise, while the evaluative and deliberate nature of analysis monitors the quality of these proposed answers. Analysis decision making has the capability to approve, correct, or override proposals by intuition thus allowing for self-monitoring. This is advantageous to the decision maker as analysis can monitor intuition and dictate a different strategy if there are signs our intuition could be wrong (Kahneman and Klein, 2009). If the decision that is ultimately expressed retains the initial proposal without much modification it can be called intuition, whereas changes to the initial hypothesis results in an analysis decision being made (Kahneman and Frederick, 2002). The use of intuition has been likened to a chess master instantaneously seeing a promising move while using analysis has been described as a person attempting to park a car in a narrow area or reading a map of a new area (Kahneman and Klein, 2009). The use of intuition and/or analysis has been described as human-centric decision making (Guo and Pedrycz, 2014).

The characteristics of intuition and analysis contrast but work concurrently (Hodgkinson and Sadler-Smith, 2018). Although both systems have had their respective characteristics researched, Dhami and Thomson (2012) notes that theories surrounding both systems have been criticised for not further exploring how intuition and analysis interact with one another. This is important as Hodgkinson and Sadler-Smith (2003) state that the switch between 'habits of mind' (intuition) and 'active thinking" (analysis) is the ultimate skill in today's organisation. If this is the case, it could be beneficial for decision makers to understand how to shift between intuition and analysis, if and when required. Existing research has shown that people rely on intuitive and analysis at the same time in a strategic management context (Hodgkinson and Clarke, 2007). Dhami and Thomson (2012) argue that the traditional view of these different modes of cognition are a false dichotomy. This is a viewpoint that Simon alluded to in the following quote:

"It is a fallacy to contrast analytic and intuitive styles of management...Every manager needs to be able to analyse problems systematically (and with the aid of the modern arsenal of analytical tools provided by management science and operations research). Every manager needs also to be able to respond to situations rapidly, a skill that requires the cultivation of intuition and judgment over many years of experience and training. The effective manager does not have the luxury of choosing between analytic and intuitive approaches to problems. Behaving like a manager means having command

of the whole range of management skills and applying them as they become appropriate "(Simon, 1987, p. 63).

The above quote by Simon, in which he states that managers don not have the luxury of choosing between an intuitive or analytical mode reinforces the view that a manager requires both approaches to be successful. Hogarth (2001) has contrasted analytical and intuitive processes, arguing that decisions made on the basis of highly complex inputs will benefit from intuitive processing and those made on the basis of less complex inputs would benefit from analytical processing. Intuitive decision making has been shown to be successful in completing tasks that involve high complexity and short time horizons (Dane and Pratt, 2007).

This section has introduced intuition and analysis decision making. Although intuition and analysis are often viewed as being dichotomous, there is a false dichotomy between the two approaches. Simon (1987) and Hodgkinson and Sadler-Smith (2003) state that intuition and analysis are interrelated and not separate. High performing decision makers require a combination of both intuition and analysis. In order to better understand how intuition and analysis operate, the next section will review the characteristics of both intuition and analysis.

2.3.1 Characteristics of Intuition and Analysis

The previous section introduced intuition and analysis as two modes of decision making. Although previously thought to be independent of one another, research has demonstrated this as not the case (Custers, 2013). In fact, managers may be required to use a combination of both analysis and intuition depending on the task they are conducting (Dhami and Thomson, 2012). It is necessary to compare and contrast the characteristics of intuition and analysis in order to gauge which characteristics are suited to specific tasks and if a combination of both can be used. Table 2 summarises the characteristics of both intuition and analysis which have been identified by Dane and Pratt (2007).These characteristics provide an insight into how these two systems operate differently. The proceeding sections will explore these characteristics.

Intuition	Analysis
Associative	Evaluative
Rapid rate of processing	Slow rate of processing
Requires Experience	Less Experience

Table 2 - Characteristics of analysis and intuition

2.3.2 Evaluative vs. Associative

The previous section identified that intuition and analysis have contrasting characteristics. This section will now compare and contrast the associative nature of intuition with the evaluative nature of analysis. The first characteristic of intuition is that it involves making associations between environmental stimuli which are matched with a non-conscious category or pattern (Dane and Pratt, 2007). Intuition involves recognising features or patterns rather than making connections through logical considerations (Klein and Myers, 1999). Additionally, the decision maker cannot usually give a verbal account of either the process by which the decision was reached or the grounds for judging if it is correct (Davis-Floyd and Arvidson, 2016). An example of intuition in action is shown by Simon (1987) with regard to chess professionals. Chess professionals can play simultaneous games, sometimes against as many as 50 opponents, and exhibit only a moderately lower level of skill than in games played under tournament conditions. In simultaneous play the professional takes less than a minute for each move as there is no time for careful analysis. Based on this, Simon (1987) conducted an experiment to find if this was visual memory or simply the chess professionals' intuition. Simon showed chess pieces on a board to a professional and a novice player, before removing the pieces and asked both individuals to put the pieces back down in the correct order. The chess professional will usually re-construct the whole position correctly and on average will place 23 or 24 pieces on their correct squares. The novice will only be able to replace about 6 pieces. In the second experiment the conditions were exactly the same as in the first experiment, except that now the 25 pieces are placed on the board at random. The novice can still replace about 6 pieces and the grandmaster also about 6. The difference between them, however, is that the first experiment does not relate to the chess professional's eyes but is based on patterns and clusters of pieces that occur on chessboards in the course of games. Based on this study it can be concluded that non-conscious associative pattern matching is intuitive. This contrasts greatly with literature and findings surrounding the analysis decision making approach (Bullini Orlandi and Pierce, 2019)

An analysis approach is described as involving systematic procedures based on mental reasoning and with a focus on detail (Allinson and Hayes, 1996, Calabretta et al., 2017). Analysis decision-making has also been described as being linear and highly logical (Allinson and Hayes, 1996, Calabretta et al., 2017). This allows the decision maker to recall the steps more easily to another person and piece by piece show how the solution to the problem was reached. This step-by-step logical nature of analysis decision making has allowed it to become more systematised by information systems. The next section will look at the speed of decision making when adopting an intuition or analytical approach.

2.3.3 Speed of Decision Making

The previous section discussed how intuitive decision making relies on a process in which environmental stimuli are matched with a category, pattern, or feature. The intuitive process was described as associative which contrasted with the evaluative process of analysis decision making. This can be described as weighing up options, evaluating costs, benefits, or outcomes. The evaluative nature has an impact on the speed of which a decision is reached with Eisenhardt (1990) stating that, strategies are irrelevant if they take too long to formulate and that there is now a "premium on moving fast and keeping pace". Speed is often viewed as the defining characteristic of intuition (Calabretta et al., 2017).This contrasts with how analytical thinking is viewed, with conscious thinking described as making connections through a slow and effortful analysis (Calabretta et al., 2017, Kihlstrom, 1987). Despite intuition and analysis being on opposite ends of the speed spectrum, existing research has found real-time data has a relationship with both, as seen by Eisenhardt (1990) stating that slow decision makers rely on planning and futuristic information. Hodgkinson and Sparrow (2002) also state that analysis decision-making is a controlled mode of processing, and it entails detailed analysis which is consciously controlled. Decision makers would typically spend a longer time on tracking the likely path of technologies, markets, or a competitors action. Once this data had been gathered a plan would be formed and this would finally then be put into action.

This is a slow process and organisations now place an emphasis on accessing real-time data which will provide them with instantaneous results (Raghupathi and Raghupathi, 2014). This contrasts with decision makers who have access to real-time data. Real-time information allows decision makers to identify problems and opportunities early, whilst also allowing the decision maker to build a deep, intuitive grasp of the business (Eisenhardt, 1990). The use of real-time data to aid decision making during problems or crisis resonates within existing literature on intuition. Khatri and Ng (2000) found that during times of environmental uncertainty the use of intuitive decision making among executives resulted in greater organisational performance. During times of environmental crisis and uncertainty there can be a shift away from standard operating procedures; adopting an intuitive approach can allow a decision-maker to arrive quickly at decisions under such circumstances (Li et al., 2016). Managers who use real-time data develop their own intuition which allows for faster and improved decision making in crisis. Slow decision makers are described as putting an emphasis on planning and forecasting information, looking to the future, and trying to predict (Eisenhardt, 1990). This section has discussed the speed of decision making when adopting an intuitive or analysis decision-making approach. The next section will discuss the level of experience required to adopt one of these approaches.

2.3.4 Level of Experience

Intuition has been described as a form of expertise or distilled experience based on a deep knowledge of the problems that continually arise on a specific job, or knowledge that is accumulated via experience in handling problems (Prietula and Simon, 1989). An often used example is how a senior foreperson can see problems arising in daily operations and will have learnt to ignore irrelevant patterns of activity and concentrate on critical patterns (Prietula and Simon, 1989). The critical patterns are then grouped together in a chunk and the linked patterns are viewed as a single unit (Gobet, 2018). This requires less processing time to recall from memory and can be automatically retrieved.

Numerous chunks become linked overtime, forming a database of knowledge and have been observed in numerous vocations such as the foreman, doctors, the chess grandmaster, and the expert manager (Prietula and Simon, 1989, Gobet, 2018). These "chunks" are also described by Chi et al. (1981) who describe the role experience plays in intuition. Expert knowledge is organised according to highly sophisticated schemas whereas novices lack this deep structure, organising their knowledge on more surface features. These schemas enable experts to quickly highlight relevant information in a problem and process it quickly and accurately. Schemas facilitate an expert's ability to analyse and interpret information in a problem, whereas a novice's lack of schemas forces them to rely on other strategies for problem solving (Glaser et al., 1988, Grünbaum and Stenger, 2018). This can also be seen in executives interviewed by Agor (1990) who stressed that intuitive processes, in part, were based on inputs from facts and experience gained over the years

"Experiences are the accumulated memory of past impressions, actions, and achievements. It is likely that, with growing experience, a person increasingly relies on this for the decision process. In contrast, the novice will tend to go more by the principles which he or she learned from books during his or her education." (Harung, 1993: 41)

If a decision maker requires experience to develop intuition, then is it just through length of time spent in a position that creates intuition? Prietula and

Simon (1989) also state that experts need to initially do some analytical thinking. This is analysis in use. Analysis decision making can be typically associated with complex problem solving and consists of gathering information, recalling relevant knowledge, making observations about the situation, and then proposing solutions (Prietula and Simon, 1989). An analysis decision-making approach is a time consuming exercise in decision making but is one of the foundations of intuition development (Dhami and Thomson, 2012, Prietula and Simon, 1989). As experience begins to build, the decision maker starts to bypass the analytical steps that were once needed. In everyday practical problem solving, relevant knowledge is likely to be acquired through informal experience rather than through direct instruction (Wittman and Pretz, 2015). Such knowledge is not easily articulated and is referred to as tacit knowledge (Cianciolo et al., 2006, Polanyi, 2015). Many researchers have described expert knowledge as intuitive in nature (Hogarth, 2001, Iivari et al., 1998).

Experienced leaders form intuitive, implicit, latent representations that reflect patterns of events in the environment acquired through experience (Schon, 1983, Gobet, 2018). A pattern of stock market gyrations may be confusing to a novice analyst and therefore require deep analytical thinking. Overtime, the novice market trader will solve or correctly be able to view the pattern of information and, if this same gyration were to occur again, it would be less confusing to the decision maker (Prietula and Simon 1989). This is in line with Pretz (2015) who states that the more experience an individual has, the less complex and more decomposable a problem will appear to that individual.

This section has compared and contrasted the individual characteristics of intuition and analysis. It was found that intuition is an associative, rapid form of decision making, which is typically seen in an expert in their domain. Simon (1987) considers that real expertise requires the use of both analytical and intuitive decision making. This argument is furthered by Hodgkinson and Sadler-Smith (2003) who state that the switch between 'habits of mind' (intuition) and 'active thinking" (analysis) is the ultimate skill in today's organisation. Often many professions and situations within organisations require people to make time pressured decisions for novel problems with vague or competing goals (Donovan, 2015). Recent years have seen a growth in the amount of data that decision-makers are required to interact with. This coupled with the limitations bounded rationality impose on human decision-making has resulted in a rise in the use of information systems to assist with decision making. The rise in the use of these information systems across organisations will be discussed in the next section.

2.4 Moves Towards a Data-Driven Approach

Previous sections discussed intuition and analysis as two human modes of cognition. The structured nature of analysis decision-making allows decision making tasks to become increasingly augmented or automated. Organisations are now incorporating business intelligence and analytical tools to compliment and/or replace some decision-making tasks. There has been a shift away from organisations seeking managers who primarily use an intuitive or analysis approach to decision making. This change is highlighted in the following quote:

"In every industry, in every part of the world, senior leaders wonder whether they are getting full value from the massive amounts of information they already have within their organizations. New technologies are collecting more data than ever before, yet many organizations are still looking for better ways to obtain value from their data and compete in the marketplace" (LaValle, Lesser, Shockley, Hopkins, and Kruschwitz, 2011, p.21).

Business intelligence and analytics have been introduced to organisations to improve decision making (Božič and Dimovski, 2019). The introduction of business intelligence has facilitated organisations to adopt data-driven decision making which is fundamental to business intelligence (Liang and Liu, 2018). The use of business intelligence and data analytics marks a shift away from managers who, in the past, used intuition or analysis as discussed in section 2.3. The introduction of business intelligence capabilities has become increasingly important as organisations are collecting more and more data across all business areas(Akhtar et al., 2019). The retail giant Wal-Mart handles more than 1 million customer transactions every hour, feeding databases estimated at more than 2.5 petabytes and Facebook is now home to over 40 billion photos and has over 1.59 billion members (Singhal et al., 2018). Mass amounts of data are being created regardless of an organisations particular industry or size (Akhtar et al., 2019). As big data continues to grow, various domains (business analysis, new product development, healthcare, tourism marketing, transportation) have sought to integrate big data into their decision-making process (Wang et al., 2016). To help analyse and improve decision making, organisations are turning to business intelligence and analytical tools to gain a competitive advantage. This section will review how business intelligence and data analytics are being used in organisations today and how these tools have altered human decision-making approaches.

Data analytics have become more and more popular as a tool to aide decision making and have transformed technology from a supporting tool into a strategic weapon (Davenport and Harris, 2007). Organisations from a wide range of domains such as business, healthcare, and even the sporting world are incorporating business intelligence and analytics tools to help improve decision making and give organisations a competitive advantage. LaValle et al. (2011) conducted a survey of 3,000 executives, managers and analysts across 30 industries and 100 countries. One of the key findings of this survey was that top performing organisations use data analytics five times more than lower performers. Half of the respondents surveyed found that improving information and data analytics were a top priority for their organisation. 60% of respondents also stated that their organisations had more data than it can use effectively. These findings indicate that organisational leaders believe analytics will exploit their growing data and computational power to get smart and innovative in ways not previously possible (LaValle et al., 2011). Organisations are now seeking the data-driven manager which marks a clear shift from the intuitive style of manager. Modern organisations have a mistrust of the intuitive type of manager and there is a desire to have managers who follow systematic procedures (Tsoukas, 2005). The data-driven manager and their use of business intelligence has been found to offer greater insights into business performance, organisational performance, and management intelligence (Sun et al., 2018).

The tendency is for top-performing organisations to apply a data-driven approach to activities right across the organisation (Davenport, 2013). The research conducted by LaValle et al. (2011) offers insight into the desire for organisations to hire individuals who use a data-driven approach to decision making through business intelligence rather than an intuition or analysis approach. Organisations prefer a manager who uses scenarios and simulations that provide immediate guidance on the best actions to take when disruptions occur (LaValle et al., 2011).This can been seen across a wide range of contrasting industries such as healthcare, sport, entertainment, financial, and aviation industries (Agrawal, 2014).

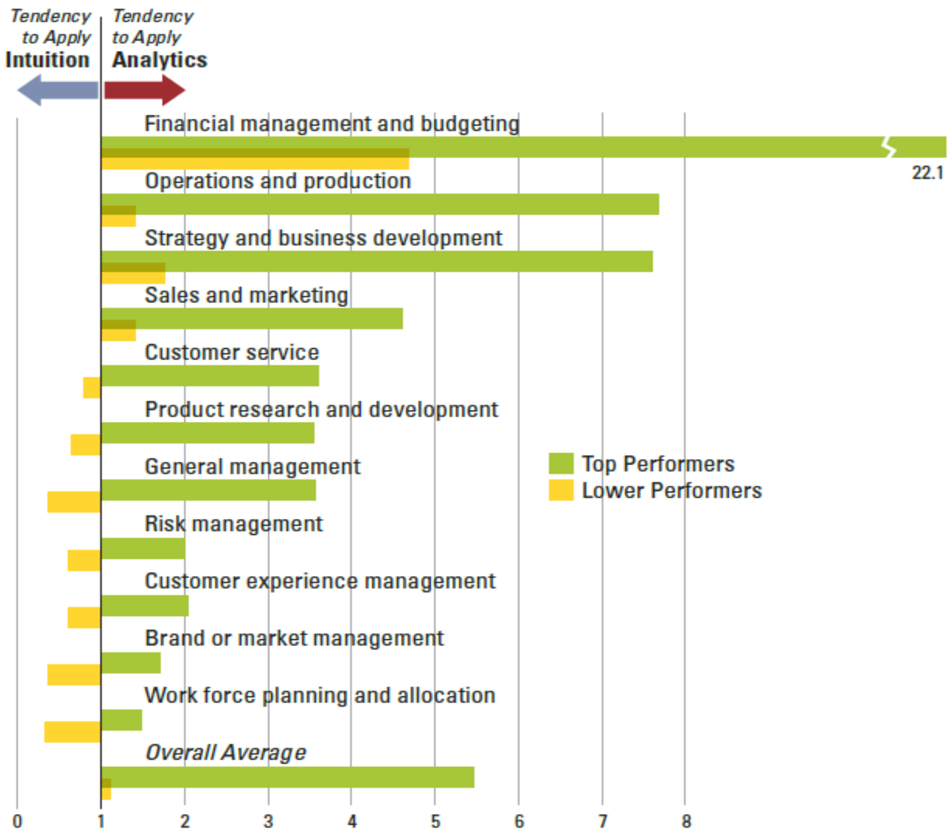

Figure 2 - LaValle et al, 2011.

Although the business areas shown in Figure 2 are in different domains, all are going beyond the use of business intelligence and analytics as decision support tools (Davenport and Harris, 2007). Organisations use analytics to better understand customers, competitors, markets, and have been successful in creating a competitive advantage for themselves (Attaran and Attaran, 2019). Organisations and executives want to understand the optimal solution based on complex parameters or new information, and they want to take action quickly (LaValle et al., 2011). Business intelligence and analytics have their roots in decision support systems which began in the late 1960s. Analytics in modern business can be defined as engaging in the use of data, either structured or unstructured, with formal analysis, statistical or machine learning, to arrive at learnings that help in making better business decisions (Agrawal, 2014).Business intelligence and data analytics offer organisations an opportunity to differentiate themselves from competitors who boast similar products and use comparable technologies (Chen et al., 2012, Davenport and Harris, 2007). This can be seen in the table compiled by Agrawal (2014) in Table 3:

Common Decisions Helped by Analytics	Objective
Concept Development and Testing	To enable testing and choice of the most promising product or service concept
Product Development and feature prioritization	To design products and proritise features using customer preferences
Advertising Testing	To enable testing and choice of the most promising advertising creative
Brand Strength, preference and perceptions	To know brand strengths and weaknesses
Customer Satisfactions and Loyalty	To know extent and strength of satisfaction and loyalty amount current customers
Marketing mix optimization	To optimally allocate marketing budget across variety of marketing options
Pricing	To set optimal price to enable business growth and customer loyalty
Customer Segmentation	To understand similarities and differences amount customers, to know who the best customers are.
Text Mining – Sentiment Analysis	To learn what customers are saying about the company on social media and other platforms.

Table 3 - Agrawal, 2014.

The overriding view from Agrawal (2014) is that through the use of business intelligence and analytics, organisations know what products their customers want, but they also know what prices those customers will pay, how many items each will buy in a lifetime, and what triggers will make people buy more (Mackenzie, 2018).This offers organisations detailed insight and advantages in the decision making process.

These insights are driving organisations to hire more and more people with a high proficiency in the use of statistics and numbers (Davenport, 2006). Since the early 1940s, more emphasis has been placed on well structured, deliberative, and quantitative decision making, with loosely structured and intuitive decision making having less of a focus (Simon, 1987). Today, a similar situation is occurring with business intelligence and analytics becoming an important tool and being viewed as the key differentiator within organisations(Božič and Dimovski, 2019).This is a concept which Simon (1987) lamented, stating that research into decision making has had "*less impact on decision making that is loosely structured, intuitive, and qualitative; and they have had the least impact on face-to-face interactions between a manager and his or her co-workers, the give and take of everyday work*" (p.57). The fact that intuitive decision making has been less favoured is surprising, as one of the major difficulties in supporting managers comes from the very nature of management work (Gjerde and Alvesson, 2019). Communication, coordination and people management account for 80% of management work which cannot be typically supported by systems (Gjerde and Alvesson, 2019, Mintzberg, 1973). Despite these concerns recent research has also shown that managers are beginning to utilise a data-driven approach more, with individuals such as investors using financial systems to forecast the price of future stocks (Cabrera-Paniagua et al., 2015).

The increasing popularity of using business intelligence to aide decision making can be seen with employees being hired specifically for their expertise with statistics or trained to develop these skills (Bohler et al., 2017). Modern business intelligence tools have grown to be sophisticated, accurate, and more useful for managers over time (Agrawal, 2014). These tools have evolved from being reporting tools to dashboards with drill-down capability, hypothesis testing, prediction, and optimisation functionality (Agrawal, 2014). Research has also found that business intelligence and analytical capabilities have changed and evolved overtime. It is proposed that there are three distinct eras of both business intelligence and analytics. Davenport (2013) refers to these eras as Analytics 1.0, 2.0, and 3.0 while Chen (2012) refers to these eras as Business Intelligence and Analytics 1.0, 2.0, and 3.0. Despite differing terminology, it is agreed that era 1.0 uses business intelligence and analytics which report on the past; 2.0 uses models based on past data to predict the future, and 3.0 uses models to specify optimal behaviours and actions. (Chen et al., 2012, Grover et al., 2018, Davenport, 2013). Although terminology on the eras may differ (Business Intelligence & Analytics 3.0 or Analytics 3.0), there is an agreed consensus that the 3.0 era is that of the data-driven manager(Chen et al., 2012, Grover et al., 2018, Rejikumar et al., 2020). This is in marked contrast with intuitive and analysis decision making which were discussed in Section 2.3. The next section will discuss decision making in the context of the data-driven manager.

2.5 The Data-Driven Manager

The data-driven manager is able to see patterns and make decisions on data which was previously thought to be invisible using information systems (Barton and Court, 2012, Akhtar et al., 2019) and to enable decision-making to move towards "territory which has historically been seen as reliant on human judgment" (Gillion, 2012, pp. 288-289). Data-driven decision making can be defined as the extent to which an organisations is open to new ideas that challenge current practice based on data-driven insight; has the data to make decisions; depends on data-based insights for decision-making; and support he creation of new service or product (Cao et Al, 2015). The data-driven manager has been identified as a manager who uses data to be more effective at making real-time decision making, responding to change and understanding customers (Akhtar et al., 2019). In addition, using a data-driven approach allows a manager to use information systems to see patterns and make decisions on data which was previously thought to be invisible

(Barton and Court, 2012, Akhtar et al., 2019). The increasing popularity of using a data-driven decision making approach can be seen with employees being hired specifically for their expertise with statistics or trained to develop these skills for use with analytics (Bohler et al., 2017) This indicates a move away from traditional managerial decision-making approaches such as intuition and analysis as outlined in previous sections. Data-driven decision-making offering managers “fact-based comprehension to go beyond intuition when making decisions” (Davenport, 2013, pp.3). The data-driven manager has been shown to have a number of advantages over traditional managerial decision-making approaches.

Research has shown companies in the top third of their industry in the use of data-driven decision making were on average 5% more productive and 6% more profitable than their competitors (McAfee & Brynjolfsson, 2012). There is a view that the increase in the amount of data which organisations collect results in a decrease on the dependency of human decision-making (McAfee, 2013). A data-driven approach has been adopted in varying roles with success. Human parole boards, for instance, perform much worse than simple formulas at determining which prisoners should be released on parole; highly trained pathologists perform worse than image analysis software at diagnosing breast cancer; purchasing professionals do worse at algorithm predicting, and Americas top legal scholars were outperformed by a data-driven decision rule at predicting a year’s worth of Supreme Court case votes (McAfee, 2013). The application of data-driven decisions in such industries is leading to a situation where Instead of having the statistics as a servant to expert choice, the expert becomes a servant of the statistical machine. (Ayres, 2007).

In addition, existing research has found that communication, coordination, and people management account for 80% of management work which cannot be typically supported by systems (Mintzberg, 1973, Gjerde and Alvesson, 2019). Research in the medical field shows that surgeons should trust their instincts far more than the systems they use in the operating theatre, as switching on particular data systems, can switch off the decision maker’s intuition (Sutton et al., 2015). Despite the much-cited (a) benefits of an organisation adopting a data-driven approach and (b) concerns this may have on traditional human decision-making approaches, very little research exists regarding the mechanism through which business analytics can be used to improve decision-making effectiveness at an organisational level (Cao et al., 2015). As a result, there is a dearth of literature focusing on how Analytics 3.0 and future analytics will improve or hinder managerial decision making (Holsapple et al., 2014).

Section 2.4 has reviewed the evolving role of business intelligence and analytics within organizational decision-making. It was found that data-driven decision making has its roots in analysis managerial decision making of the past. The well-structured, rule based, statistical nature of these decisions has allowed these tasks to become automated. Business intelligence and analytics have evolved over time to create three distinct areas, BI&A 1.0, BI&A 2.0, and, BI&A 3.0. The widespread adoption of BI&A over time has seen a decline in the trust and use of human decision-making approaches such as intuition and analysis. Although using a data-driven approach to decision making is now the preferred option for many organisations, what is not clear is how this approach interacts with human-centric decision making such as intuition (Guo and Pedrycz, 2014). This represents a gap in existing research. One theory which aims to improve managerial decision making is Cognitive Continuum Theory, although it has yet to be applied from an IS perspective with Dhami & Thomson (2012, p.9) commenting that "Cognitive Continuum Theory also needs to be expanded to include an understanding of the impact of information technology and support systems on the task and cognition". Cognitive Continuum Theory proposes that modes of cognition that individuals utilise are in fact temporal and that individuals will move between differing decision-making approaches. If modes of cognition are temporal, the rise and focus on organisations seeking individuals to focus solely on a data-driven approach may become problematic. The next section will look at cognitive continuum theory.

2.6 Cognitive Continuum Theory

The previous sections have reviewed intuition and analysis as forms of human decision making. It was also found that larger datasets have increased the use of business intelligence and data analytics which have given rise to the data-driven manager. This has marked a shift away from organisations seeking managers who use intuitive and analysis decision making. In addition, data analytics were also reviewed as an automated decision-making system. Despite these differing decision-making approaches and system having distinct advantages, there are scenarios or tasks where these may or may not be advisable to use. Research in domains such as management has found that there are many obstacles and challenges which can inhibit the use of pure analysis or pure intuition (Dhami and Thomson, 2012). Intuitive decision making is best used by experienced decision makers in unstructured environments; in contrast, analytical decision making approaches are more suited to structured environments (Dane and Pratt, 2007). It has also been found that task characteristics can prompt either an intuitive or an analysis decision making approach (Offredy et al., 2008, Parker-Tomlin et al., 2017). The concept of managers being proficient in multiple decision making approaches is not new and successful managers require a combination of intuition and analysis (Constantinescu and Constantinescu, 2017).

Existing research outlined above has shown that individuals can oscillate between differing decision-making approaches. What is not clear however, is if individuals will oscillate between differing decision-making approaches when using an information system. It is vital to understand if this occurs, as adopting the correct decision-making approach when conducting a task will make a positive outcome more likely. Cognitive Continuum Theory (CCT) aims to account for the switch between 'habits of mind' and 'active thinking' and thus improve managerial decision making (Dhami and Thomson, 2012). The theory proposes that there are differing modes of decision making based on two factors: mode of cognition and task structure. (Parker-Tomlin et al., 2017, Cader et al., 2005). CCT aims to improve decision making by defining the characteristics of a task and assigning the optimum decision-making approach to this task. Polanyi (2012) describes this process well in the context of mathematical creativity:

"The manner in which the mathematician works his way towards discovery, by shifting his confidence from intuition to computation and back again from computation to intuition, while never releasing his hold on either of the two, represents in miniature the whole range of operations by which articulation disciplines and expands the reasoning powers of man" (Polayni, 2012, pp.137)

The phenomena of shifting from intuition to analysis that, as described by Polayni, is not just limited to mathematics. Research has found this concept in professions such as management (Simon, 1987, Mahan, 1994), engineering (Hammond, 1997), and in the medical domain (Custers, 2013).

The environments that managers operate in are not always stable with managers required to solve both structured and unstructured problems. It has been proposed that psychological processes adapt to the environments in which they function (Dhami et al., 2004). Brunswik (1956) introduced the notion of quasirationality as a compromise between the use of pure analysis and pure intuition. Problem solving outside of "pure" intuition or "pure" analysis can be described as Quasirationality (Custers, 2013, Parker-Tomlin et al., 2017). Section 2.3 described how intuitive and analysis decision making lay upon a continuum of decision making. This principle also applies to modes of cognition which lay between "pure intuition" and "pure analysis" and can thus be described as quasirational. Hammond (1978b) developed a framework (Figure 3 - Hammond, 1978b.) outlining both pure intuition, pure analysis, and three forms of quasirationality. These three forms are:

1. Mostly intuition and some analysis.
2. Mostly analysis and some intuition.
3. Equally intuitive and analytical.

CCT allows researchers and practitioners to understand the oscillations between intuitive and analysis decision making. This is achieved by matching the task characteristics of a particular decision to pure analysis, pure intuition, or quasirational decision making. An oscillation is defined as moving between the three decision-making approaches before stopping at one particular decision-making approach when conducting a task (Bjørk and Hamilton, 2011, Cader et al., 2005) . A decision maker oscillating between analysis, intuition, and a quasirational state before stopping at one approach when conducting a task has been found in the medical and management domains (Dhami and Thomson, 2012, Parker-Tomlin et al., 2017).Research has found that a quasirational model which combines managerial intuition with a statistical model repeatedly outperformed both pure intuition and pure analysis (Blattberg and Hoch, 1990, Artinger et al., 2015).

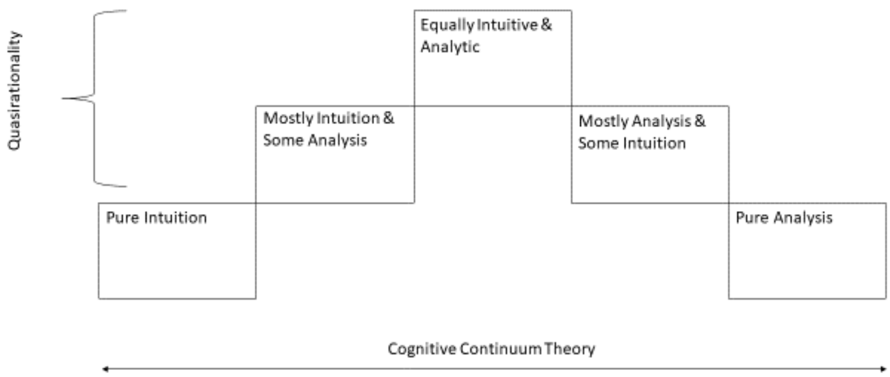

Figure 3 - Hammond, 1978b.

Section 2.3 discussed how there are identifiable characteristics of intuition and analysis. These characteristics can also be extended to determine when best to use a quasirational approach. The factors influencing whether intuition or analysis were used included the type of information, the environment the decision maker is in, and the level of experience of the decision maker. Although these factors are applicable for inducing "pure intuition" or "pure analysis", research has shown a combination of both characteristics are required to induce quasirationality. The matrix in figure 4 summarises the concepts emerging from current research on CCT.

Dhami & Thomson (2012) have stated that most research on judgment and decision making has focused on the strengths of analytical cognition and the use of intuitive decision making. Intuitive decision making has tended to be the less researched of the two with Simon (1987) stating that research into intuition has been overshadowed by research into more analytical charged decision making. There is a view that intuition is an important part of managerial decision making with researchers such as Hodgkinson and Sadler-Smith (2018),Dane and Pratt (2007), and Artinger et al. (2015) focusing on the benefits that intuition brings to decision making.

It has also been argued that managers require a range of decision-making approaches to be successful (Hodgkinson and Sadler-Smith, 2018). This is outlined by (Dhami and Thomson, 2012) who argue:

"This is a crucial omission because if managers focus too strongly on, say, analytic techniques, at the expense of using intuition in a context where substantial use of the latter is likely to be beneficial, then not only is the optimal decision outcome unlikely to be achieved but this process is likely to prove very expensive for the organization" Dhami & Thomson, 2012, p.317).

The "crucial omission" highlighted by Dhami & Thomson (2012) has also been discussed by Forbes (2007), Simon (1987),Hodgkinson and Sadler-Smith (2003), and Parker-Tomlin et al (2017). They recommend that further research is required to find the correct combination of required intuitive and analysis decision making used by managers in specific situations or tasks. CCT allows researchers to define the individual properties of a task and find if analysis, intuition, or quasirationality was used (Cader et al., 2005). Dhami & Thomson (2012) conducted a literature review on CCT finding one paper relating to management (Mahan, 1994), two papers relating to engineering (Hamm, 1988b; Hammond et al., 1987), two papers relating to clinical decision making (Hamm, 1988a; Kam, Chismar, & Thomas, 2004), one paper retail (Mathwicka, Malhotrab, & Rigdon, 2002) and four papers relating to nursing (Cader, Campbell, & Watson, 2005; Offredy, Kendall, & Goodman, 2008; Standing, 2008). It is noticeable that a wide and varied range of occupations have been researched from a cognitive continuum perspective.

Title	Author	Year	Journal	CCT	Bounded Rationality	Satisficing	Characteristcs of DM	Quasirationality	Heuristics	Cognition	Volantary decide	Environment	Task Properties	Subtask	Perfomance improved	CCT Task Orientated	Training to improve CCT	Individual	Group	1-6 Modes of Inquiry	1-9 Modes of practise	Pattern Recognition	Functional Relations	Oscillation	Alternation	Bias Affects Judgement	Cognitive Feedback	IS Study	Management	Medical	Highway Engineer
Medical Education and Cognitive Continuum	Custers	2013	Academic Medicine	X		X	X	X	X			X	X			X	X	X												X	
On the relevance of Cognitive Continuum Theory	Dhami et al	2012	European Management Journal	X	X		X	X	X			X	X		X			X	X	X		X	X	X	X		X		X	X	X
Cognitive Continuum Theory in nursing decision-	Cader et Al	2005	Journal of Advanced Nursing	X			X	X		X		X	X					X		X		X	X	X	X					X	
Moment-By-Moment Variation in Experts'	Hamm	1988	IEEE Transactions of Systems	X			X	X			X	X	X	X				X						X							X
patient scenarios to explore nurse prescribers' pharmacological	Offredy et Al	2008	International Journal of Nursing Studies	X			X	X				X						X		X										X	
Cognitive Adaption and its Consequences: A	Dunwoody et Al	2000	Jounral of Behavioural Decision Making	X			X	X				X	X					X								X					
and Decision Making in Nursing - Nine modes of	Standing et Al	2007		X			X	X				X			X					X	X					X				X	
Human Judgment and Social Policy	Hammond	1996	Oxford University Press	X			X	X				X	X					X		X				X							

Figure 4 - Cognitive Continuum Theory Concept Centric Matrix

There have been calls for research of CCT in other areas such as information systems with Custers (2013) stating that more research needs to be conducted on how information systems impact CCT in the medical domain and Dhami et al. (2012, p.7) stating that "Cognitive Continuum Theory also needs to be expanded to include an understanding of the impact of information technology and support systems on task and cognition".

To understand how cognitive continuum may be applied to information systems it is necessary to understand why shifts in cognition occur. Research has shown that shifts between differing decision-making systems can be induced via the properties of a task the individual is working on (Dhami and Thomson, 2012, Parker-Tomlin et al., 2017). Task properties are therefore critical for understanding which mode of cognition that a decision maker is or should be using. The next section will review the characteristics of what has been researched to date linking task and decision making.

2.7 Task Properties

The characteristics of a task have been found to have a great impact on the specific mode of cognition used by a decision maker whether this is pure intuition, pure analysis, or a quasirational state (Parker-Tomlin et al., 2017) This is also a view shared by Hammond (1996) who recorded specific task characteristics favour the use of analysis or intuition; this can be seen in Figure 5 - Hammond (1996).

Task characteristics that induce analysis and intuition	
Analysis-Inducing	**Intuition-inducing**
Less than five cues	More than five cues
Successively presented cues	Simultaneously presented cues
Low cue redundancy	High cue redundancy
Unequal weighting of cues in ecology	Equal weighting of cues in ecology
Cues objectively measured	Cues perceptually measured
Nonlinear cue functions	Linear cue functions
Task Outcome Available	Task outcome unavailable

Figure 5 - Hammond (1996)

For the optimum decision making approach the mode of cognition the problem solver adopts should be appropriately matched to the properties of the task (Dhami and Mumpower, 2018). CCT favours neither analysis nor intuition and is entirely dependent on the task which mode of cognition is the optimum to use (Cader et al., 2005). Depending on the characteristics of the task, it may be more suited to an analytical, quasirational, or intuitive decision-making approach. If there is a mismatch between task properties and mode of cognition, it can result in issues with problem solving and the overall quality of a decision (Dhami and Mumpower, 2018). As task structure has been found to be critical for a decision maker using the optimum cognitive function, this would indicate that the utilisation of information systems need to be designed with this in mind (Parker-Tomlin et al., 2017). To date there has been no study conducted on the relationship between CCT and the use of information systems such as data analytics (Dhami and Thomson, 2012).

Task properties can affect the decision making mode of cognition in three different ways (Pirruccello and Rubarth, 2015, Cader et al., 2005):

- the task complexity (number of information cues, redundancy of cues and the principle for combining information)
- the level of ambiguity of its content (existence of a principle to organize information, familiarity with content, potential for accuracy in judgement)
- its presentation (potential for decomposition into subtasks, visual or quantitative presentation and time available to undertake the task).

Cader et al. (2005) researched this phenomenon by investigating a nurse deciding on the significance of the tracing from an electrocardiograph, needing the correct amount of time to compare it, and contrast it with a normal electrocardiograph. To increase certainty in the outcome of this task, the nurse can potentially divide the electrocardiograph into sections to facilitate analysis. In contrast unstructured tasks have properties that favour an intuitive approach. An unstructured task has a low level of decomposition, certainty, and needs to be resolved quickly (Muir, 2010). During times of environmental uncertainty or organisational crisis there can be a shift away from standard operating procedures; it has been found that adopting an intuitive approach is beneficial to a decision-maker in these circumstances (Li et al., 2016).The relationship between task structure and decision making has also been seen outside of CCT. It has been found that decision making is related to task structure and that problems lie on a continuum of structure (Ramrathan and Sibanda, 2017).

Structured tasks which have a definitions, rules, and relationships are better suited to analysis.(Laughlin and Adamopoulos, 1980, Licorish and MacDonell, 2017). Shapiro and Spense, (1997) state that *"at one end are well structured problems, to which established decision rules can be applied to yield an acceptable solution"*.

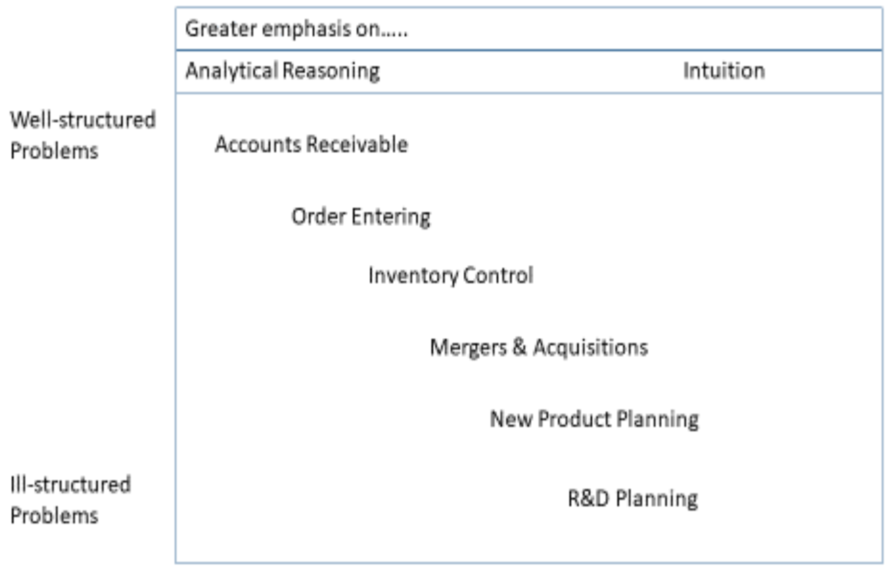

Figure 6 - Shapiro and Spence, 1997.

This can be summarised in Figure 6 shows that more structured tasks such as accounting are better suited to an individual adopting analysis to make a decision. These tasks can be automated by information systems due to their structured nature. These systems can be seen from small businesses using basic data extraction to support decisions to large organisations using ERP systems to monitor a customer's entire order cycle from manufacturing to delivery (Licorish and MacDonell, 2017). These task characteristics contrast with those when an intuitive approach is advised. Intuitive decision makers are often required in environments where there is an absence of well-accepted decision rules for dealing with unstructured tasks (Ramrathan and Sibanda, 2017). Dane and Pratt (2007, p.45) also state that intuition is a "holistically associative process that may actually help to integrate the disparate elements of an ill-defined problem into a coherent perception of how to proceed". The use of intuition when working with unstructured tasks is beneficial as it collates various pieces of information into a single view to solve the problem (Pachur and Spaar, 2015). Adopting an intuitive approach has also been found to be advantageous when working with unstructured tasks, but these tasks are more difficult and complex to automate when compared with structured tasks.(Axelrod, 2015).

Rather than use the term structured and unstructured environments, Cader et al. (2005) refer to structured tasks as functional relations. Functional relations refer to inferences made from observations of statistical data. Unstructured tasks are referred to as pattern recognition, which refer to inferences drawn from patterns of information recognised from experience. Pattern recognition and it being drawn from years of experience was discussed in Section 2.3.4 as being one of the defining characteristics of intuition. The relationship between pattern recognition and functional relations is not static. The relationship can change, overlap, and oscillate during a task. CCT aims to explain this phenomena, introducing the concept of quasirationality and the ability to oscillate between different modes of cognition depending on the task (Standing, 2008).

When performing a task, a decision maker will also need to ensure that the decision-making approach used aligns with the task properties of the scenario. Task properties can be deconstructed into two components, task non-routineness (routine versus non-routineness) and task interdependence

(Karimi et al., 2004). Task non-routineness refers to the extent to how often a decision maker will carry out a task (Kuegler et al., 2015). The greater the amount of ambiguity a decision maker faces when performing a task, the more information processing and information needs a decision maker will require (Kuegler et al., 2015). As task non-routineness increases, task interdependence may inadvertently increase as more data and information exchange is require to complete a task successfully (Karimi et al., 2004, Hollingsworth, 2015).

This section has found that there is a task structural continuum to decision making. It can be concluded that different decision-making approaches are required depending on the nature of the task. The next section will review the role the environment plays on decision making from both a task and cognitive continuum perspective.

2.8 Environment Structure

The previous section explored how task structure plays an important role in deciding the optimum decision-making system. Related to the task structure is the environment in which the decision maker finds themselves in. All decision makers will find themselves in different environments when they are expected to make decisions (Goll and Rasheed, 1997). A manager may find themselves under extreme time pressure and stress, whereas in contrast another manager may find themselves in a relaxed environment where there is no time pressure to make a decision. Environmental features have major implications on all aspects of management (Goll and Rasheed, 1997). Decisions that people make are often susceptible to the demands exerted on them by the environment, which can lead to stressful and difficult conditions for decision makers (Porceli and Delgado, 2009). Research conducted by Karimi et al. (2004) found that managerial tasks are affected by rapid changes in the decision-makers operating environment.

Environments that pilots, medical personal, and managers operate in often require a large amount of complex information that needs to be processed in a short period of time. Environment uncertainty and complexity has been shown to increase the difficulty in decision making (Maitland and

Sammartino, 2015). Dynamic environments can be problematic for intuitive decision makers as the quality of an intuitive decision requires an assessment of the predictability of the environment in which the decision is being made and of the individual's opportunity to learn the regularities of that environment (Kahneman and Klein, 2009).

In addition, a dynamic environment poses three challenges to analysis when compared with undynamic environments:

- Time constraints in collecting data/information;
- Need to collect a large amount of data to deal with environmental instability,
- Lack of reliability of the data or information (Khatri and Alvin Ng, 2000).

An example of this is in stock market trading. Yong and Taib (2009) showed that investors face the highest risks compared to other forms of financial investments such as bond, treasury bill, and fixed deposit when they invest in the stock market. This is primarily due to stock price fluctuations which occur almost every second and most people see the share price movement as unpredictable, or to use a different term "random walk"(Yong and Taib, 2009) . Investing in shares can often cause many individual investors to have their 'hand burnt' where they lose their initial investment. Fluctuations in information brought about by the environment also arises in other areas such as sport. Mascarenhas (2005) highlighted that referees have to respond almost immediately to events in a game that unfolds dynamically, and which may have many nuances, ambiguities and uncertainties.

The environment can also generate information in different ways which will impact the decision-maker. For example, Simon (1957) observed that managers were working under conditions of information overload which impacted managerial decision-making. This is evident today with individuals regularly required to make decisions under conditions of information overload (Persson, 2018). The abundance of information available to individuals also results in increasing competition for the attention of individuals, groups, and organisations (Lee et al., 2016); this again increases the potential for information overload to fuel biases in decision making (Persson, 2018). Information overload may result in increasing costs of collecting, storing, sharing information, and an increasing risk that all this information becomes a distraction from more relevant information or indeed from the job itself (Van Knippenberg et al., 2015). There is now a wealth of information available to individuals from emails, the web, consumer data, and social media (Davenport, 2013). This can cause issues with decision making for more knowledge intensive work. The ability to effectively, and efficiently allocate attention to, and process a diversity of information increasingly comes at a premium (Van Knippenberg, 2015).

The environmental characteristic of time pressure has also been found to affect decision making. Time pressure indicates that the time constraints can induce some feeling of stress and create a need to cope with the limited time (Liu et al., 2017). When faced with high levels of time constraints, decision makers tend to rely most heavily upon negative information and may become increasingly risk seeking in decision making (Saqib and Chan, 2015, Wright, 1974). Under time constraint, decision-makers either filter information or omit certain information from consideration altogether (Shachaf et al., 2016). Time-pressure has been shown to reduce the quality of decision-making (Godinho et al., 2016) and induce extreme judgements (Kaplan, Wanshula & Zanna, 1993). It has also been commented that strategies are irrelevant if they take too long to formulate (Eisenhardt, 2008, Glassman et al., 2014) and that there is a premium on moving fast and keeping pace (Eisenhardt, 1990). The ability to make decisions rapidly when there is an abundance of information can increase time pressure and therefore increase stress.

Due to dynamic environments creating characteristics of complexity, instability, time pressure, and information overload, information systems have been introduced to aide decision makers combat the above stressors. Differing domains have introduced information systems to counter the issues dynamic environments create. Yong and Taib (2009) give the example of stock traders. With the help of computer capabilities, investors can perform technical analysis on historical stock prices which helps them in making their trading and investment decision. Mosier et al. (1998) and Satchell (2016) show how aircraft flight management systems assume increasing control of cognitive flight tasks, such as calculating fuel-efficient routes, navigating, or detecting and diagnosing system malfunctions and abnormalities. Calder and Durbach (2015) demonstrate how data analytics allow sporting professionals to collect detailed match information to inform management decision making, strategy, tactics, and corrective coaching. These examples show that information systems have been introduced across a number of volatile environments to improve performance.

It has also been found that dynamic environments will affect the task interdependence and task non-routineness facing a decision maker. This is highlighted by Melville and Ramirez (2008) who state:

"When changes in the environment occur, they give rise to uncertainty, as established routines can no longer be used. Firms face new information requirements as additional information must now be collected, processed and distributed in order for the firm to make decisions and complete its activities. To continue to operate efficiently, a firm must align its information processing capabilities with its new information requirements" (Melville and Ramirez,2008, p. 250).

As an environment becomes increasingly dynamic it will increase the task non-routineness encountered by the decision maker (Karimi et al., 2004). This results in task interdependence inadvertently increasing as more data and information exchange is required to complete a task successfully (Hollingsworth, 2015; Karimi et al., 2004).

This section has reviewed the role the operating environment has on decision making. It was found that there are dynamic and undynamic environments in which decision makers are required to operate. Dynamic environments were found to have (i) increasing time pressure; (ii) potential for information overload or lack of information; and (iii) unreliable information. These characteristics can impact a decision maker by causing them to filter key pieces of information, rely on negative information, or increase their propensity to take risks. The next section will discuss how this literature review was conducted.

2.9 Conclusion, Research Objective, and Research Questions

This chapter provides the foundations of this research. Section 2.2 introduced the concept of bounded rationality for decision makers, which was built upon in Section 2.3 when intuition and analysis were discussed. This section also characterises intuition and analysis and found that the automatic, non-conscious, associative nature of intuition contrasts with the deliberate, systematic, and evaluative analysis decision-making system. Section 2.4 discussed how organisations are now seeking to use business intelligence and analytics in their decision-making process. This marks a shift away from organisations who would traditionally seek managers who use an intuitive or analysis approach. Section 2.5 explored this in more detail by looking at the data-driven manager. Section 2.6 introduced Cognitive Continuum Theory which discussed and explored that decision-makers will shift between differing decision-making approaches when conducting a task. Section 2.7 reviewed the effect that task structure has on decision-making, whilst Section 2.8 discussed the differing characteristics of environments decision makers need to operate in. On analysing existing research, this literature review has highlighted a paucity of information systems research exploring the interplay between human decision-making approaches and a data-driven approach. With the mass introduction of information systems into dynamic and undynamic environments and the obligation for decision makers to use these systems, there is a very real need to undertake study of this phenomenon. There exists a substantial and important gap in our knowledge of how and why individuals move between a more human, intuitive approach or a data-driven approach while having access to information systems.

Therefore, the research objective for this study is:

To explore oscillations in decision-making approaches while having access to information systems in dynamic and undynamic environments.

For empirical research to be considered strong, the research questions should address a gap in the literature (Eisenhardt and Graebner, 2007). To achieve the research objective two exploratory research questions have been formulated. The research questions for this study are as follows:

Research Questions 1:

How do decision-making approaches oscillate while having access to information systems?

This chapter identified that decision makers will use a combination of intuitive, analysis, and data-driven approach to decision-making. Research from engineering, medical, and management domains have found that individuals will oscillate between differing decision-making approaches. Despite calls to do so, there has not been research conducted on how decision-maker oscillate between differing decision-making approaches while having access to information systems (Dhami and Thomson, 2012). Answering this research question will allow practitioners and academics to understand how modes of cognition oscillate when using information systems. This is important to understand as existing research shows that using a decision-making approach most aligned with a task can improve task outcome.

Research Questions 2:

How does the dynamic or undynamic environment impact on the oscillation of decision-making approaches while having access to information systems?

This chapter established that academic scholars and practitioners have placed an increasing emphasis on managers using a data-driven approach to decision making. What is not clear however is if environmental changes may oscillate a decision makers decision-making approach while having access to information systems. Dynamic environments have been found to have increasing time constraints, complexity, high risk, and instability when compared with undynamic environments (Maitland and Sammartino, 2015). As information systems continue to permeate throughout organisations and society in dynamic and undynamic environments, it is important for practitioners and academics to understand the effects the environment has on decision making while having access to information systems. Further discussion on both research questions and how they can address the gap in existing research can be read in Section 1.2.

The next chapter will discuss the various research strategies, data collection, and analysis methods available to the researcher before the most applicable for this study is selected and discussed.

Chapter 3: Research Strategy

The research objective for this study was defined in Chapter 2 as:

To explore oscillations in decision-making approaches while having access to information systems in dynamic and undynamic environments.

Cognitive Continuum Theory was found to be the theoretical lens to meet this study's research objective. Despite Cognitive Continuum Theory being the most appropriate theoretical lens for this study, Cognitive Continuum Theory has yet to researched from an information systems perspective (Dhami and Thomson, 2012). Cognitive Continuum Theory not yet being applied to the information systems domain deems this research study as exploratory. Exploratory research is recommended by Patton (1990) when "new fields of study where little work has been done, few definitive hypotheses exist, and little is known about the nature of the phenomenon" (p.31). An exploratory research study seeks to discover "what is happening" and "to seek new insights" (Robson, 2002).When undertaking such a study, exploratory research questions are recommended (Marshall and Rossman, 1989)

Exploratory research questions ask:

- What is happening in this social programme?

- What are the salient themes and patterns in participants meaning structures?
- How are these patterns linked? (Marshall and Rossman, 1989)

As such the exploratory research questions formulated for this study are:

Research Questions 1:

How do decision-making approaches oscillate while having access to information systems?

Research Questions 2:

How does the dynamic or undynamic environment impact on the oscillation of decision-making approaches while having access to information systems?

These research questions are both exploratory in nature. The first research question seeks to uncover the underlying mechanisms or patterns of how modes of cognition oscillate while having access to information systems. The second research question seeks to understand how these mechanism or patterns are linked with the environment the decision maker operates in. As such, both of these research questions satisfy the criteria for exploratory research set out by (Marshall and Rossman, 1989).

Having found that the research objective and questions are exploratory in nature, the next step is to find the most aligned research philosophy and research strategy with this study.This chapter details the research philosophy and research strategy for this study. The chapter begins by discussing the different ontological and epistemological scientific modes of inquiry available to the IS researcher. The ontological and epistemological fit of critical realism is found to be most aligned with this research study and is used as the underlying research paradigm in this research. The suitability of critical realism to the research objective is discussed in Section 3.1.4.

Once the most suitable research paradigm has been selected, the various methods available to undertake this study are discussed in section 3.2. Given the research objective and the fit of critical realism, an interpretivist methodology of direct observation is found to be most suitable. Direct observation as a research methodology is discussed in detail in Section 3.3. The chapter continues by discussing the appropriateness of adopting a multiple case study approach and gives an overview of the four research sites selected for the study (Section 3.4). Once the data collection method and multiple case study locations are selected, how the data will be analyzed is then discussed in chapter 3.5. The chapter concludes in section 3.6.

Further discussion on both research questions and how they can address the gap in existing research can be read in Section 1.2. The next section of this chapter will introduce the main research paradigms used in the Information Systems domain. These will be discussed and the paradigm best suited to this research study will be described and its use justified.

3.1 Research Philosophy

Information systems is an interdisciplinary field with numerous different theoretical and conceptual foundations based on differing backgrounds (Recker, 2005). The interdisciplinary nature of this field has led to *"different views on nature of theory, knowledge, and epistemology"* (Gregor, 2005, p.3). Adopting the correct research paradigm is important as Recker (2005) states that *"an evaluative criticism of research work is not possible without understanding the perception of science underlying the research to be evaluated*" (p.2). This section will review research philosophy from three perspectives:

- Ontology
- Epistemology
- Methodology

The ontological perspective asks what is the form and nature of reality and, therefore, what is there that can be known about it? (Lincoln et al., 2011). Ontology is concerned with the question of whether or not a 'real world' exists: does this reality exist beyond human speech and cognition process? (Niehaves, 2007). Ontology is also concerned with two alternative positions, realism vs. idealism. Burrell and Morgan (1979) believe that realism "postulates that the social world external to individual cognition is a real world made up of hard, tangible and relatively immutable structures. For the realist, the social world exists independently of an individual's appreciation of it [...] the social world has an existence which is as hard and concrete as the natural world" (p. 4).

The idealism position contrasts with that of the realist ontological viewpoint. Muniategui et al. (2006) argue that idealism "*posits that the existence of objects depends on someone perceiving them*" (p.3).

Epistemology is typically linked to ontology and methodology when looking at philosophical approaches. Epistemology is the second aspect of a research paradigm (Dammak, 2015). The ontological beliefs are our beliefs regarding what our reality is, our epistemological assumption are the assumptions around how we acquire knowledge about the world, and the methodological selection are the means to help us achieve the above (Gichuru, 2017)

The epistemology perspective refers to the theory of knowledge and how this knowledge is acquired. There are two basic points which are looked at:

- What is knowledge?
- How do we obtain 'valid' knowledge? (Hirschheim and Klein, 1992)

As with ontology, epistemology is concerned with two alternative viewpoints positivism and anti-positivism. Burrell and Morgan (1979) argue that positivism aims *"to explain and predict what happens in the social world by searching for regularities, causal relationships between its constituent elements",* and in contrast, anti-positivism believes that the social world *"can only be understood from the point of view of the individuals who are directly involved in the activities which are to be studied"* (p.5).

The methodology identifies particular practices used to obtain knowledge of reality, while also being concerned with how the researcher goes about finding out this knowledge (Guba, 1990). This viewpoint leads to methodological questions which seek to find out "how the inquirer can go about finding out whatever he or she believes to be known?" (Guba and Lincoln, 1994,p. 108).

This section has discussed the overarching research philosophy from an ontological, epistemological, and methodological perspective. The subsequent sections will now discuss the positivist and interpretivist paradigms as these are the two most widely used paradigms in information systems research (Goldkuhl, 2012). The critical realist paradigm will also be discussed as it is considered as an alternative to Positivism and Interpretivism in IS research (Mingers, 2004). The most appropriate paradigm for this research study will then be selected.

3.1.1 The Positivist Paradigm:

Positivism is an approach that is typically associated with the application of methods of the traditional sciences to the study of social reality and beyond (Bell et al., 2018). The phrases "how things 'really' are" and "how things 'really' work' are the basis of the ontological beliefs (Guba, 1990). Positivist research believes that an objective physical and social world exists independently of humans (Dubé and Paré, 2003). The positivist paradigm assumes that an apprehensible reality exists and is driven by immutable natural laws (Guba and Lincoln, 1994). Positivist studies are premised on the existence of prior fixed relationships within phenomena, which are typically investigated with structured instrumentation (Orlikowski and Baroudi, 1991). A positivist methodology is underpinned by the concepts of repeatability, reductionism, and reliability/refutability (Pather and Remenyi, 2004). Repeatability is when researchers do not rely on the results of one instance of an experiment but repeat it numerous times to ensure the results are accurate (Vidgen and Braa, 1997). Reductionism is where the whole is further and further reduced into its constituent parts (Hirschheim, 1985). Refutability occurs when a hypothesis being tested cannot be repeated with the same results as the original researchers (Oates,2006).

Positivism has been criticized for not allowing researchers to examine human interactions and their behaviours in an in-depth way (Crossan, 2003). This is due to the nature of positivist research which has a focus on measurement, facts, and rigor (Ryan, 2018). The emphasis on scientific and mathematical approaches to positivist research has resulted in some issues with IS studies

(Klein and Myers, 1999). The over reliance on statistical measures has meant that a majority of information systems research only captures the "what", but does not open the black box to understand the "how" and "why" (Lee et al., 1997). Focusing solely on 'what?' provides a challenge for an information systems researcher who wishes to research users interacting with an information system. This is a concept that Myers and Avison (2002) agree with stating, "the design and use of information technology in organisations, in particular, is intrinsically embedded in social contexts, marked by time, locale, politics, and culture." (p.63).

The next section will look at an alternative to the positivist paradigm, the interpretivist paradigm.

3.1.2 Interpretivist Paradigm

The aim of the interpretivist paradigm is to understand subjective meanings which are usually obtained using qualitative research methods (Goldkuhl, 2012). This contrasts with the positivist paradigm which has a focus on facts and measurement (Ryan, 2018). The interpretivist paradigm can be defined as a set of beliefs that focus on the idea that the knowledge of the world is constructed (Easton, 2010). Interpretivism seeks to work with subjective meanings created in the social world (Goldkuhl, 2012). By adopting an interpretivist paradigm, the researcher will work with subjective meanings and "*acknowledge their existence, reconstruct them, understand them, avoid distorting them, and use them as building-blocks in theorizing" (Goldkhul, 2012, p.137).*

The ontological position of Interpretivism is that reality is not given but socially constructed and dependent on subjective perception, cognition, and language (Berger and Luckmann, 1991) This ontological position maintains that there are multiple realities which are both time and context dependent (De Villiers, 2005). Interpretivism can be seen as suitable for information systems as the findings are subjective; this is advised when a study involves complex human behavior and a social phenomenon (De Villiers, 2005). Information systems contain physical components but are designed for and used by humans. A particular information system can be understood differently by different people (Doolin, 1998).

"Events, persons, objects are indeed tangible entities. The meanings and wholeness derived from or ascribed to these tangible phenomena in order to make sense of them, organize them, or reorganize a belief system, however, are constructed realities" (Lincoln and Guba, 1985, p. 84).

This implies the information system is an artefact that is used to create meaning by the interacting human actors who are involved with the information system (Doolin, 1998). Interpretive information systems research can be described as attempting to understand the impact of information systems on organisational activity through "*an understanding of the context of the information system, and the process whereby the information system influences and is influenced by its context*" (Walsham, 1993, pp. 4). Information systems research can be categorized as interpretive if the knowledge gained from a phenomena is found using language, consciousness, shared meanings, documents, tools, and other artefacts (Klein and Myers, 1999).

This study seeks *'to explore oscillations in modes of cognition while having access to information systems in dynamic and undynamic environments*. This requires the researcher to explore the underlying mechanisms which cause oscillations in modes of cognition. An alternative paradigm which seeks to identify the underlying mechanisms which constitute reality is critical realism. The next section will look at critical realism as an alternative to the positivism and interpretivist paradigm and discuss its suitability to the research objective.

3.1.3 Critical Realism

The previous sections have discussed the positivist and interpretivist paradigm available to the researcher. This section will discuss critical realism which is a relatively new approach to ontological and epistemological issues but is being adopted in many different disciplines such as, economics, management, and information studies (Easton, 2010). The critical realist paradigm has found broad appeal as it relates to how many think about the world (Edwards et al., 2014). The broad appeal highlighted by Edwards (21014) has led to critical realism becoming an increasing popular paradigm for information systems research (Hjørland and Wikgren, 2005). Critical realism offers a paradigm which argues that *"patterning of social activities are brought about by the underlying mechanisms constituted by people's reasoning and the resources they are able to summon in a particular context"* (Pawson & Tilley, 1997, p.220). The argument has been made that *"information systems are social systems and it makes sense to apply a modern social philosophy such as critical realism to their examination" (Dobson,2009, p.808).* The technical perspective of information systems often dominates but the social and human perspective also need to be considered. The convergence of both information systems and its management issues allow information systems research to be classified as the field of social science (Caldeira, 2016). The viewpoint is also supported by Morton (2006) who believes that critical realism is suitable for IS research that contains a social dimension, involving complex interactions or outcomes that may not be predictable. A critical realist analysis can help to identify the underlying mechanisms of the social dimension which can explain particular outcomes (Morton, 2006). This is of particular relevance to this study as it seeks to understand and explore shifts in modes of cognition, when using information systems in dynamic and undynamic environments.

The critical realist recognizes that to understand the world the underlying mechanisms that generate events need to be identified (Hjørland and Wikgren, 2005). The critical realist also understands that while the world is real and exists, they also accept "*the interpretive view that society is both produced and reproduced by its members, who may have different perceptions and interpretations about the same reality" (*Caldeira*,2016. p. 4).* Critical realism combines a realist ontology with an interpretive epistemology (Bhaskar, 2014). Critical realism neither accepts or rejects the ontological and epistemological position of positivism and Interpretivism but offers an alternative (Williams et al., 2017). Critical realism is made up of a transitive epistemological and an intransitive ontological dimension. The epistemological dimension is transitive as our perceptions of reality change continually; The ontological dimension remains intransitive as mechanisms constituting reality are ‘relatively enduring’(Dobson, 2005). This is further summarized by Dobson (2005) who states that for the critical realist

“there exists a reality totally independent of our representations of it; the reality and the “representation of reality” operating in different domains—roughly a transitive epistemological dimension and an intransitive ontological dimension. For the critical realist, the most important driver for decisions on methodological approach will always be the intransitive dimension—the target being to unearth the real mechanisms and structures underlying perceived events” (p.1).

This is further described by Bal (2016) who states that “*transitive knowledge relates to qualities of changeability or provisionality of our knowledge of the real, thus the transitive dimension comprises of our theories of the events and structures that we seek to understand in the intransitive dimension (p1)”.*

To unearth the real mechanisms and structures as described Dobson (2005), the critical realists reality is separated into three domains (Sayer, 1992). These three domains are shown in Figure 7 and contain the real, the actual, and the empirical domain.

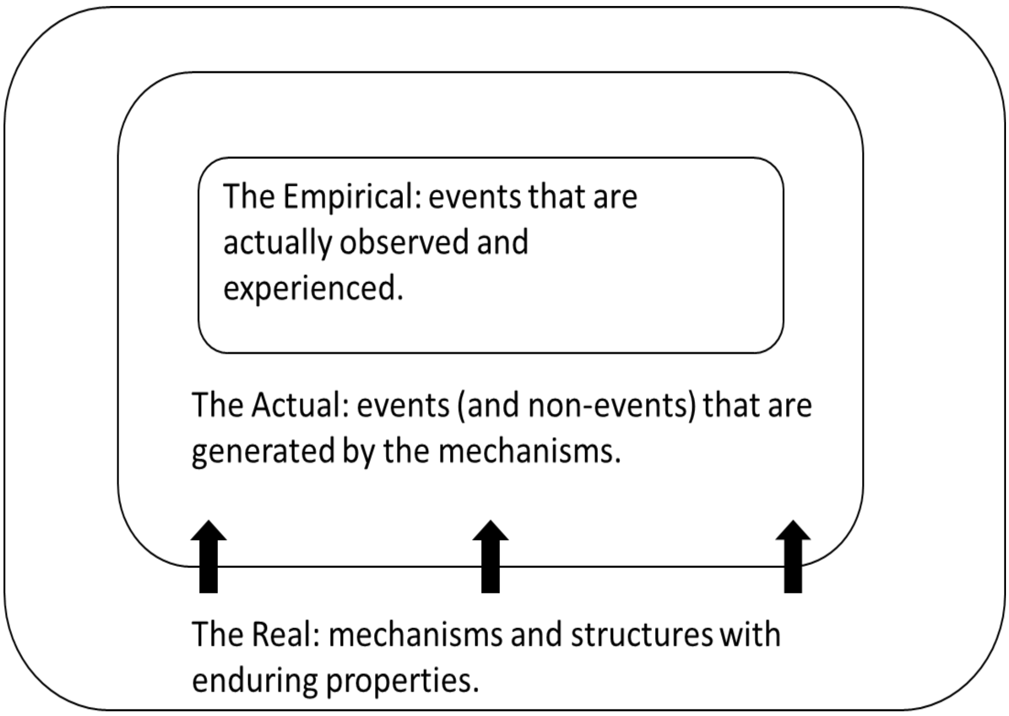

Figure 7 - The three domains. Mingers (2004)

The real layer is described by Dobson (2005) as *"the transcendental, nonactual or deep, that is structures, mechanisms, and associated powers" (p.2).* At the real layer, critical realism takes the position that social structures, natural objects, material artefacts, and conceptual entities such as language, opinions, and goals are real and exist independently of our perception of them (Fleetwood, 2005). This layer is described by Bergin et al. (2008) as "*the deep dimension where mechanisms produce events" and also, "the most important" layer (p.171).* The real layer is shown by Mingers (2004) to be *"one of complex interaction between dynamic, open, stratified systems, both material and non-material, where particular power structures give rise to certain casual powers"* (p.10). The real layer is the theoretical building block of critical realism and consists of structures and mechanisms which produce events at the actual layer (Caldeira, 2016, Easton, 2010). The real layer is beyond what we experience or observe and has powers that can be activated or not (Sayer,2000). Mechanisms can vary and according to Mingers et al. (2013) can *"be nonphysical and non-observable, the interaction of which could potentially have generated the events"* at the actual domain (p.797). The real layer is a transitive dimeson as it comprises the production of knowledge by drawing upon existing theories and results (Mingers, 2004).

At the actual layer, there are mechanisms that create events at the real level and only some of the outcomes or events may be observed. This implies that the actual is observable, but it is not always capable of being observed. This is described by Easton (2010) who states that *" we see just the tip of an iceberg but that doesn't mean that the invisible three-quarters is not there or is unconnected to what we see"(p.123).* The events created at the actual layer can be defined as "*a specific happening or action resulting from the enactment of one or more mechanisms"* (Wynn & Philips, 2012, p.792). The actual layer for the critical realist is described by Sayer (1992) as, "to ask for the cause of something is to ask 'what makes it happen', what 'produces', 'generates', 'creates' or 'determines' it, or, more weakly, what 'enables' or 'leads to it' (p.104.). Sayer (1992) goes on to state that "particular interpretations (of causality) can only be justified in terms of their compatibility with our most reliable beliefs…" (p.104.). This is the belief that assumptions, working together with other assumptions, create a system of thinking about the world that we find acceptable (Easton, 2010). Events are created at the actual layer which include the behavior of people, systems, interactions as they occur, or as have happened (Easton, 2010). Having a greater understanding of the actual layer will bring the researcher closer to answering the research objective; exploring and understanding the shifts in modes of cognition when using information systems in dynamic and undynamic environments. This is due to the events which are generated at the actual layer being observable at the empirical layer.

The final layer is the empirical layer which contains the subset of the actual layer that is observable (Volkoff and Strong, 2013). This view is reinforced by Easton (2010) who describes the empirical layer as *"where observations are made and experienced by observers"* (p.123). These experiences are described by Wynn and Williams (2012) as a subset of the actual events which may be observable in a given context. The mechanisms created at the real layer, trigger events at the actual layer, and these events may or may not be observable in the empirical layer (Bygstad et al., 2016). Mechanisms, such as the impact of time pressure in this study, may or may not be activated which can hinder direct observability at the empirical layer (Dobson, 2005). The context in which the mechanism is activated must also be correct for it to be observable at the empirical domain (Wynn and Williams, 2012). A mechanism may or may not be activated given the context (Bygstad et al., 2016). The context can include values, traditions, the social organization, and relations (Caldeira, 2016). The context is relevant to this study as the literature review found that decision makers are required to operate in dynamic and undynamic environments which can shift their decision-making approach.

In summary, the goal of a critical realist is to understand and explore mechanisms and is based on three core beliefs:

(i) Structures and objects are real and exist independently of our perception of them (Fleetwood, 2005).

(ii) There are mechanisms which exist that generate events and outcomes.

(iii) There are a subset of mechanisms which are observable for the researcher (Volkoff and Strong, 2013).

Methodologically, a case study approach is recommended by Easton (2010) for a critical realist researcher who uses research questions such as 'what caused the events associated with the phenomenon to occur?'. This viewpoint is shared by Morton (2006) who describes case studies as ideal for a critical realist study because they allow for a focus on the mechanisms, and their interaction, that lead to observed outcomes. A critical realist case study offers advantages to an IS researcher as it sits between a positivist and interpretivist approach (Wynn and Williams, 2012). This is advantageous as a critical realist case study allows for a *"more detailed causal explanations of a given set of phenomena or events in terms of both the actors' interpretations and the structures and mechanisms that interact to produce the outcomes in question" (Wynn Jr and Williams, 2012, p. 788).* When conducting a critical realist case study, the researcher is required to identify the mechanisms involved (Easton, 2010). A critical realist approach allows the researcher to understand why mechanisms have impacts if they are observable (Whittle and Spicer, 2008). The identification of these mechanisms will assist the researcher in answering the research questions.

This section has reviewed the critical realist paradigm and concluded that it aligns best with this particular research study. The next section will apply the critical realist paradigm to the research objective.

3.1.4 Critical Realism applied to the Research Objective

Having explored a positivist, interpretivist, and critical realist paradigm it was found that the critical realist paradigm was most aligned to this research study. The objective of this research is *"To explore oscillations in decision-making approaches while having access to information systems in dynamic and undynamic environments".* To meet this objective, it is vital to understand underlying mechanisms which can lead to shifts in modes of cognition when using information systems in dynamic and undynamic environments. The previous section outlined that the ontological position of a critical realist study is divided into three domains; the real domain, the actual domain, and the empirical domain (Wynn and Williams, 2012, Dobson, 2005) . The mapping of the research objective to the three ontological domains of critical realism is shown in Figure 8. Mapping the research objective to the three ontological domains shows the fit between the research objective and the critical realist ontology.

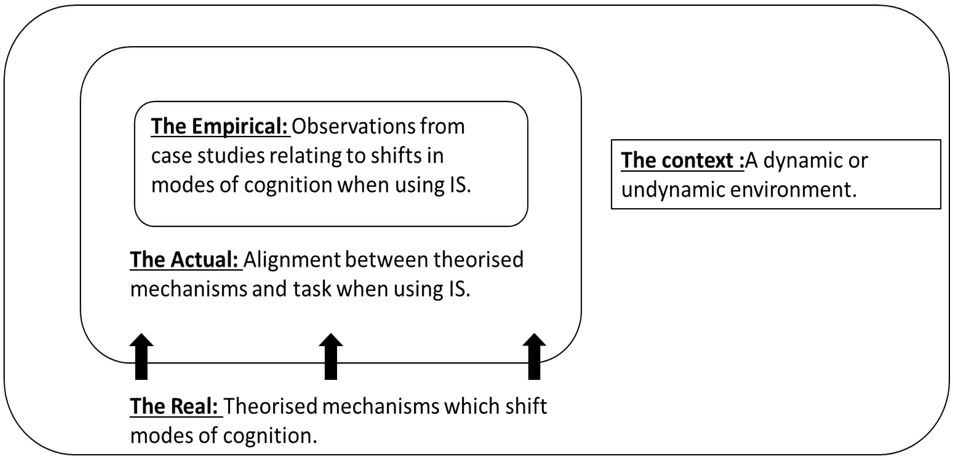

Figure 8 - Critical Realist domains applied to the research objective

In addition, Figure 8 also displays the context (a dynamic or undynamic environment) in which a mechanism (Williams et al., 2017) may or not be impacted by. Identifying the context is recommended by McAvoy and Butler (2018) as it will allow the researcher to find if the context has impact on observations at the empirical domain on a case by case basis. Identifying the context of the individual case study is important as the literature review identified decision makers operate in dynamic and undynamic environments. As such, the context shown in Figure 8 is informed by the work of (McAvoy and Butler, 2018).

As well as the ontological fit, it is also necessary to show the alignment of epistemological fit. The previous section outlines that the critical realist adopts an interpretive epistemology and that it is created by society or social dimensions *"who may have different perceptions and interpretations about the same reality" (*Caldeira*,2016. p. 4)*. The study of information systems involves a social dimension with complex interactions or outcomes which are not predictable (Morton, 2006). The interpretive epistemological viewpoint of critical realism *"seeks to posit descriptions of reality based on an analysis of the experiences observed and interpreted by the participants, along with other types of data"* (Wynn et al, 2012, P.793). The interpretivist epistemological nature of the critical realist paradigm provides a good approach to answer the research questions of this study:

Research Questions 1: How do decision-making approaches oscillate while having access to information systems?

Research Questions 2: How does the dynamic or undynamic environment impact on the oscillation of decision-making approaches while having access to information systems?

As the study of information systems is a social science (Caldeira,2016) it is necessary to understand the mechanisms which create events as shown in Figure 7. The critical realist paradigm applies to cognitive continuum theory as a shift in decision making (the empirical) is reliant on events (the actual) which is reliant on mechanisms such as time pressure (the real). Understanding the mechanisms which create events will allow the researcher to answer the research questions.

This section has applied the research objective to the three different domains of critical realism. In doing so, Figure 8 has reinforced and displayed the ontological alignment with the research objective of this study. Epistemological critical realism was also found to fit this research study. The critical realist paradigm has been found to fit this research study and will therefore be adopted. The next section will discuss the research strategy.

3.2 Research Strategy

This section outlines the various research designs available to researchers embracing a critical realist approach to research. A critical realist approach is typically conducted using qualitative research methods and these are focused upon. Section 3.3.1 will discuss the research design approach and section 3.3.3 will discuss and justify why an observational approach is best suited to this research. Section 3.5 will review the research method which is a multiple case study approach. Section 3.6 will discuss the data analysis method used and section 3.7 will provide the conclusions for this chapter.

3.2.1 Research Strategy Approach

The research strategy determines how empirical data is collected and analysed (Yin, 1994). The research strategy also builds a general plan for the research regarding how it precedes in order to fulfil its purpose (Saunders and Lewis, 2000). When formulating a research strategy, it is important to acknowledge that different modes of research allow researchers to understand different phenomena and for different reasons (Deetz, 1996). The methodology chosen depends on what the researcher is trying to do rather than a commitment to a particular paradigm (Cavaye, 1996). The methodology employed must match the particular phenomenon of interest (Krauss, 2005).

3.2.2 Research Methods

This section will provide an overview of the research methods available and used by the researcher. The research objective of this study is to:

"*To explore oscillations in decision-making approaches while having access to information systems in dynamic and undynamic environments.*

Different modes of research allow the researcher to understand different phenomena for different reasons (Deetz, 1996). Krauss (2005) argues that the methodology employed must match the particular phenomenon of interest. By focusing and understanding the phenomenon under examination, rather that selecting a methodology and proceeding, a researcher can select the correct methodology for the study (Falconer and Mackay, 1999). There are differing types of qualitative research methods available such as action research, case study research, and ethnographic studies (Myers, 1997). Despite these differing methods being available, when research is exploratory, the methodological approach is recommended to be a case study (Marshall and Rossman, 2014). Adopting a case study approach allows for the gathering of rich qualitative evidence (Gregor, 2006). Furthermore, a multiple case study approach is recommended as it allows the researcher to gain a deeper understanding of the research objective (Yin, 1994). As the objective of this research is exploratory, the most appropriate research methodology for this study is a multiple case study approach.

Case study research involves the collection of evidence from multiple sources in relation to a particular set of circumstances (Remenyi and Williams, 1995). The evidence for a case study approach can be collected through qualitative research, quantitative research, or a combination of both. Examples of evidence sources include fieldwork, archival records, verbal reports, observations, or a combination of each (Yin, 1981). Case studies allow for the collection of complex and rich evidence via a systematic process for collecting and analysing the data (Remenyi and Williams, 1995). Case studies differentiate themselves from field studies as they offer an in-depth examination of an activity or event, known as a 'case' (Hair, 2007). Actions taken by individuals in the case are describe in detail, which include, the reactions, responses, and effects on other participants and are compared and contrasted in order to draw conclusions (Hair, 2007).

The use of a case study approach is applicable to this study as Cognitive Continuum Theory is currently an under-researched phenomenon in information systems. When research and theory are at an early formative stage a qualitative approach is best suited (Yin, 1981, Benbasat et al., 1987). A case study should be used when the boundaries between phenomenon and context are not clearly evident (Yin, 2003).

Yin (2003) identifies three core principles to a successful case study:

1. Use of multiple sources of evidence.
2. Creation of a case study database.
3. Maintain a chain of evidence.

The researcher was able to build multiple sources of evidence by recording and documenting evidence over a number of visits to key decision maker.

This allowed the researcher to build a rich body of evidence across multiple case studies. Evidence gathered during the case study was stored in Microsoft excel. The creation of this excel matrix allowed the researcher to compare and contrast various pieces of evidence across multiple case studies. The use of multiple sources of evidence and creation of a case study database allowed the researcher to build and maintain a chain of evidence. The chain of evidence was built over time by documenting the unit of analysis which allowed for detailed and rich analysis.

This section has outlined the research design of this study. The methods available to the researcher when conducting a qualitative case study approach will now be discussed in the following sections.

3.2.3 Observational Research Methods

The previous section outlined the research design of this study. This research was found to be exploratory in its nature. When undertaking an exploratory study, it is recommended that the research undertakes a qualitative, multiple case study approach

There are a number of methods associated with qualitative, case study research. These methods include: (i) observation; (ii) interviews; (iii) questionnaires; (iv) documents; (v) texts; and, (vi) the researchers' impressions and reactions (Myers, 1997). Qualitative research allows the researcher to understand a phenomenon from the point of view of the participants, as well as, its social and institutional context, which can often be lost when textual data is quantified (Kaplan et al., 1994).

Documentary information is likely to be relevant to every type of case study and can take form of, letters, emails, agendas, administrative documents, and newspaper clippings (Yin, 2013). The use of documentary evidence is not suitable for this study, as the researcher seeks to understand how key decision-makers interact with an information system.

Interviews are another commonly used qualitative research method and have been described as being one of the most important sources of case study information (Yin, 2013). Three different types of interviews are available to a researcher: (i) unstructured interviews; (ii) semi-structured interviews; and (iii) individual in-depth interviews (DiCicco-Bloom and Crabtree, 2006). Unstructured interviews are not fully unstructured, but rather guided conversations (DiCicco-Bloom and Crabtree, 2006). In unstructured interviews, data is typically collected through observation and recorded field notes as the researcher observes or participates in an activity (DiCicco-Bloom and Crabtree, 2006). This process allows the researcher to highlight particular key events and elicit information about the meaning of observed behaviors, interactions, and rituals. Semi-structured interviews are the second type of interview method available to the researcher. The semi-structured interview is typically used with a set of predetermined open-ended questions with other questions emerging from the dialogue between interviewer and interviewee (Opdenakker, 2006). The final type of interview is an individual in-depth interview which allows the researcher to delve deeply into social and personal matters (Lucas, 2014). In this type of interview, the interview may still remain open-ended and assume a conversational manner but the researcher is more likely to be following a certain set of evidence (Yin, 2013). Interviews are not an appropriate research method for this study as individuals who engage in intuitive decision making cannot recall the steps in making a decision (Calabretta et al., 2017). As this study seeks to explore and understand shifts in decision-making approaches when using an information system in dynamic and undynamic environments adopting an interview approach is not possible. The research would not be able to see the individual interact with the information system in a live environment.

Observation is defined by Marshall and Rossman (1989) as "the systematic description of events, behaviours, and artefacts in the social setting chosen for study" (p.79). Observation allows the researcher to create a “written photograph” of the phenomena under investigation (Kawulich, 2005). Observational research is advantageous as it allows the researcher to put background context to a particular phenomenon. Direct and participant observation are two observational methods available to a researcher. Direct observation will typically take place during meetings, sidewalk activities, factory work, or classrooms. Direct observation allows a researcher to assess the occurrences of particular behavioral patterns during certain periods of time in the field (Yin, 2013). Participant observation offers researchers a special mode of observation in which the researcher is actively takes part in the daily activities, rituals, interactions, and, events of the people being studied as one of the means of learning the explicit and tacit aspects of the phenomenon's' culture (DeWalt and DeWalt, 2010). Observation is also useful in collecting data in unstructured environments in naturalistic settings by researchers who observe and/or take part in common and uncommon activities of people being studied (DeWalt and DeWalt, 2010). Observation is a suitable research method for this study as it this study seeks to explore and understand shifts in decision-making approaches when using an information system. Observation is appropriate for an information systems study as a researcher can understand how a system is actually used in the workplace (Yin, 2013).

This section has reviewed the different qualitative research methods available to the researcher. The different types of evidence collection methods such as, documents retrieval, unstructured interview, semi-structured interview, individual in-depth interview, direct observation, and participant observation were reviewed. Documentary evidence and interviews were deemed not appropriate for this study. Observation was selected as the most appropriate research method for this study and direct observation will be discussed in more detail in the next section.

3.3 Data Collection: Direct Observation

The previous section identified observation as the most suitable research method for this study. This section will outline why direct observation is the most appropriate for this study. Direct observation is a method of collecting evaluative information in which the evaluator watches the subject in his or her usual environment without altering that environment (Holmes, 2013). It is a suitable method to use when other methods available such as interviews and documentary evidence are deemed unsuitable (Taylor-Powell and Steele, 1996). Direct observation is a suitable data collection method when the goal is to evaluate an ongoing behavior process, event, or situation, or when there are physical outcomes that can be readily seen (Holmes, 2013). Direct observation differs from participant observation as the researcher doesn't typically try to become a participant in the context; the direct observer aims to be as unobtrusive as possible so as not to bias the observations (Trochim, 2006).

Direct observation is the most appropriate data collection method for this study as it allows the researcher to explore and understand how the key decision maker oscillates their decision-making approach while having access to an information system. It would also allow the researcher to gather data on the phenomena of interest whilst the key decision maker works as normal, uninterrupted. This is important for this study as decision makers can often not recall the steps after the event in making a decision (Calabretta et al., 2017).

The environment the unit of analysis operates in is also an important consideration. Direct observation is recommended in complex environments, such as real time and stressful environments (Woolsey, 1986). Observation is also appropriate to collect data in unstructured environments, in naturalistic settings by researchers who observe the activities of people being studied (DeWalt and DeWalt, 2010). This is another factor which makes adopting a direct observational approach important for this research study. This study will seek to understand how decision makers shift between differing decision-making approaches when using information systems in dynamic and undynamic environments. As this study seeks to gather data in differing and changing environments, a direct observational approach is the most suitable for this study.

A direct observation study was deemed appropriate due to the critical-realist approach adopted for this study. The exploratory nature of this study required a more open, naturalistic research method. A direct observation approach allows the researcher to explore emergent themes and patterns which occur whilst the unit of analysis worked in their natural environment, uninterrupted. Using a direct observation approach will also allow the researcher to investigate if an oscillation in decision making (the empirical) is reliant on events (the actual) which is reliant on mechanisms such as time pressure (the real) in a given context (dynamic or undynamic environment). Understanding the mechanisms which create events in a given context will allow the researcher to answer the research questions. The next section will discuss the four individual case studies, before an overview of the data analysis techniques are discussed.

3.4 Case Studies

A multiple case study approach was deemed appropriate for this study as Benbasat et al. (1987) argue that "multiple case designs are desirable when the intent of the research is description, theory building or theory testing... multiple-case designs allow for cross-case analysis and extension of theory" (p.373). A multiple case study approach strengthen results by replicating pattern-matching across the case studies (Tellis, 1997). It is recommended for a researcher to find case study locations where

1. Replication of results are predicted from the case studies.
2. Contrasting results are predicted from the case studies. (Tellis, 1997, Yin, 1984).

The case studies selected for this study aimed to satisfy the criteria outlined above. The literature review outlined in Chapter 2 found that decision makers operate in two distinct environments. The dynamic environment was characterized as having increasing time pressure, potential for information overload or lack of information, and unreliable information; the undynamic environment had the opposite characteristics. Four case studies were iteratively built over time: two cases from a dynamic environment, and two cases from an undynamic environment as shown in Table 4.

Dynamic Environment	**Role**		**Undynamic Environment**	**Role**
Boeing 737-800 Cockpit	Pilot		Pharmacy	Manager
Air Traffic Control	Manager		National Grid Control Room	Manager

Table 4 - Multiple Case Studies

In addition to satisfying the environment the decision maker was in, the researcher also sought two further criteria when selecting the unit of analysis for each case study:

1. The unit of analysis should be a manager or occupy a senior role. This ensures the unit of analysis is a subject matter expert in their domain.
2. The unit of analysis has access to an information system to perform their working tasks.

All of the units of analysis outlined in Table 4 were highly experienced, highly knowledgeable, and considered subject matter experts in their domains. All of the units of analysis were required to use various information systems when completing tasks in their day-to-day jobs. These individuals matched the criteria outset by the researcher in that they:

i. Operated in a dynamic or undynamic environment.
ii. Held a managerial role or were considered subject matter experts.
iii. Used an information system to perform their tasks.

Observation for each of the case studies took place over a period of 9 months. Cumulative observation time for the four case studies was 50 hours. The next section will discuss the analysis of the observation data which was collected.

3.5 Data Analysis:

Once the data has been collected the researcher is required to analyse the data. A common method of qualitative data analysis is thematic analysis (Aronson, 1995). Thematic analysis relies upon coding, which aims to look at what the data says and aims to identify patterns within the data (Sgier, 2012). Coding allows for rich and insightful understandings of complex phenomena (Braun and Clarke, 2006)

Data analysis is based upon a common set of principles which involve:

i. The researcher immersing themselves within the data to uncover new insights
ii. Developing a coding system for the data

iii. Linking the codes of data to form specific themes of analysis (Morse and Richards, 2002).

Phase	Action	Key Tasks
1	Clean and Edit Data	• Prepare raw data files. • Create multiple backups of raw files • Create a common format. • Researcher immerses themselves with the data and explores emergent themes.
2	Creation of a Coding System	• Create specific codes for the data. • Ensure codes are unique and specific • Remove irrelevant and repeating data. • Start to ask questions of the dataset.
3	Analysis of Codified Data	• Creation of a matrix of data • Content analysis of emergent themes • Data reduction allows for focus on key themes • Cross-case analysis on all four case studies

Table 5 - 3 Phase Data Analysis Approach

Data analysis followed a three-stage process and a high-level overview of this is shown in Table 5. The next sections will discuss the three stages conducted by the researcher in more detail.

Phase 1 – Cleaning and editing the data:

Phase 1 of the data analysis involved the researcher immersing themselves in the data by initially cleaning and editing the data as outlined by Thomas (2003). The first step of this process was the preparation of the raw data files. At this stage, the researcher migrated all the recorded observational data into a common format. This included a common font type, font size, margin, and observational comments were highlighted. The researcher also ensured that multiple backups were created of each data file. Once the data was cleaned and put into a common format, the next stage for the researcher was to closely read the text. All pieces of observational data were read in detail by the researcher. This allowed the researcher familiarize themselves with the observational data, gain an understanding of the phenomena, and explore the emergent themes from the data (Thomas, 2003). This method of closely reading the text allowed the researcher to fully immerse themselves in the data as recommended by Morse and Richards (2002). A sample of clean and edited raw data is shown in Figure 9.

Observation	**Observation**
Preforms pre-flight checks, looks at instruments and setups various systems such as the transponder. Confers with ATC in relation to pre-flight setup and route.	Time pressure was extremely high for the pilot, which led to a visible increase in stress levels. The pilot needed to make continuous decisions with little time for analysis of all the instruments

Figure 9 - Sample of Clean and Edited Raw Data from Notes

Phase 2 – Creation of a coding system:

Phase two of the data analysis process was the development of a coding system for the cleaned and edited dataset. Coding is the creation of tags or labels that provide meaning to data found during a study. Once the codes are created, Basit (2003) states codes are "*attached to chunks of varying-sized words, phrases, sentences or whole paragraphs, connected or unconnected to a specific setting, they can take the form of a straight forward category label or a more complex one" (p. 144).* Adopting a coding system also allowed the researcher to remove data which was deemed irrelevant or repetitive. Miles and Huberman (1994) recommend the following steps when coding data:

i. Create a list of codes prior to fieldwork but be prepared to revisit these codes.

ii. Ensure codes fit a structure and are distinct from one another.

iii. Keep codes semantically close to the terms they represent

iv. Define how the codes will be operational.

Adhering to the steps outlined above by Huberman and Miles (1994) allowed the researcher to create categories of data. Creating categories of data allowed the researcher to compare and contrast the data. This is an important step as Basit (2003) describes how the creation of categories allows the researcher "ask questions, to compare across data, to change or drop categories and to make a hierarchical order of them" (p.144). An example of the categories created can be seen in Figure 10; This process was repeated across all four case studies which allowed the researcher to compare and contrast data across all four case studies. Once the coding mechanism was developed, the next stage of the process was to analyze the codified data.

Coding Tags	**Related To**
Intuition	Decision Making Type
System Aided Judgement	Decision Making Type
Data-Driven Decision Making	Decision Making Type
Time Pressure	Factor
Information Changes	Factor
Task Type	Factor

Figure 10 - Sample Coding Tags

Phase 3 – Analysis of codified data:

Qualitative data analysis is described by Rabiee (2004) as aiming to "*bring meaning to a situation rather than search for truth focused on by quantitative research*" (p.657). Phase three of the data analysis was conducted using thematic analysis to identify the emergent themes from the codified data which aimed to bring meaning to the situations as described by Rabiee (2004). Miles and Huberman (1984) recommend that content analysis should follow three steps:

i. Place information into different arrays

ii. Create a matrix of categories

iii. Place each piece of evidence into the relevant category.

Data was collected from four individual case studies. An observational study was conducted of a pilot, air-traffic controller, pharmacist, and national grid controller as shown in Table 4. This data was then studied by the researcher and coded. The codification of the data allowed the researcher to create a matrix of categories. Each piece of data was then placed into a relevant category within the matrix. An example of a completed matrix can be seen in Table 6. The creation of this matrix allowed the researcher to compare, contrast, and ask questions of the data as recommended by Table 6.

Adopting a thematic analysis approach also enabled the use of data reduction. Data reduction is the process of selecting, focusing, simplifying, abstracting and transforming data (Miles and Huberman, 1984). Data reduction allowed the researcher to focus on key pieces of data that were consistent across all four cases. This enabled the researcher to conduct cross-case analysis on the key decision maker across all four case studies. This allowed the researcher to explore and understand the research phenomena in detail.

This section has discussed the data analysis method for all four case studies. The researcher adopted a three-phase approach. Phase 1 involved editing and cleaning the data, phase 2 codifying the data, and phase 3 thematically analyzing the data. The next section will conclude the chapter.

Observation		
Theme	**Decision Making Under Stress**	**Potential Personal Impact on Pilot?**
Data Driven Decision Making	Time pressure was extremely high for the pilot, which led to a visible increase in stress levels. The pilot needed to make continuous decisions with little time for analysis of all the instruments	
Data Driven Decision Making	The pilot was visibly nervous throughout the simulation of a landing. The pilot was visibly sweating, had a nervous voice when speaking to ATC, and when interacting with the computer systems. This was during mild conditions.	*The pilot was extremely nervous about making any errors in front of his instructor. This was visible when making most decisions, with the pilot visibly sweating, and audibly nervous even during mild conditions.*
Data Driven Decision Making	The increased stress levels outlined above created pilot error. This was noted when the pilot was requested to amend his flight instruments by ATC. The pilot due to increased stress and time pressure incorrectly changed the system to the wrong settings. This cause the aircraft to miss its correct flight path.	*Pilot was unable to relax during the flight causing him to interact with the system incorrectly. This resulted in a pilot error which his instructor had to point out to him and made a note of.*

Table 6 – Sample Thematic Analysis of Pilot Case Study

3.6 Chapter Conclusion:

This chapter discusses how the research study was conducted. The chapter began by discussing differing philosophical approaches. The positivist and interpretivist research paradigm were discussed before a critical realist approach was deemed the most suitable for this research study. Once the philosophical approach of the study was selected, it was found that a multiple case study approach using direct observation was most suitable to this research.

The data collection strategy was also presented in this chapter. The researcher selected four suitable units of analysis for the study. The environments the unit of analysis operated in were categorized as being dynamic or undynamic. Two sites were selected from each environment. These included a Boeing 737-800 series pilot and air-traffic controller on the dynamic side, and a pharmacist and national grid control manager on the undynamic side.

The selection of four case studies allowed the researcher to compile rich and rigorous data. After selecting the most appropriate methodology for this research study, the subsequent chapters will present the findings of each case study before a cross-comparison is presented.

Chapter 4: Dynamic Environment

Chapter 3 outlined the research philosophy most aligned with this research topic. It was found that a critical realist approach was most suitable for this study. When conducting a critical realist study, a case study is most applicable (noted in Chapter 3). As such, this chapter will now discuss two case study sites in detail. The first of which is an international flight training academy for pilots which is approved by the European Aviation Safety Agency (EASA). The unit of analysis in this case study is the aircraft pilot. The second case study takes place at an international air traffic control tower. The unit of analysis is the air traffic control manager. Both case studies will look at the environment, task, and decision-making approaches of the unit of analysis. The chapter will begin with the aircraft pilot (Section 4.1) and the air traffic control manager (Section 4.8) will follow. The chapter will conclude with a summary.

4.1 Pilot Introduction

This section presents a case study of aircraft pilots who operate a simulation of a Boeing 737 aircraft. As discussed in Chapter 2, utilising the correct decision-making approach given the task characteristics can improve decision-making effectiveness. In highly dynamic environments, the contextual familiarity of a task can alter rapidly, which may affect decision making performance if the decision-making approach is not amended to reflect the changes in the environment. This chapter will look at a pilots decision-making approach through the theoretical lens of cognitive continuum theory. The concepts which will be reviewed are environmental dynamism, contextual task familiarity, sensitivity to a negative outcome and the decision-making approach utilised by the decision maker. These concepts were identified in Chapter 2 of the literature review.

The literature review detailed the importance of utilising the correct decision-making approach in a given context and this chapter will build on this argument by reviewing observations of factors which influenced a decision makers' decision-making approach in a dynamic environment.

4.1.1 Case Study Background

This case study took place at an international flight training academy for pilots which is approved by the European Aviation Safety Agency (EASA). The training academy has been training international aircraft cadets for over twenty years and works closely with leading airlines such as British Airways, Emirates Air, Cathay Pacific, and Virgin Atlantic Airways. Aircraft pilots were an ideal candidate for this study as pilots are required to operate in dynamic environments, often under situations of high risk, time pressure, and uncertainty as identified in Chapter 2. Observation for the case study took place in a Boeing 737-800 simulator. The Boeing 737-800 simulator had 31 distinct systems with which the pilot had to interact with.

These were comprised of 24 pictorial, 6 analogue, and 1 combination of both. Pilots of a Boeing 737-800 need to be comfortable operating a range of information systems including: automation, communications, emergency systems, flight controls, flight instruments, navigation, and warning systems which will all have an impact on their job performance. As well as interacting with the information systems, the pilots also need to interact verbally with their co-pilot, and air traffic control. A pilot is also required to use these resources individually or use a combination of all three depending on the task. Interactions with air traffic control, the co-pilot, and the information system will occur throughout the aircrafts flight, including pre-take off checks, take off, during flight, and landing. A pilot needs to be able to interpret and put into action information that is being relayed to them from both their co-pilot and air traffic control. Air traffic control can provide the pilot with information relating to weather conditions, take off, landing instructions, flight path, and emergency information. A pilot is required to interact and interpret the information provided by air traffic control whilst at the same time operating various on-board information systems.

For the purpose of this case study, four individual pilots were observed on different days. Each pilot had completed over 100 hours of theoretical classroom training, over 23 hours of dual flight training, and over 8.5 hours of solo flight training. The pilots had a high level of understanding with regards operating modern system driven airlines and also, the interpersonal and human development skills of commanding a fast transport jet liner in complex demanding European airspace. The photo in Figure 11 is the Boeing 737-800 simulator the pilots operated.

The next section will review and discuss the operating environment that the pilots worked in.

Figure 11 - Boeing 737 Cockpit

4.1.2 Pilot Scenarios

The following section will outline and describe a series of scenarios in which the pilots were involved with. These scenarios ranged from mundane tasks such as pre-take off checks to more unusual scenarios such as engine failure. All four pilots studied were required to complete 7 distinct scenarios. These scenarios will now be discussed in further detail.

<u>Scenario 1 – Land Aircraft in Routine Conditions</u>

The first scenario the pilot is required to perform is landing the aircraft in moderate and calm weather conditions with visibility levels being normal for the pilot. The pilot was expected to interact with the on-board information systems, interact with air traffic control and use the human eye to manually land the aircraft safely. The pilot is also required to perform this task in front of a pilot instructor who will be grading their performance of the task. This exam like setting increases the stress that the pilots are placed under.

A pilot performing this task is required to use the on-board information system and use the information provided by air traffic control to adjust the (i) speed of the aircraft, (ii) altitude of the aircraft, and (iii) angle of decent the aircraft is taking. Pilot errors that occur at this point could result in a failed landing attempt or a catastrophic crash of the aircraft. The pilot is expected to use a combination of their own judgement and the data provided by the information system and air traffic control.

<u>Scenario 2 – Land Aircraft during Turbulence.</u>

A scenario involving the pilot being required to land the aircraft during turbulence. In the build-up to a landing attempt the pilot is required to adjust numerous systems on the aircraft such as lowering speed, altitude, and adjusting the approach angle. The pilot is also required to communicate verbally with air traffic control to discuss the landing attempt and receive clearance from air traffic control that they are clear for landing. The pilot will also be asked by air traffic control for specific status updates regarding the landing. The pilot is required to compute and provide this information to air traffic control rapidly. Despite the turbulence, the pilot is required to adopt the correct altitude, speed, flight angle, and landing approach. Any deviation from a normal reading, would be a red flag for their instructor who was observing and may result in the pilot failing the course. The presence of an instructor who was grading the pilot on their performance resulted in this being an exam situation for the pilot.

<u>Scenario 3 – Mechanical Failure Scenario.</u>

A mechanical error can occur at any time when the pilot is operating the aircraft. This can occur at pre-take off, take-off, mid-flight, and landing of the aircraft. Aircraft pilots train extensively to cover a wide range of mechanical errors which may affect them during a flight. A training exercise involving mechanical failure was observed when conducting observation for this study. A Boeing 737-800 series aircraft features two CFM56 turbofan engines which improve flight efficiency. These engines are reliable and can have a lifespan of thousands of hours of operation. The engines have regular scheduled inspections and maintenance to ensure they operate correctly. Despite this, aircraft engines can fail or malfunction which will require the engine to be shut down and the pilot is expected to locate the nearest safe runway to land the aircraft. A scenario of engine failure was simulated and observed. During the simulation of a mechanical failure, the pilot was observed and graded by a qualified flight instructor. A mechanical failure scenario is one of high stress and high time pressure for the pilot. The pilot is required to liaise with air traffic control and use their navigational system to attempt to land the aircraft as soon as possible. The pilot was being graded by a flight instructor to ensure that they were responding correctly in this emergency scenario and that there were no signs of panic.

<u>Scenario 4 – Fly aircraft in poor weather conditions.</u>

A pilot is required to operate in dynamic conditions with weather patterns often dramatically changing over the course a flight. The simulation for the pilot was no different and the pilot was required to contend with deteriorating conditions. This occurred when severe fog and hail was introduced into an in-flight simulation. Prior to these conditions, the pilot remained calm taking on board information from air traffic control and amending existing settings on the information systems based on information provided by air traffic control. In conditions with heavy levels of fog and hail, the pilot is expected to keep the aircraft stable, but also be in a position to take on board and interpret information from air traffic control. This is critical as the pilot's visibility of the surrounding terrain is minimal and they're reliant on air traffic control and their information systems to provide guidance. Failure for the pilot to interpret information from either source could have deadly consequences in a live environment. This scenario aimed to test the pilot's ability to interact with the information system and air-traffic control under pressure.

<u>Scenario 5 – Fly Aircraft during Turbulence.</u>

A common scenario any pilot will face is the issue of turbulence. Turbulence was introduced to the simulation without the pilot's prior knowledge the event would be occurring. This was to grade the pilot on whether they could perform under the pressures of severe turbulence. Prior to the conditions of severe turbulence being introduced the pilot was relaxed, calm and composed whilst flying the aircraft. The pilot felt comfortable and at ease interacting with air traffic control, the co-pilot, and the on board information system of the aircraft. It was noted in the observation, that the pilot was able to give clear and concise instructions to both air traffic control and the co-pilot during mild weather conditions. As high levels of turbulence were introduced, the pilot's decision-making approach altered due to the operating environments shift. The pilot began to become visibly nervous and was visibly sweating when attempting to keep the aircraft stable and on course during the turbulence. This scenario will be explored in further detail in subsequent sections.

<u>Scenario 6 – Request Landing in Fog.</u>

The pilots also experienced poor weather conditions when attempting to land the aircraft. In a scenario of fog, the pilot will be unable to view their outside conditions and will become reliant on the information system and support from air traffic control. It is vital that the pilot does not become over-reliant on one form of information and is able to remain calm and clear in their decision-making. When adverse weather conditions such as extreme fog were introduced the pilot would become visible nervous and stressed. The pilot would be more hesitant when interacting with the information system and in some cases be visible sweating. The pilot would also become audibly nervous when interacting air traffic control. The pilots' voice wouldn't sound as confident when interacting with air traffic control during severe weather conditions. During simulations of the dynamic weather patterns the pilots would be observed and their performance graded by a flight instructor. The flight instructor would look to grade the pilots on their performance whilst under conditions of increased stress.

Scenario 7 – Request Landing Clearance.

The final scenario that the pilots were required to undertake was landing the aircraft in calm conditions. Visibility for the pilot was very high and the conditions could be described as ideal for flying. In the build-up to an attempted landing the pilot must adjust numerous systems on the aircraft such as lowering speed, altitude, and adjusting the approach angle. The pilot is also required to communicate verbally with air traffic control to discuss the landing attempt. The pilot also needs to receive clearance from air traffic control that they are clear for landing. The pilot needs to ensure that the aircrafts various systems are configured correctly and that the information being provided to them by air traffic control has been inputted correctly. Despite the ideal environmental conditions, failure for the pilot to correctly setup the aircraft for a landing can result in critical and life threating scenarios occurring. The pilot also maintains communication with air traffic control and is occasionally asked specific questions regarding landing. It is necessary for the pilot to rapidly respond to these queries to ensure the safe landing of the aircraft.

This section has provided a high-level overview and background of the various scenarios the pilots were required to complete. It is important to note that during these scenarios all the pilots were being examined and graded by a qualified flight instructor. The result of these examinations would count towards obtaining a commercial pilots license. This was an added pressure the pilots would need to contend with; in addition, the pilots also had significant financial costs having committed upwards of 100,000 euro. Both the examination and the potential financial consequences would be significant stressors for the pilots whilst performing these tasks. The subsequent sections will now review these scenarios under the following sections:

- Operating Environment
- Pilot Error
- Mechanical Error
- Dynamic Weather
- Information Fluctuations
- Time Pressure
- Task Familiarity
- Task Non-Routineness
- Task Interdependence
- Intuition
- System Aided Judgement
- Data Driven Decision Making.

4.2 Operating Environment

The pilots operating the Boeing 737-800 simulator are required to perform to an exemplarily standard in a very challenging operating environment. The challenges the pilots face are numerous and include:

(i) Interacting with over 30 information systems

(ii) Interacting with air traffic control

(iii) Interacting with a co-pilot who look to the pilot for guidance

(iv) Using the pilots own judgement for pre-flight checks, flight paths, aircraft speed, aircraft turning angles, and altitude.

The aircraft pilots are expected to perform these tasks in an environment which has high time pressure, high levels of personal stress, and information fluctuations. Pilot error accounts for over 50% of all aircraft crashes (Kumar and Malik, 2003). Graduating aircraft pilots are required to perform to an impeccable standard of flying during training. Despite this, pilot errors may occur at all times when operating the aircraft including, pre-flight, take off, mid-flight, and landing the aircraft. Pilot errors can include;

(i) Improper flying procedures

(ii) Flying VFR into IFR conditions

(iii) Controlled flight into terrain

(iv) Descending below minima

(v) Premature descent

(vi) Excessive landing speed

(vii) Missed runway

(viii) Fuel starvation

(ix) Navigation errors

(x) Wrong runway take off/landing

(xi) Mid-air collisions caused by the pilot.

A pilot needs to be aware of all these potential errors when flying the Boeing 737-800 in order to have a safe and successful flight. The factors listed above are in the pilots control and a pilot needs to remain aware of these factors. However, there are also factors which are outside the pilots control that they need to monitor and remain aware. Mechanical failure can occur at any time for the pilot, pre-flight, mid-flight, and on landing. Mechanical failures for aircrafts can include

(i) Engine failure;

(ii) Equipment failure;

(iii) Structural failure;

(iv) Design flaws in the aircraft;

(v) Maintenance errors.

Pilots need to use their own judgement in conjunction with feedback from the information systems on board the Boeing 737-800 aircraft to monitor any mechanical issues that may arise. Any one of these mechanical errors can cause catastrophic errors for an aircraft pilot. Weather conditions can also play havoc with the environment in which the aircraft pilot needs to operate in. Weather conditions can alter at any time for the pilot especially when flying over long distances. Changes in weather conditions can affect the pilots operating environment during take-off, mid-flight, and at landing. The pilot needs to contend with many different types of weather conditions such as

(i) Calm weather

(ii) Severe turbulence

(iii) Wind shear

(iv) Mountain wave

(v) Poor visibility

(vi) Heavy rain

(vii) Severe winds

(viii) Icing

(ix) Thunderstorms and lightning strikes.

Pilot error, mechanical failures, and dynamic weather are all factors a pilot needs to contend with if they are to have a successful and safe flight. The pilot needs to remain calm and alert at all times in order to lessen the catastrophic consequences of these errors. The pilot is ultimately responsible for ensuring the safe arrival of all passengers and must remain alert of their operating environment to reduce the probability of error and failures occurring. The next section will review the individual scenarios that the pilot needs to work through on a daily basis.

4.2.1 Pilot Error

Pilot error is the leading cause of aircraft crashes since the 1960s, with over 50% of all crashes due to pilot error. If pilot error occurs in a Boeing 737-800 aircraft this can have catastrophic ramifications for a pilot, often resulting in multiple fatalities or severe injuries to crew and passengers. Pilot error can occur during pre-take off checks, take-off, mid-flight, and landing. As discussed in scenario 1 pilot error can occur from a wide range of factors. As pilot error can have such serious ramifications pilots of a Boeing 737-800 aircraft are expected to maintain a high level of concentration for the duration of their time on board the aircraft. The aircraft pilot needs to be in a position to interact, confer, and take information on board from both the information systems, and air traffic control.

At all times, the pilots were expected to monitor the on-board information systems and interact with air traffic control. The pilots were expected to take on board new information, and/or provide air traffic control with a status update of the aircraft. As the operating environment the pilots operated in was dynamic, the pilots often found interacting with the information system and other humans to be quite difficult and stressful.

Scenario 1 outlines such a case and can be seen in Figure 12. The pilot had adopted a system aided judgement approach prior to this task commencing. However, once the pilot was requested to perform this task, it could be seen that the pilot was visibly nervous throughout the simulation of the landing which began to impact their task performance and decision-making approach. The pilot was visibly sweating and there were audible nerves in the pilots voice when speaking to air traffic control. This was also seen when the pilot was stating what they were doing with the on-board systems to air-traffic control. It was noted that the pilots' voice began to shake when audibly describing their interactions with the information system, such as "lowering landing gear" or "lowering throttle". As this was a simulation, the pilot was extremely nervous about making any errors in front of the course instructor. The increased level of stress resulted in pilot error.

The pilot was advised by air traffic control to amend the on board information system to take a specific angle when approaching the airport for a landing. Due to increased stress levels the pilot changed the angle incorrectly which resulted in the aircraft missing the correct flight path. The pilot was unable to remain calm and interpret information being provided to them correctly. The pilot who had previously been using a combination of their own judgement and the on-board data provided by the information system but had now shifted to relying exclusively on the data provided by the information system as shown in Figure 12. Due to the stress of the scenario, the pilot was unable to interpret the information being provided to them by air traffic control. The increase in stress levels altered the decision-making approach of the pilot who was unable to rely on their own decision making ability and began to solely rely on the information system as can be seen in Figure 12. A potential reason for the increase in stress levels was the inexperience of the pilot in performing this task who was visibly nervous throughout. Another potential factor is the pilot was being graded by an instructor for the duration of the task in an exam like setting. The potential of a personal negative outcome for the pilot as a result of failing the task may have increased stress levels and altered the decision-making approach.

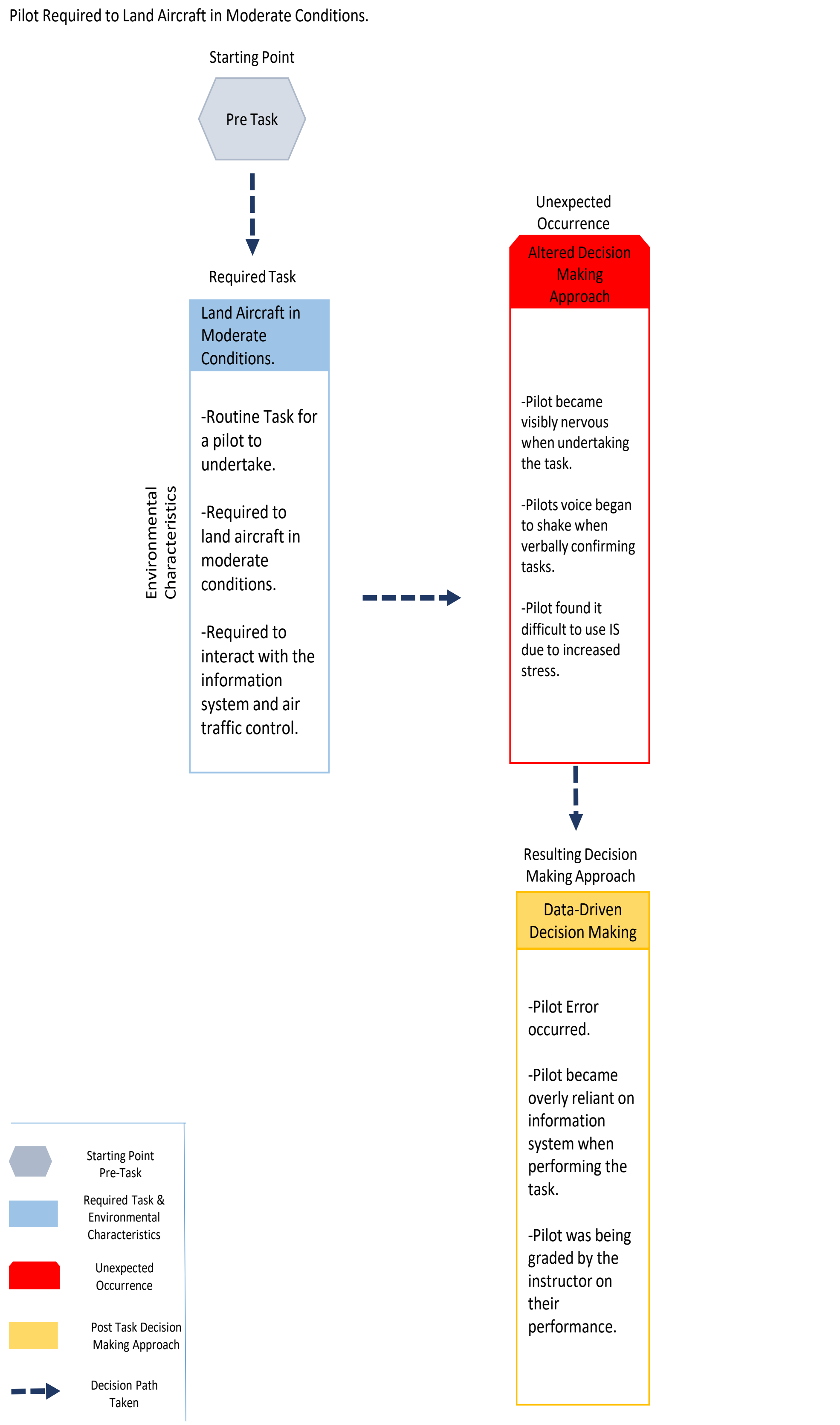

Figure 12. Landing scenario – system aided judgement to data driven decision making.

Scenario 7 (see Figure 13) further highlighted the difficulty the aircraft pilot had in interacting with air traffic control and utilising the on board information systems in tandem. Figure 13 is similar to Figure 12 in that the pilot was required to perform this task in front of a pilot instructor who was grading the pilots performance of the task. This exam like setting increased the stress that the pilot was under. The pilot began to find the interactions with air traffic control difficult to conduct whilst also utilising the information systems on board the Boeing 737-800. During the task, the pilot was asked for a specific reading on the angle they would be taking on approach by ATC. The pilot was not expecting this question and visibly became nervous, finding it difficult to give the correct response to the question in a timely manner. The increase in stress for the pilot can be seen in Figure 13. As the pilot was focusing on landing the aircraft the pilot found it difficult to interact with the system, compute the answer, and verbally respond to air traffic control. The pilot was highly focused on the information system and taking the correct flight path for landing the aircraft. An incorrect drop in altitude, incorrect speed, or flight angle would have resulted in pilot error which the pilot was desperate to avoid as the pilot was being graded by their flight instructor. The pilot was now fixated on the information system and had moved towards a data driven decision-making approach as can be seen in Figure 13. This shift in decision making from the pilot being able to use their own judgement and the data from the information system to becoming overly focused on the information system would lead to a pilot error occurring.

The navigational information system became the dominant cue for the pilot and the pilot found it difficult to give attention to the peripheral cues such as advice from air traffic control. Due to the pilot being unable to interact with air traffic control correctly the pilot was unable to land the aircraft. The pilot had to attempt a go-round whereby the pilot would attempt to land the aircraft again. This resulted in the pilot receiving a negative grade from their flight instructor.

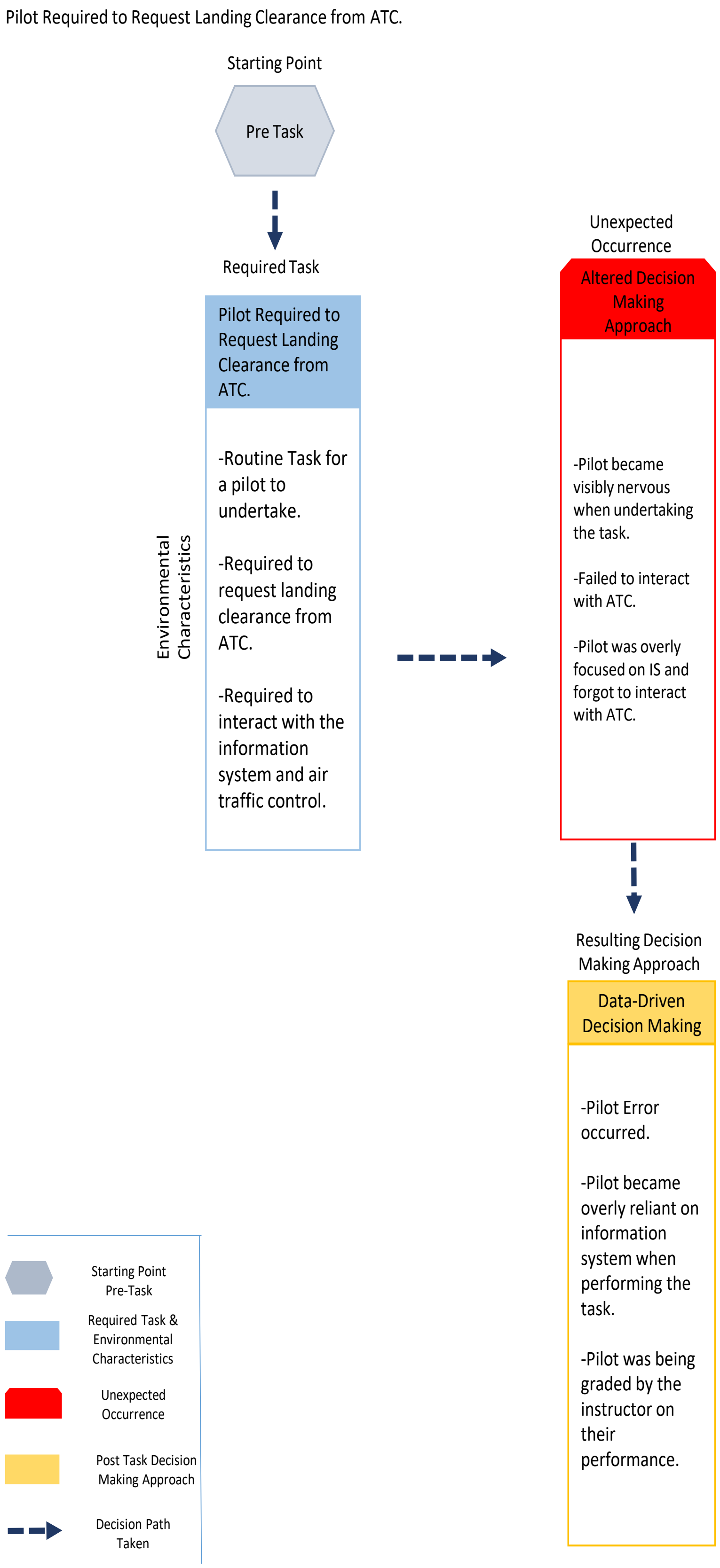

Figure 13. Landing Scenario – system aided judgement to data driven decision making.

The pilot who was now visibly stressed and focused solely on the navigational information systems of the aircraft failed to instruct air traffic control of the failed landing attempt and subsequent go-round. The failure to inform air traffic control of this resulted in further pilot-error occurring and further negative marks from the flight instructor. The altering of the pilots decision-making approach when attempting to land the aircraft resulted in the pilot becoming overly focused on the information system. This resulted in a shift away from using a combination of both the pilots intuition and the information system which was detrimental to task performance. This sift ultimately resulted in a serious pilot error occurring as shown in Figure 13. Another potential factor is the pilot was being graded by an instructor for the duration of the task in an exam like setting. The potential of a personal negative outcome for the pilot as a result of failing the task may have increased stress levels and altered the decision-making approach. The pilot is aware that that the flight instructor is observing their behaviour and looking to find any potential errors in their task performance.

This section has highlighted how errors created by the pilot can have serious negative consequences to the safety of the flight. The next section will review data collected involving mechanical errors which can have catastrophic consequences for a pilot.

4.2.2 Mechanical Error

Aircraft mechanical errors can have catastrophic consequences for an aircraft pilot. These consequences can result in serious injuries and/or fatalities even when the situation is managed correctly. Mechanical errors bring about extreme levels of time pressure, stress, and reductions in information levels for an aircraft pilot. Mechanical failure can occur at any time for the pilot, pre-flight, mid-flight, and on landing. Mechanical failures for aircrafts can include engine failure, equipment failure, structural failure, design flaws in the aircraft, and a maintenance error. These mechanical errors are normally outside of the aircraft pilots control. The pilot needs to be continuously aware and monitor feedback from the on-board information systems to ensure everything is proceeding as normal.

A mechanical error can occur at any time when the pilot is operating the aircraft. This can occur at pre-take off, take-off, mid-flight, and landing of the aircraft. Aircraft pilots train extensively to cover a wide range of mechanical errors which may affect them during a flight and a training exercise involving mechanical failure was observed when conducting observation for this study. During the simulation of a mechanical failure the pilot was being observed and graded by a qualified flight instructor.

The pilot was flying in conditions of extreme fog with visibility for the pilot very low as can be seen in Figure 14. The pilot required the use of navigational information systems and moderate assistance from air traffic control to keep the aircraft on the correct navigational path. During this period the pilot was heavily dependent on using a data driven decision-making approach. The pilot would rely solely on the navigational information system and weather information system. Both of these systems were producing up to date and rapid levels of real time data to assist with flying the aircraft safely. Despite the difficult weather conditions, the pilot felt comfortable flying the aircraft with the aid of the information system feedback. Whilst in mid-flight, a warning signal from the information system began to display. The warning signal is visually displayed on the information system Graphical User Interface (GUI) by a flashing red light. There is also a loud warning signal emitting from the information system to indicate that an error is occurring with the aircraft. The emitting warning signal indicated that the aircraft had lost power from both engines of the aircraft. The pilots' sole focus was on attempting to stabilise the aircraft and finding a safe location to land the aircraft.

When the warning signal began to sound, the pilot became more constricted in their decision-making approach. The pilot was no longer concerned about using data from the weather information system on board. The pilot had previously been interacting, interpreting, and working closely with numerous on-board information systems, and using this as the basis to fly the aircraft.

Mechanical Failure in Poor Conditions.

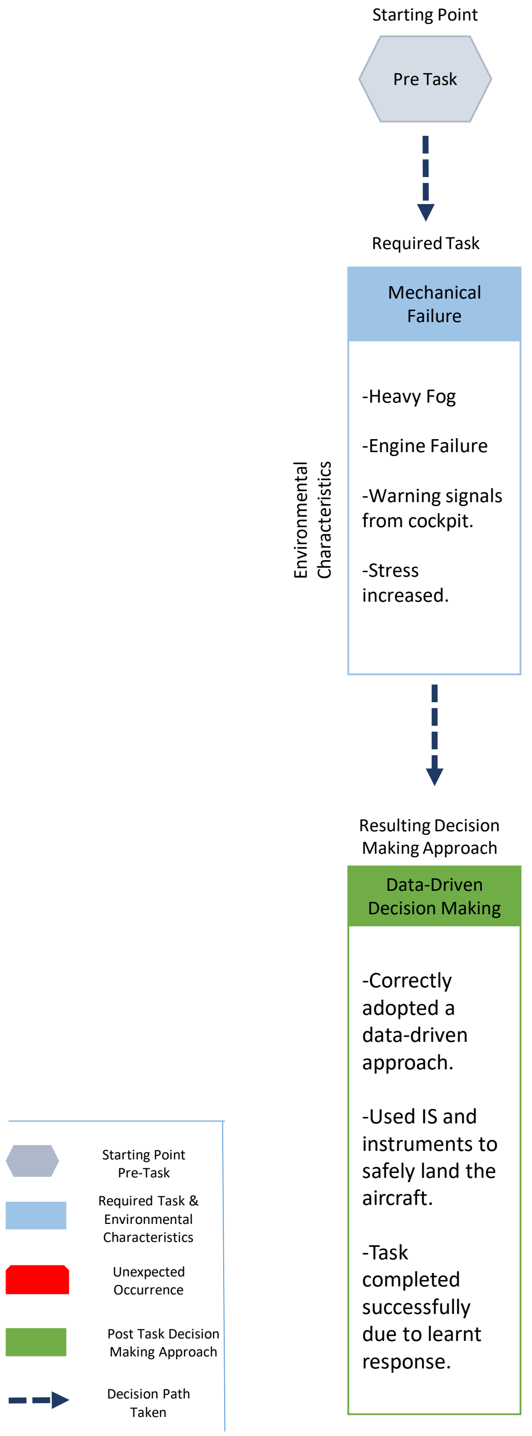

Figure 14. Mechanical Failure - System Aided Judgement to Data Driven

The pilot had previous experience of dealing with this life threating scenario and thus, had a well-learned response to this scenario. The pilot knew which information systems to interact with, how to channel their attention, and pieces of information to focus on. As the pilot was utilising the correct information system for this particular scenario, it allowed them to safely land the aircraft. This avoided catastrophic consequences for the pilot and the aircraft. This section has reviewed mechanical failure and its effects on aircraft pilots. It was found that errors such as mechanical failures occur outside of the pilots control. It was found that mechanical errors mid-air, such as engine failure present the pilots with life threatening situations, which results in heightened stress levels, time pressure, and information fluctuations. Changes in the operating environment will cause the pilots decision-making approach to alter.

The next section will look at data collected surrounding how weather conditions can affect the operating environment of an aircraft pilot.

4.2.3 Dynamic Weather

Weather conditions are dynamic and can vary greatly over a medium to long distance when flying a Boeing 737-800 aircraft. Weather conditions affect aircraft pilots at all times including pre-flight, take-off, mid-flight, and landing the aircraft. The pilot can avail of weather information through a number of means such as updates provided by air traffic control and updates provided by the internal information systems of the aircraft or using their own vision. The pilot needs to interpret this information and take a successful course of action in order for the aircraft to arrive at its destination safely. The literature review argued that if the aircraft pilot is able to align their decision-making approach with the scenario characteristics presented by the dynamic weather conditions pilots task performance should be improved. This section will review observations on the effects of weather conditions on the pilots decision-making approach.

The weather the aircraft pilots needed to contend with was extremely volatile. It was seen that weather conditions would change rapidly, often changing from mild conditions to more extreme conditions such as, fog, wind shear, rain, and turbulence. The pilot needs to remain continuously aware of the information system feedback relating to weather conditions as weather conditions can have catastrophic impact on the safety of an aircraft. In conditions of mild weather, the pilot was relaxed, calm and composed. The pilot felt comfortable and at ease interacting with air traffic control, the co-pilot, and the on board information system of the aircraft. The pilot was able to give clear and concise instructions to both air traffic control and the co-pilot during mild weather conditions. During mild conditions, the pilot was able to rely on both their own judgement and the information system when making a decision. The pilot would often receive requests for a status update or on which flight path the aircraft was adopting from air traffic control. Once this request was received, the pilot using a combination of their own judgement and the information system would need to interact with the information system, interpret the data, and relay this information to air traffic control. The pilot was generally at ease preforming this task during mild flying conditions and displayed no visible or audible signs of stress or nervousness.

It was found that as weather conditions began to shift the pilot's decision-making approach would also shift. As changing weather conditions are a factor that are outside the pilots control the pilot needs to remain alert of changing weather patterns at all times. The pilot needs to rely on information from air traffic control, the information system on board the aircraft, and using their own visibility of the situation. Severe weather conditions are a serious issue that an aircraft pilot needs to contend with and can have catastrophic consequences for all on board an aircraft.

High levels of adverse weather were observed during mid-flight simulations with the pilots. Adverse weather conditions would normally arise suddenly for the pilot and this caused a visible increase in stress for the pilot. When adverse weather conditions such as extreme fog or turbulence were introduced the pilot would become visible nervous. The pilot would be more hesitant when interacting with the information system and in some cases be visible sweating. The pilot was also audibly nervous when interacting air traffic control. The pilots voice wouldn't sound as confident when interacting with air traffic control during severe weather conditions. During scenarios of adverse weather, such as a high level of turbulence, warning signals would sound and the aircraft simulator would shake which would increase the stress levels the pilot was subjected to. These adverse weather conditions were found to alter the decision-making approach of the pilot. A number of observed instances were recorded of the pilot altering their decision-making approach towards adopting a data driven approach. During simulations of the dynamic weather patterns the pilots would have their performance graded by a flight instructor. The flight instructor would look to grade the pilots on their performance whilst under conditions of increased stress.

Figure 15, which relates to scenario 6, shows the changes in a pilots' decision-making approach as more severe weather conditions are introduced. The pilot had been adopting a system aided judgement approach when flying the aircraft in mild weather conditions. However, this judgement would change as an extreme level of fog was introduced to the simulation. During a scenario of extreme fog, it was observed that the pilot began to monitor their instruments too closely, and as a result, stopped communication with air traffic control. The pilot would become more stressed becoming audibly and visibly nervous. As this shift in decision-making approach occurred during the final descent it resulted in pilot error. The adverse weather conditions resulted in pilot error as the pilot did not remain in contact with air traffic control and became overly fixated on the information system. This change in decision-making approach can be seen in Figure 15. By adopting the incorrect decision-making approach and becoming overly fixated on the information system the pilot took an incorrect flight path on the final approach and was unable to land the aircraft. The pilots decision-making approach began to shift towards a data driven decision-making approach as the operating environment altered around them due to the dynamic weather conditions as seen in Figure 15.

Due to the pilot, adopting an incorrect decision-making approach for the task and subsequently veering the aircraft off course, the flight instructor who was observing the simulation failed the student for this task. The causation for the shift in decision-making approach was observed to be the heightened stress the pilot was placed under due to adverse weather. This resulted in the pilot becoming fixated on the information system. Potentially the personal negative consequences of being observed and graded by a flight instructor may have also altered the pilots' decision-making approach when performing this task.

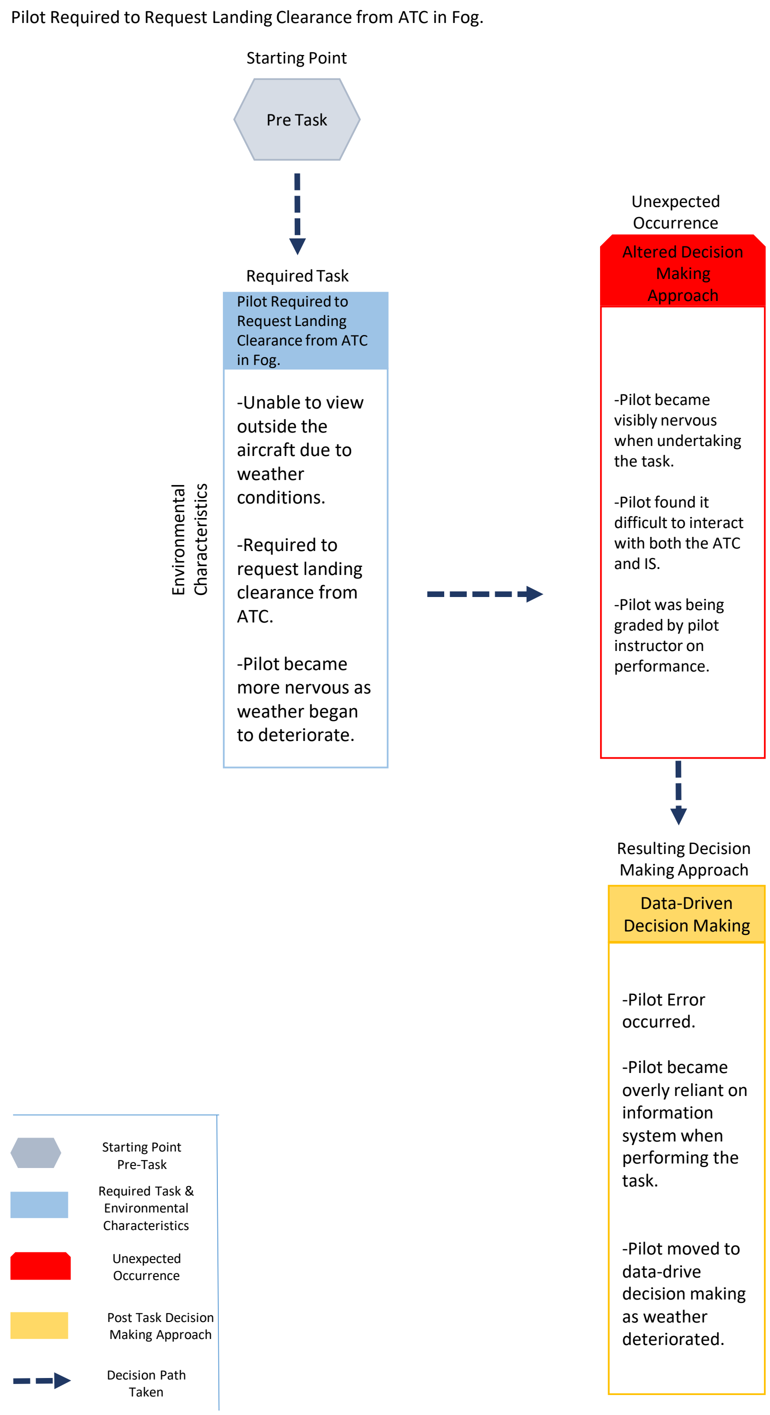

Figure 15. Heavy Fog – System Aided Judgement to Data Driven Decision Making.

A further example of the weather conditions affecting a pilot was seen in scenario 2 and shown in Figure 16. The increased turbulence resulted in the pilot becoming overly focused on their information system. The pilot no longer communicated with air traffic control which resulted in a pilot error occurring. The flight instructor who was observing the pilot made note of this error and failed the pilot on his performance for this task. It must also be noted that the pilot may have been potentially experiencing an increase in pressure from being observed and graded by the flight instructor which may have altered their decision-making approach.

This section has reviewed the effects of weather conditions on a pilots' decision-making approach. It was found that the weather conditions a pilot operates under are not static but rather dynamic. These dynamic weather patterns can often be unpredictable and can range from ideal flying conditions to severe weather conditions which may be dangerous to fly in. In both of the observed scenarios discussed in this section pilot error occurred as a direct consequence of the incorrect decision-making approach being taken for the task. The next section will discuss information fluctuations and review its influence on the decision-making approach being adopted by aircraft pilots.

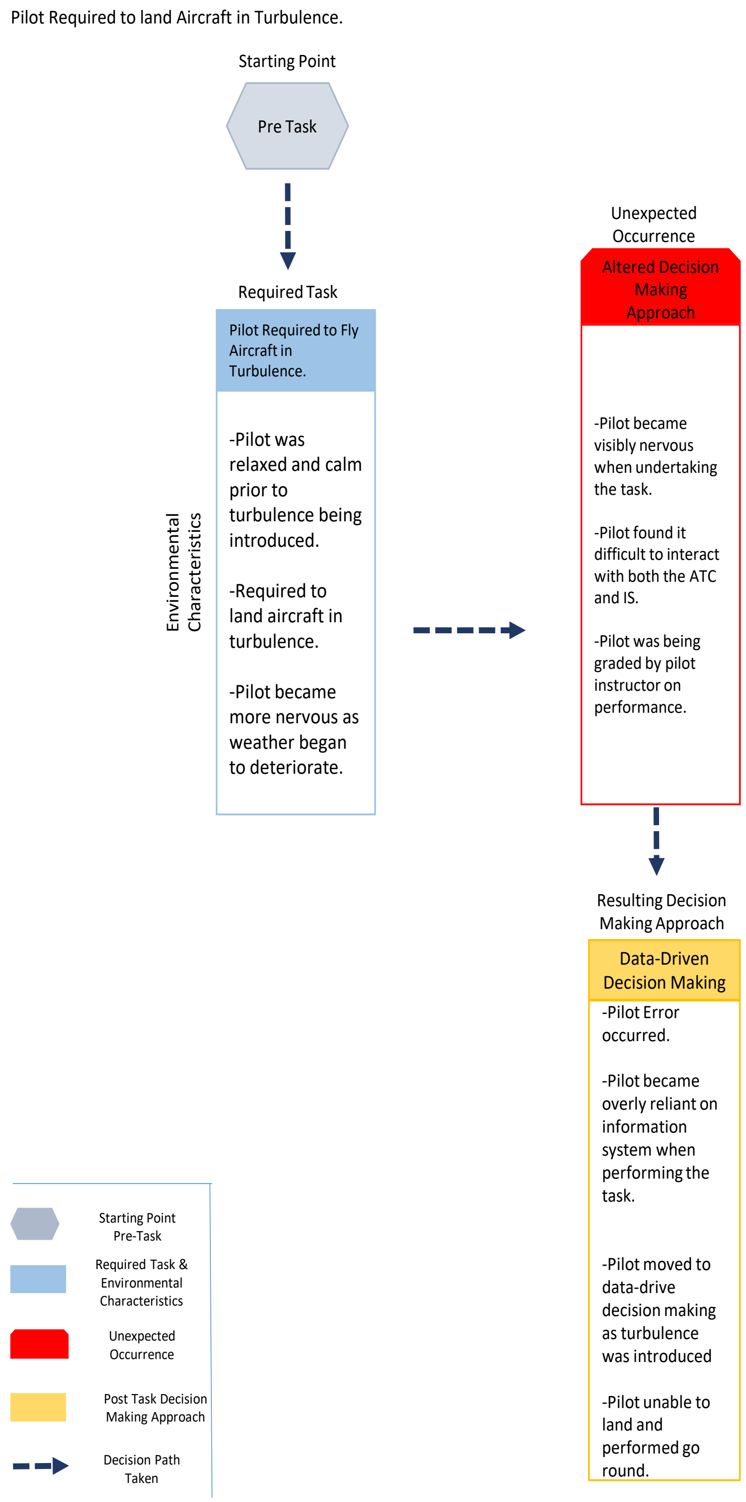

Figure 16. High Turbulence when landing the aircraft.

4.2.4 Information Challenges

Information flow was continuous and rapid during pre-flight, take off, flight, pre landing, and landing for the pilot. From an information systems perspective, the pilots need to take information on board from 31 different information systems. These information systems were made of 24 which were pictorial (using dials as a display), six which were numeric (the pilot would need to interpret the data), and one display which was a combination of both pictorial and numeric data. These systems range in usage from navigation systems, to weather systems, and include systems to monitor the safety of the aircraft. The large number of information systems and different display methods resulted in the pilot needing to be continuously alert. The pilot would also need to interpret and act on verbal information being provided to them by air traffic control.

The pilot would normally rely on a combination of both their judgement and the information systems for their decision-making approach on the aircraft. This was certainly the case when flying under mild/normal conditions for the pilot. The pilot felt comfortable and at ease performing tasks under these conditions. The pilot had the correct amount of information available to them in these conditions from both the information system and air traffic control. It was observed that the pilot was able to give clear and concise instructions to both air traffic control and the co-pilot when the pilot was flying in fair weather conditions. In moderate conditions the pilot was able to interpret information from air traffic control and amend information setup based on this. Air traffic control would provide the pilot with information regarding navigational coordinates, weather conditions, and landing information. The pilot needs to remain calm and correctly interpret the information that is being provided to them. The opposite scenario would also occur when the pilot was requested by air traffic control for specific status updates. These updates referred to current flight path and the pilot felt quite comfortable giving these updates. It was noted that the pilot was able to give clear instructions to both air traffic control when instructed to. Once the request was received, the pilot was able to use a combination of their own judgement and the information system to interpret the data and relay the information back to air traffic control. No pilot errors were recorded when conducting these tasks in moderate conditions.

As the operating environment would shift so too would the levels of information being provided to the pilot. The pilot would experience a flux in information levels. Adverse weather conditions would arise intermittently during the simulation and the pilot would be expected to successfully navigate this. When weather conditions such as a high level of fog were introduced the pilot would become visible nervous. The pilot would become more hesitant when interacting with the information system and would be visibly sweating. The pilot was also audibly nervous when interacting with air traffic control. During these conditions the pilots' visibility would be lowered. The pilot would become more reliant on the information system and air traffic control to assist with navigation. It is of critical importance for the pilot to be comfortable with both. The pilot is expected to keep the flight stable whilst also working with air traffic control and interacting with the numerous information systems on board.

In these weather conditions the pilot was no longer comfortable interacting with both the information system and air traffic control. Changes in information levels as a result of the environmental change, resulted in the pilot searching for more information. This drew the pilot's attention to the navigational information system. The information system became the dominant information cue for the pilot. Perceived peripheral cues such as air traffic control were filtered out. The pilot was drawn to the information system, as this provided the most amount of information on navigational matters. The pilots' decision-making approach had now switched to relying solely on a data-driven decision-making approach. The pilot was now at the final approach stage of the journey and was receiving landing information from air traffic control. The pilot was expected to receive information from air traffic control, interpret this, and amend the information system accordingly. The pilot was now over reliant on the information system and the pilot did not remain in contact with air traffic control. This resulted in a pilot error as the aircraft veered off its correct flight trajectory. The pilot took an incorrect flight path on the final approach and was unable to land the aircraft. The correct approach would have been for the pilot to use a combination of their own judgement and the information system, rather than switching to a purely data driven decision-making approach.

The findings presented in this section support the argument that information fluctuations impact the operating environment of an aircraft pilot. This can often be detrimental to a pilot's job performance and alter their decision-making approach. The next section will review the pilots' decision-making approach from a time pressure perspective.

4.2.5 Time Pressure

The findings presented in the previous sections have shown how pilots operate in a dynamic environment with contributing factors such as pilot error, mechanical error, and weather errors. The dynamic environment can result in pilots needing to be aware of several factors that are in and outside their control .

The literature review concluded that time pressure has been shown to reduce the quality of decisions made, reduce propensity to take risks, and increase the stress that an individual is under. This study has shown that pilots need to operate with different parties such as air traffic control, their co-pilots, relaying information to them, as well as, taking on feedback and making decisions. The pilots also need to operate, monitor, and interpret the 31 different information systems on board the Boeing 737-800 aircraft. The pilot is ultimately responsible for ensuring the safe arrival of all passengers and as such must remain alert of their operating environment to reduce the probability of error and failures occurring. The following sections will show that aircraft pilots need to contend with scenarios of high time pressure and failure to do so can result in errors occurring which can have consequences for both the pilot and passengers.

Time pressure is generally at a moderate level for the pilot at all times, including pre-flight, take-off, mid-flight, and landing of the aircraft. Whilst time pressure was at a moderate level the pilot felt comfortable and at ease preforming the tasks they were required to conduct. These tasks included interacting with air traffic control, the co-pilot, and interacting with the on-board information system of the aircraft. It was observed that the pilot was able to give clear and concise instructions to both air traffic control and the co-pilot during conditions of moderate time pressure. The pilot when operating under moderate time pressure was also able to interpret information from air traffic control and amend the setup of the information system based on this. This was a critical process as air traffic control can provide vital data surrounding navigational coordinates and landing information. The pilots need to be in a position to remain calm and correctly interpret the information that is being provided to them. During moderate time pressure conditions, the pilot was able to rely on both their own judgement and the information system when making a decision. This was observed when weather conditions were mild which resulted in decreasing stress levels for the pilots.

This allowed the pilot additional time to review key instruments before take-off, mid-flight and, landing. During these conditions the pilot was also very comfortable interacting air traffic control. A pilot will often receive requests for a status update or on the flight path from air traffic control. Once the request was received the pilot was able to use a combination of their own judgement and the information system to interpret data. This information was then relayed back to air traffic control. At a moderate level of time pressure the pilot was generally at ease preforming these tasks and displayed no visible or audible signs of stress. The pilot also committed no pilot errors whilst conducting these processes at moderate levels of time pressure.

As the operating environment would shift so too would the time pressure on the pilot. The increase in time pressure would also alter the decision-making approach of the pilots.

In scenario 3 as shown in Figure 17, the pilot was forced to react when the plane had engine failure. This is considered a life threatening occurrence for all on-board the aircraft. The pilot is under extreme levels of time pressure to find a solution and to attempt to resolve the issue. Once the warning signal began the pilot began to become visibly and audibly stressed. There was a nervousness in their voice when interacting with their co-pilot and air traffic control. The pilot also didn’t seem as confident in their actions when attempting to stabilise the aircraft. The increase in time pressure caused by the life threatening scenario resulted in the pilot's attention being focused on the dominant cue, the altitude system. The pilot sough to use the system to stabilise the aircraft. The pilot was no longer concerned with peripheral information and this was filtered out. The pilot's sole focus was on attempting to stabilise the aircraft and finding a safe location to land the aircraft. Prior to the warning signal sounding the pilot had been flying the aircraft at low altitude which left little room for error for the pilot when attempting to stabilise the aircraft.

The time pressure the pilot was now under and the need to find a solution immediately resulted in the pilot becoming more constricted in their decision-making approach. The pilot no longer looked to interact with most information systems on board the aircraft and began to restrict themselves to monitoring the flight stabiliser and altitude system of the aircraft. The pilot was focused on these dominant cues and peripheral cues began to be filtered out. The pilot who had previously been working with weather systems ignored these systems immediately. The pilot had a well-learned response to this scenario and knew which information systems to interact with. As the pilot was utilising the correct information system for this particular scenario it allowed them to safely land the aircraft. This avoided catastrophic consequences for the pilot and the aircraft.

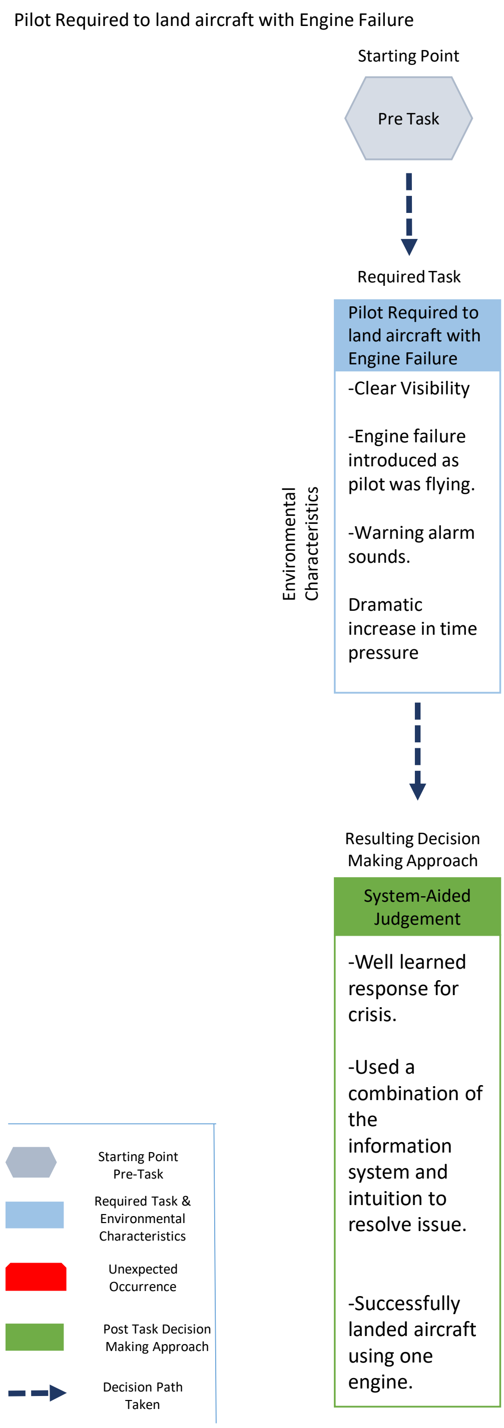

Figure 17. Time pressure – No Shift due to well learned response.

Time pressure was also observed in situations that were under the pilots own control and not as a result of external factors such as mechanical failure or weather conditions. Scenario 7 were the pilot is required to request landing clearance from air traffic control was an example of this and is shown in Figure 18. The pilot was under time pressure to ensure that the information systems were setup correctly and that the information being provided to them by air traffic control would be implemented. The pilot was asked for a specific reading by air traffic control on the angle they would be adopting for the approach. The pilot was not expecting this question and due to the time pressure in needing to give a response, found it difficult to interact with the system, compute the answer, and verbally respond to air traffic control. The time pressure of attempting to ensure the systems were correct to land the aircraft resulted in the pilot adopting a data driven decision-making approach.

The pilot was highly focused on the information system and taking the correct flight path for landing the aircraft. An incorrect drop in altitude, incorrect speed, or flight angle would have resulted in the aircraft veering off course. The navigational information system became the dominant cue for the pilot and the pilot found it difficult to give attention to for what they perceived as peripheral cues. The pilot had adopted an incorrect decision-making approach due to the time pressure created by needing to land the aircraft. The correct course of action was for the pilot to use their own judgement to interact with air traffic control and also interact with the information system. Due to the pilot adopting the incorrect decision-making approach (a data-driven approach) the pilot was unable to land the aircraft correctly. The pilot had to attempt a go-round and attempt the aircraft again. This constituted a pilot error due to time pressure.

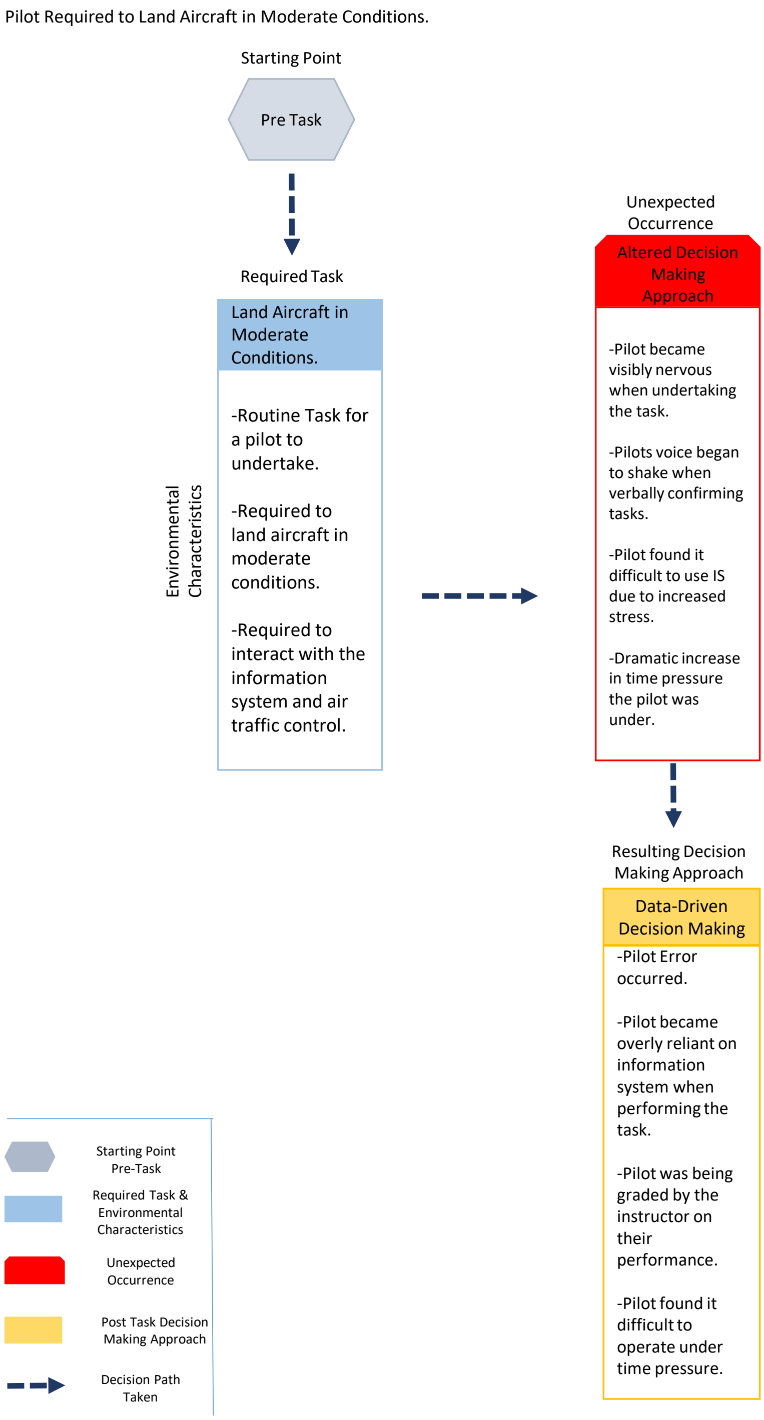

Figure 18. Landing Scenario – System Aided Judgement to Data Driven Decision Making.

This section has reviewed the effects of time pressure on a pilot's decision-making approach. Time pressure was viewed as being both an external factor outside of the pilots control but also brought about due to the incorrect decision-making approach being used by the pilot. Pilot errors were observed and recorded due to time pressure being applied to the pilot which can lead to life threatening scenarios if not managed correctly. The altering of the decision-making approach by a pilot due to time pressure can have serious ramifications for performance. The next section will review data observed regarding task familiarity.

4.3 Task Familiarity

The previous section identified that aircraft pilots operate in a highly dynamic environment. It was found that factors such as the operating environment, information fluctuations, and time pressure were all contributing factors which altered the environment the pilots operate in. The dynamism of the environment leads to an increase in uncertainty and ambiguity that the pilots need to face. These operating environments have been shown to be unexpected, constantly changing, and difficult to analyse. The literature review concluded that when the decision-making approach used is aligned with the task characteristics of the scenario decision making performance can be improved. Task characteristics can be viewed and deconstructed to task non-routineness and task interdependency. The following sections will present the findings from data collected in relation to task non-routineness, and task interdependency

4.3.1 Task Non-Routineness

The literature review identified that task non routineness is comprised of task variety and task difficulty. Task variety is the frequency of unexpected and novel events that occur when preforming a task. Task difficulty refers to the way individuals respond to problems that arise and refers to the degree to which a decision maker lacks a formal, well – defined search procedure to solve a given problem. This section will review data collected surrounding the pilots' decision-making approach from a task non routineness perspective. The previous section outlined the dynamic environment that aircraft pilots operate in. The dynamic environment was characterised by various changes in the operating environment with pilot error, mechanical error, and the weather conditions all having the potential to alter the environment the pilot operates in.

Task variety can be considered low or high for a decision maker. Low task variety infers that decision makers will have less uncertainty about the task at hand or future activities. High task variety infers that a decision maker will find it increasingly difficult to predict problems and future activities arising. Both low and high task variety were observed during the data collected with aircraft pilots.

In scenarios when a high level of task variety is occurring the decision maker will find it increasingly difficult to predict problems and future activities before they arise. This can lead to the decision maker becoming more reactive rather than proactive which can have serious consequences when flying a Boeing 737-800 aircraft. The previous section identified that aircraft pilots operate in a highly dynamic environment. Highly dynamic environments often lead to situations of high task variety occurring. High task variety were observed in situations which are outside the pilot's control which are difficult to predict and difficult to react to. An example of such a scenario was identified in scenario 3 and shown in Figure 19.

The pilot was operating the aircraft in conditions of extreme fog and with visibility for the pilot very low. The pilot required the use of navigational information systems and assistance from air traffic control to keep the aircraft flying on the correct navigational path. The pilot was utilising a combination of their own judgement and the use of the information system as the decision-making approach for flying the aircraft. Although the weather conditions were not favourable the pilot was comfortable and relaxed. The pilot had considerable previous experience of flying the aircraft in these conditions and was able to utilise the information being provided to them by air traffic control and the information system. When in mid-flight a warning signal began to sound from the information system. The warning signal is displayed on the information system GUI by a flashing red light. There is also a loud warning signal to indicate that there is a severe error occurring with the aircraft. The warning signal was to indicate that the pilot had lost power from both engines of the aircraft. The pilot now had become stressed and there was a nervousness when interacting verbally with air traffic control to inform them of the situation. The task variety the pilot was now experiencing was very high, with a high degree of uncertainty surrounding the task. The high degree of task uncertainty and task difficulty drew the pilot's attention to the information system. The pilot's attention was now being focused on the dominant cue, which was the altitude system, and attempting to utilise the information system to land the aircraft safely.

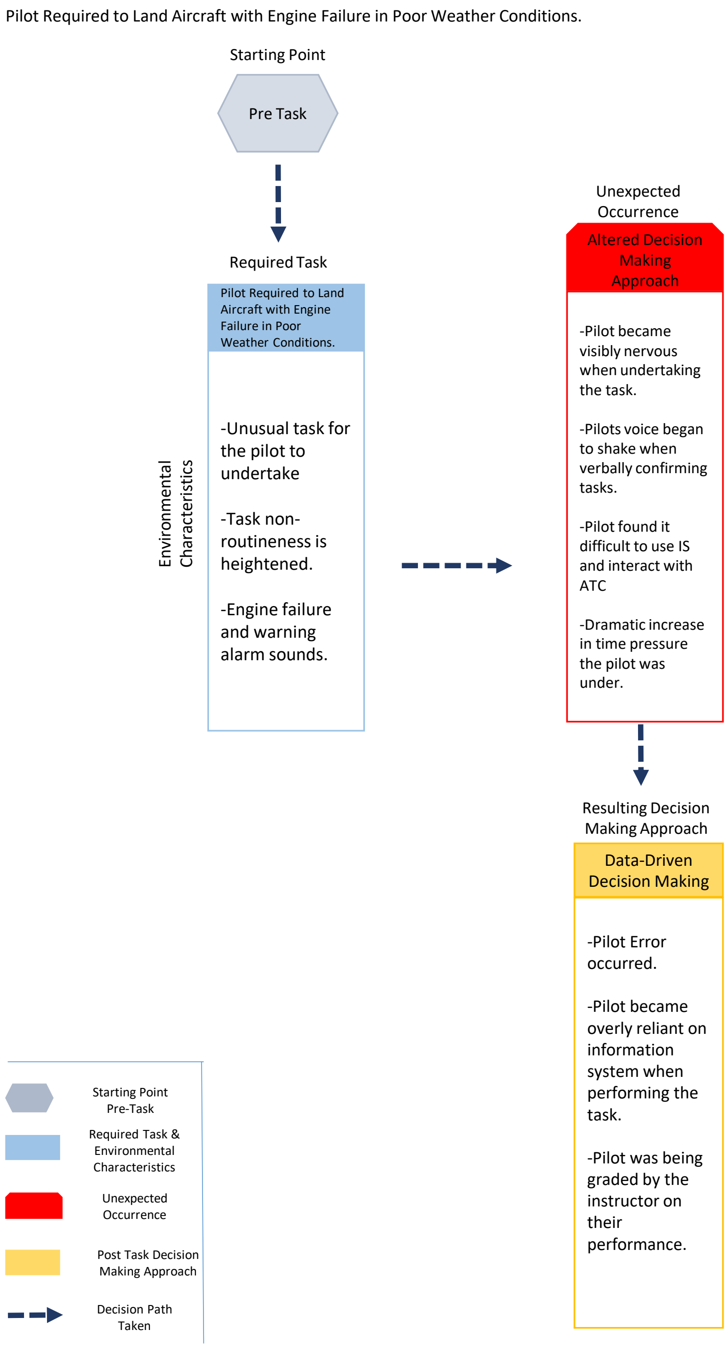

Figure 19. Task Non-Routineness – System Aided Judgement to Data Driven Decision Making.

The pilot had previously adopted a combination of their own judgement and the information system when flying the aircraft. As task uncertainty and difficulty increased due to the dynamism of the environment the pilot shifted towards a data driven decision-making approach.

The pilot became more constricted in their decision-making approach. The pilot no longer interacted with most of the information systems on board and began to restrict themselves to monitoring the altitude system of the aircraft. The pilot shifted their decision-making approach to becoming more reliant on the information system. The rate of descent that was occurring was now so great that the altitude system was giving incorrect readings. The pilot using this data believed they had more time available to them to stabilise the aircraft however this was not the case. This scenario shows that mechanical failure of an aircraft will heighten levels of task variety and task difficulty that a pilot faces. Due to the heightened levels of task variety and task difficulty the pilots decision-making approach altered. The pilot had previously been using a combination of their judgement and the information system. This altered as the environment increased the task variety and task difficult the pilot faced. This resulted in the pilot adopting a data driven decision-making approach which would ultimately lead to the aircraft crashing.

Scenario 5 shown in Figure 20 outlines the pilot flying in turbulence and is a further example of task non-routineness being heighted for the pilot. As a turbulence increased the task variety and task difficulty also increased for the pilot.

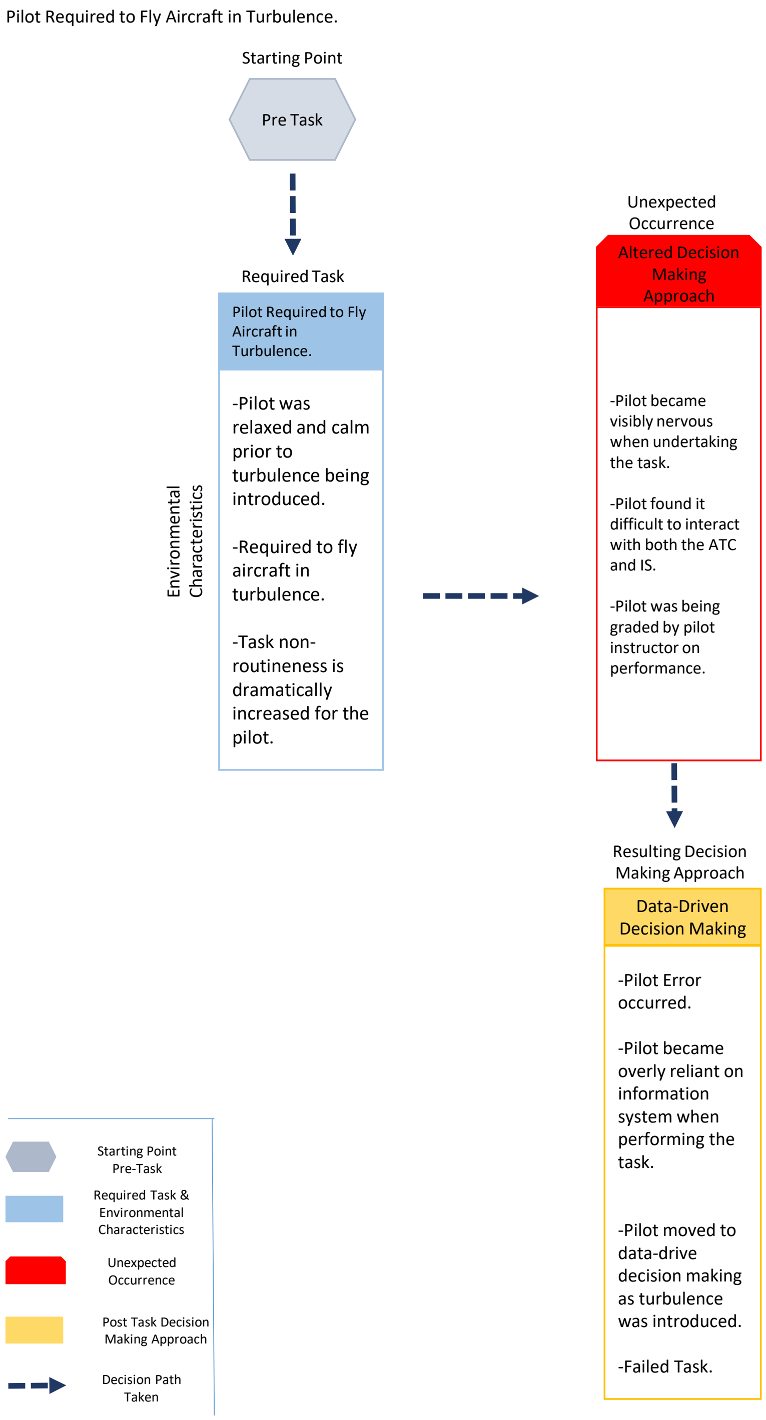

Figure 20. Task Non-Routineness – System Aided Judgment to Data Driven Decision Making

The pilots decision-making approach began to shift from using a combination of their judgement and the information system towards a data driven approach. The pilot was now focused on the information system and using the various on board systems to guide the aircraft. Due to the pilot becoming overly focused on their information system the pilot stopped communicating with air traffic control. The increase in task variety and task difficulty as a result of the environmental shift resulted in a pilot error occurring.

This section has reviewed data collected from a high task variety and high task difficulty perspective. It was found that environmental shifts such as mechanical failure or weather changes can create scenarios of higher task non-routineness. In such scenarios the decision maker has no formulated plan they can call upon. This can result in a pilot experiencing a high level of task variety and task difficulty which will shift their decision-making approach. If the decision-making approach adopted by the aircraft pilot is not suitable for the task they are currently performing a decrease in job performance can occur. This can have catastrophic consequences for an aircraft pilot.

4.3.2 Task Interdependence

The literature review showed that as environmental uncertainty increases interdependent tasks become more important due to the increased need for coordination to resolve ambiguity. This section will review data collected from a task interdependence perspective.

Interdependence is required between the aircraft pilot and air traffic control at all times whilst the aircraft is operational. This includes pre-flight, take-off, mid-flight, final approach, and landing of the aircraft. During these times, the pilot is expected to interact with air traffic control, interpret information being relayed to the pilot, and amend the on board information systems accordingly. The air traffic control is expected to be in a position to give or take information from the aircraft pilot throughout the duration of the flight. Numerous interactions between the pilot and air traffic control were observed during the pilots simulation of the Boeing 737-800 aircraft. Whilst in mid-flight during conditions of mild weather, the pilot was relaxed, calm and composed. The pilot felt comfortable and at ease interacting with air traffic control and the on-board information system of the aircraft. It was noted that the pilot was able to give clear and concise instructions to air traffic control during mild weather conditions. During these conditions the pilot was able to rely on both their own judgement and the information system when making a decision. The pilot would often receive requests for a status update or the flight path from air traffic control. Once this request was received, the pilot was able to use a combination of their own judgement and the information system to process the request. The pilot would interact with the information system, interpret the data, and relay this information to air traffic control.

Although a high level of interdependence is mandatory between an aircraft pilot and air traffic control this relationship can break down. Scenario 5 shown in Figure 21 is an example of the pilot being required to have a high level of task interdependence whilst under increased stress. During a scenario of increased turbulence, the pilot became visibly nervous and stressed. The stress was observed in the pilots' body language, speech, and interactions. The pilot was required to keep the flight stable and interact with air traffic control as the flight was approaching its' landing.

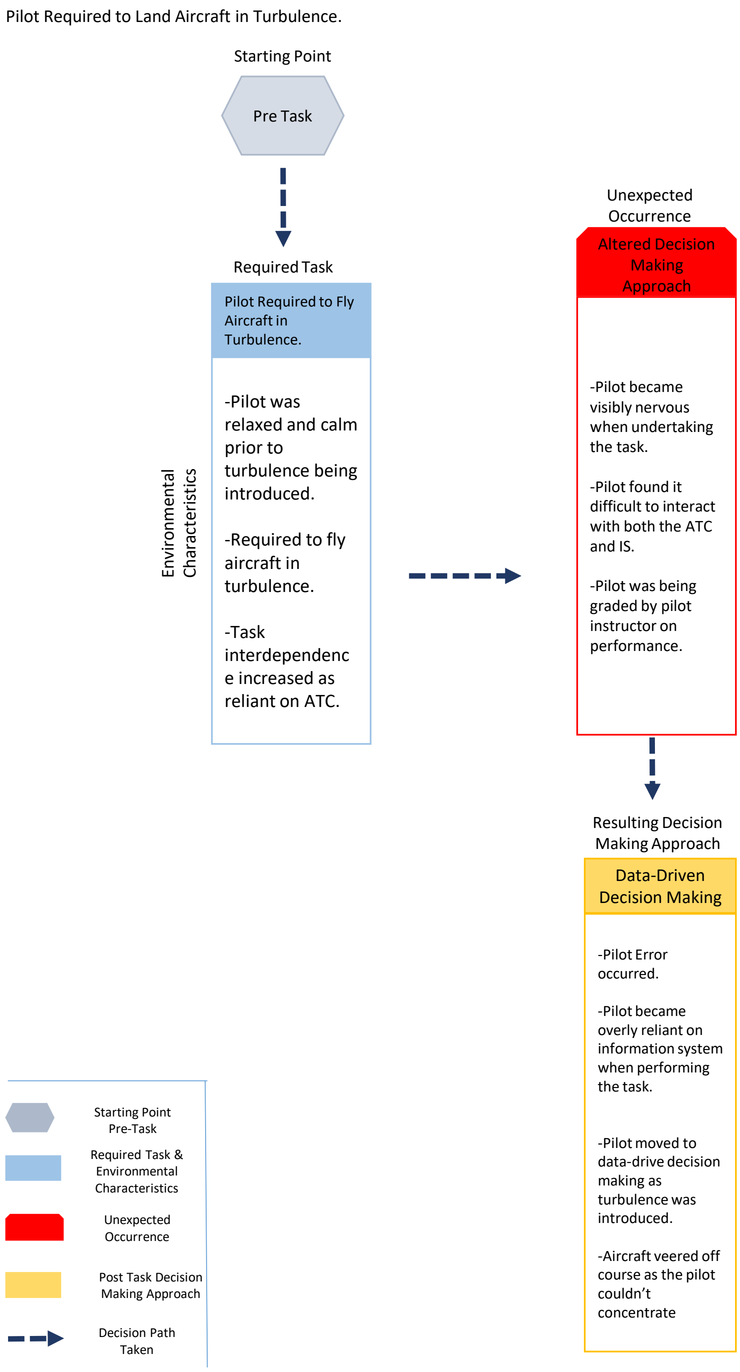

Figure 21. Time pressure – System Aided Judgement to Data Driven Decision Making.

The pilot found the interdependence between them and the air traffic control difficult and began to focus solely on the information system. The pilot who was now overly focused on the information system began to misinterpret the information being provided to them by air traffic control. The pilot was expected to receive information from air traffic control, interpret this, and amend the information system on board. Due to the shift in the pilots decision-making approach to focus solely on the information system the pilot missed vital pieces of information regarding landing coordinates from air traffic control. The aircraft now began to veer off course and pilot error would occur. The pilot took an incorrect flight path, did not receive landing confirmation from air traffic control, and was thus unable to land the aircraft. The correct approach for the pilot to adopt would have been using the information system in conjunction with their own judgement. This would have allowed the pilot to interact and interpret the information being provided to them by air traffic control.

This section has reviewed data collected involving aircraft pilots and task interdependency in dynamic environments. It was found that as the environment would become more dynamic, a greater level of interdependency between air traffic control and the pilot was required. The next section will review data collected from an intuitive perspective.

4.4 Intuition

The literature review conducted in chapter 2 concluded that intuition is an associative and rapid decision-making approach utilised by domain experts. It was shown that in domains of high stress and high time pressure that intuitive decision making can be an effective tool. Domains such as stock market trading, the medical profession, and factory workers were all shown to benefit from experienced decision makers who could rely on an intuitive decision-making approach. In these environments the use of an intuitive decision-making approach allows the decision maker to cut through vast quantities of information to arrive at a decision rapidly. Literature has also shown that as environmental uncertainty increases there is a shift away from structured, standard operating procedures to a more intuitive decision-making approach. In these scenarios, time pressure can be extremely high which requires a decision maker to arrive at a decision rapidly. Based on the characteristics of intuition from the literature review, it would be advantageous for an aircraft pilot to be able to use an intuitive decision-making approach in certain scenarios such as a crisis.

An intuitive decision-making approach was observed during different scenarios. During the pre-take off phase the pilot felt comfortable and at ease interacting with air traffic control, the co-pilot, and the on-board information system of the aircraft. At the pre-take off phase, the pilot will be asked questions by air traffic control surrounding system setup and the general flight plan. The pilot was able to offer instantaneous feedback to air traffic control, without relying on the information system for this. It was noted that the pilot was able to give clear and concise instructions to air traffic control. As well as air traffic control, the pilot's interactions with their co-pilot were instantaneous, offering guidance to the co-pilot and asking for specific requests or updates. The rapid and intuitive response to requests from air traffic control was also observed mid-flight during conditions of mild weather. During mid-flight the pilot may often receive a request or be provided with information to alter the setup of the on-board information system. The pilot was able to rapidly and intuitively interpret this information and either respond to air traffic control or amend the setup of the system. This is of critical importance as the information being provided can be of a time critical nature. An example of this would be when altering the landing coordinates for the aircraft.

It was observed how a pilot would shift to an intuitive decision-making approach when asked directly a question by air traffic control. These questions would relate to navigation and the pilot would be expected to perform a rapid instantaneous calculation and provide feedback to air traffic control. Prior to the change in decision-making approach adopted by the pilot they were interacting with both the information system and air traffic control. The pilot then received a request from air traffic control in relation to the angle they were going to use for turning the aircraft. This information is unavailable to the pilot from the information system, however as the pilot had a high level of experience in answering this question they replied with ease. The pilot was able to give the correct response to air traffic control rapidly using their own intuition. The pilot felt comfortable in this scenario and had experienced this type of question a number of times in the past. After this scenario the pilot returned to using a combination of their judgement and the information system for flying the aircraft. Despite the above scenarios when the pilot felt comfortable using an intuitive approach it was found that an intuitive decision-making approach was rarely used.

This section has reviewed data collected from an intuitive decision-making approach. It was found that the pilots felt comfortable using an intuitive approach when they had prior experience of a situation and were comfortable with knowing what the outcome would be. The pilots did not use adopt an intuitive approach when a novel or unexpected scenario would occur. It was also found that in situations when a crisis may occur, such as engine failure, the pilots would shift away from an intuitive decision-making approach. Overall it was found that a pure intuitive decision-making approach was rare for the pilots to utilise. The pilots were found to more commonly use a system aided judgement approach, relying on both intuitive responses and the guidance of the information system. The next section will review data collect from a system aided judgement perspective.

4.5 System Aided Judgement

The literature review in chapter 2 showed how the use of intuition and a data driven decision-making approach is becoming increasingly attractive and beneficial to decision makers in organisations. An aircraft pilot is no different to this but is also required to use their own judgement in conjunction with the information system. A pilot is required to interpret, compute, and relay information back and forth between the information system and air traffic control. The ability for a pilot to combine a data driven approach and incorporate human judgement is of critical importance. A breakdown in a pilots' decision-making process and communication channels can have catastrophic and fatal consequences for all those on board.

System aided judgement was observed to be the most common form of decision-making approach for the pilot to adopt. This was the default decision-making approach during pre-take off, take off, mid-flight, and landing procedures. Whilst utilising a system aided judgement approach the pilot was in a relaxed, calm, and composed. The pilot felt comfortable when using this approach whilst interacting with air traffic control, the co-pilot, and the on-board information system of the aircraft. It was observed that the pilot was able to give clear and concise instructions to air traffic control and the co-pilot whilst adopting this decision-making approach. This was observed during favourable weather conditions for the pilot.

Occasionally the pilot may receive requests from air traffic control for a status update or on the current flight path the pilot is using for the aircraft. Once this request was received the pilot would use a combination of their own judgement and the information system to answer the request. The pilot needs to interact with the information system, interpret the data from the system, and relay this information to air traffic control. The pilot was generally at ease performing tasks such as these during favourable flying conditions. The pilot would display no visible or audible signs of stress or nervousness when performing these tasks. In addition to the above, the pilot is also expected to use a combination of their judgement and the information system when gaining clearance for landing the aircraft. The pilot is required to liaise with air traffic control to ensure they have clearance for landing, are following the correct flight path, and have performed the correct pre-landing checks. From an information systems perspective, the pilot is required to make numerous adjustments to systems on the aircraft such as lowering speed, altitude, and adjusting the approach angle. The pilot is also expected to communicate and work with air traffic control to gain the correct clearance and take the necessary flight path for a safe landing. This scenario was observed with an experienced pilot and with an inexperienced pilot. The experience pilot was able to work with both the information system and air traffic control successfully to land the aircraft. The inexperienced pilot began to encounter difficulties when beginning the approach for landing.

When beginning the approach for landing the moderately experienced pilot became audibly nervous when attempting to interact with air traffic control. The pilot had moderate experience of landing the aircraft and thus both task variety and task difficulty were high for the pilot. At this point, the pilot began to become over reliant on the information system when attempting to land the aircraft. The pilot had shifted their decision-making approach to a data driven approach from system aided judgement. The pilot who was now fixated on the dominant cue of the information system began to filter out background peripheral cues such as the air traffic controller.

The pilot who had previously found it straightforward to answer a request from air traffic control was now finding it difficult. An incorrect drop in altitude, incorrect speed, or flight angle would have resulted in pilot error occurring for the pilot. This would have constituted a failure for the pilot. As the pilot had started filtering out the information being provided to them by air traffic control, the pilot missed a vital piece of information provided to them regarding navigational data. Due to this information not being interpreted the pilot was unable to take the correct landing approach and needed to attempt a go-round. The pilot also stopped communicating with air traffic control. The pilot who was now fully focused on the information system and using this to navigate the aircraft failed to inform air traffic control of the aborted landing attempt. The pilot moved away from a system aided judgement approach and adopted a data driven approach to decision making. This can be seen in Figure 22.

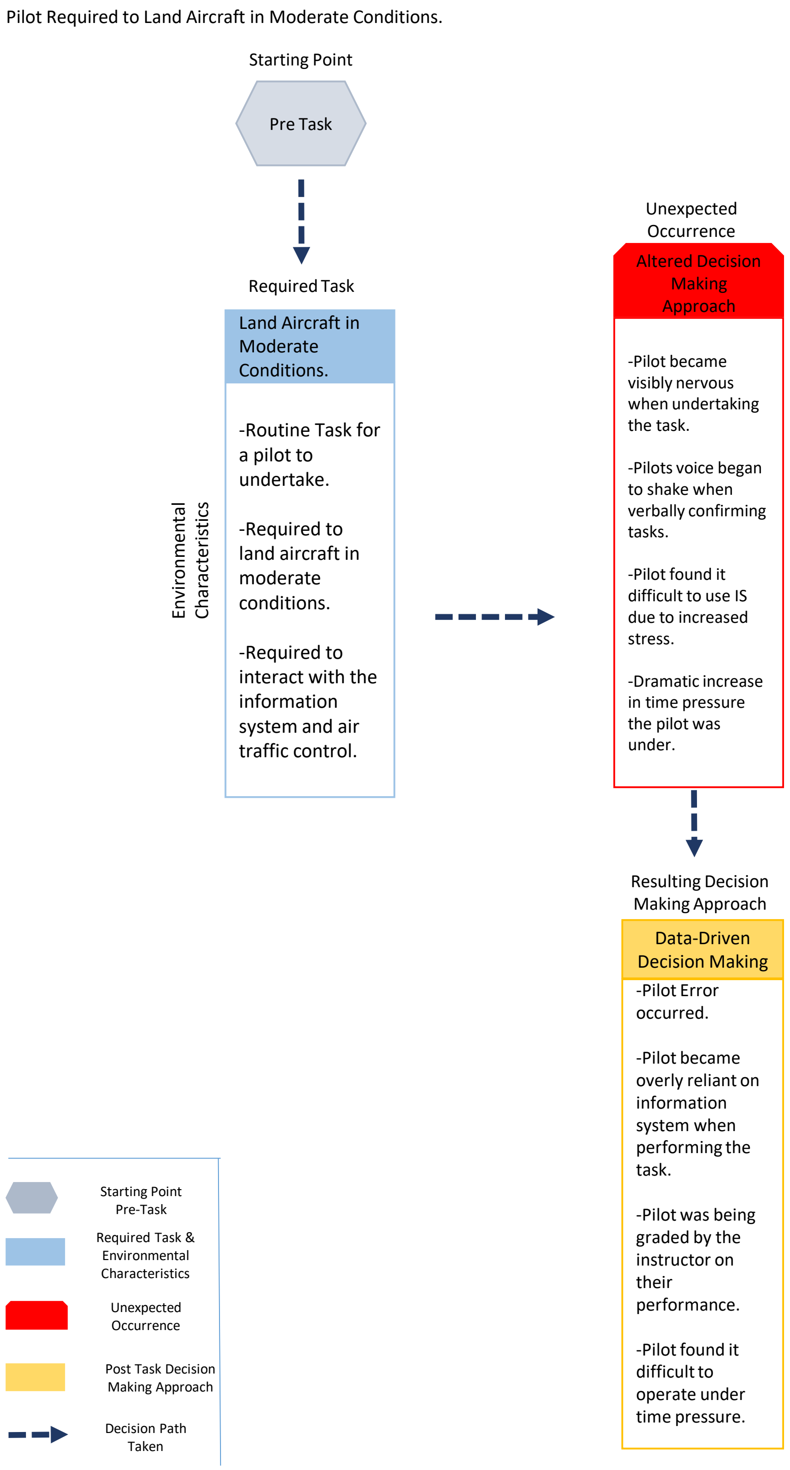

Figure 22. Landing scenario – system aided judgement to data driven decision making.

A similar shift in decision-making approach was observed in a scenario which was outside the pilot’s control. Weather conditions an aircraft pilot operates in can be very volatile and range from favourable flying conditions to unfavourable flying conditions. As a result of this the pilot is required to interact with both air traffic control and utilise the on-board weather information system in order to gain the complete picture of the task at hand. During favourable weather conditions the pilot was at ease performing such tasks as liaising with air traffic control whilst also being in a position to monitor and interpret the information being given to them by the on-board information system. As the weather conditions would begin to alter so too would the pilots decision-making approach. During a scenario of heavy fog (Figure 23) it was observed that the pilot began to become overly focused on the information system. The pilots decision-making approach had shifted from a system aided judgement approach to a data driven approach. The pilot who had poor visibility was now experiencing a high level of task non-routineness.

Due to the shift in decision-making approach the pilot failed to keep in communication with air traffic control. As the pilot was beginning the final approach to landing keeping communication open with air traffic control was vital to receive information regarding landing procedures. The pilot is expected to receive information from air traffic control, interpret the information, and amend the setup of the information system accordingly. Due to the deterioration in weather conditions and subsequent shift in decision-making approach the pilot failed to do this. The pilot did not remain in contact with air traffic control, took an incorrect flight path, and was unable to land the aircraft. This constitutes a pilot error. The pilot used the information system as the dominant cue. This resulted in the pilot filtering out perceived peripheral information from air traffic control which was in fact vital for the safe landing of the aircraft. This shift in decision-making approach ultimately lead to pilot error occurring.

This section has reviewed data surrounding a system aided judgement decision-making approach. It was found that this was the most common form of decision-making approach used by the pilots, however in scenarios were the environment would shift with novel and unexpected events occurring, task non-routineness would increase. This would lead to the pilots altering their decision-making approach, and moving towards a data driven decision-making approach

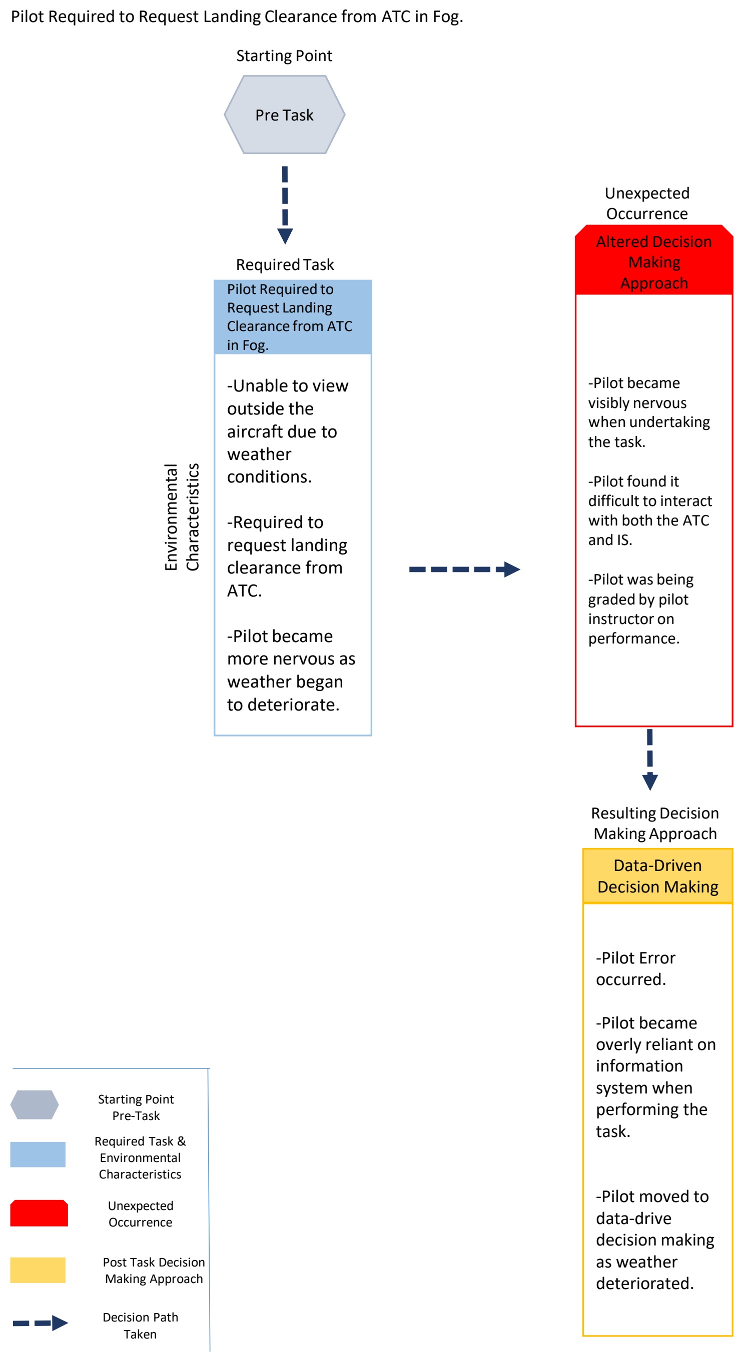

Figure 23. Adverse Weather – system aided judgement to data driven decision making.

4.6 Data Driven Decision Making

The literature review in Chapter 2 showed how organisations in many different industries are moving towards are a data driven decision-making approach. Data driven decision making is now seen as a key differentiator in organisations and employees are being hired specifically for their expertise with analytical tools. Aircraft pilots are no exception to this and are expected to have a high level of analytical competence when utilising on board information systems. A pilot cannot remain strictly with a data-driven approach to their decision making. A pilot is also expected to interact with air traffic control and a co-pilot. The pilot will be required to interpret, compute, and relay information back and forth between the information system and air traffic control. The ability for a pilot to combine a data-driven approach and incorporate human judgement is of critical importance. A breakdown in a pilot's decision-making process can have catastrophic and fatal consequences for all those on board.

Aircraft pilots are required to use a combination of their own judgement and a data driven approach when working on specific tasks. One example of this is when a pilot is required to gain clearance for landing an aircraft as shown in Figure 24. The pilot is required to liaise with air traffic control to ensure they have clearance for landing, are following the correct flight path, and that they have performed the correct pre-landing checks. From an information systems perspective, the pilot is required to make numerous adjustments to systems on the aircraft such as lowering speed, altitude, and adjusting the approach angle. In one scenario, the pilot was operating in moderate weather conditions with high visibility and no turbulence. Despite the moderate weather conditions, the pilot became nervous when interacting with air traffic control. The pilot had moderate experience of landing an aircraft and thus task variety and task difficulty were high for the pilot. The pilot was visibly sweating and audibly nervous when attempting to interact with air traffic control. The pilot began to become overly focused on interacting with the information system to attempt to land the aircraft. During the course of the flight, the pilot received a query from air traffic control that they were not expecting. The pilot who had been so overly focused on the information system, was thrown by this question, and found it difficult to answer. The pilot was now fully focused on using the information to keep the aircraft on the correct path to landing. An incorrect drop in altitude, incorrect speed, or flight angle would have resulted in pilot error occurring. As this was a simulation exercise this would have constituted a failure for the pilot in this scenario. The shift from using a combination of judgement and the information system to adopting a data driven approach to decision making would ultimately lead to the pilot committing a pilot error. The pilot who was overly focused on the information system and missed a piece of information the air traffic control had relayed to them regarding landing coordinates. The pilot was unable to take the correct approach to land the aircraft and had to attempt a go-round.

In addition to not interpreting the information being provided to them by air traffic control, the pilot also failed to inform air traffic control that the landing attempt was aborted. This was again due to being overly focused on using the information system to navigate the aircraft. The pilot failing to inform air traffic control and conducting an aborted landing attempt would constitute pilot error in this scenario. When a novel scenario for the pilot such as landing the aircraft arose the pilots task non-routineness was increased. As a result the pilot shifted their decision-making approach towards a data driven decision-making approach. The pilot then began to filter out peripheral information which was background to the information system such as information from air traffic control. This would ultimately lead to pilot error and a deterioration in job performance.

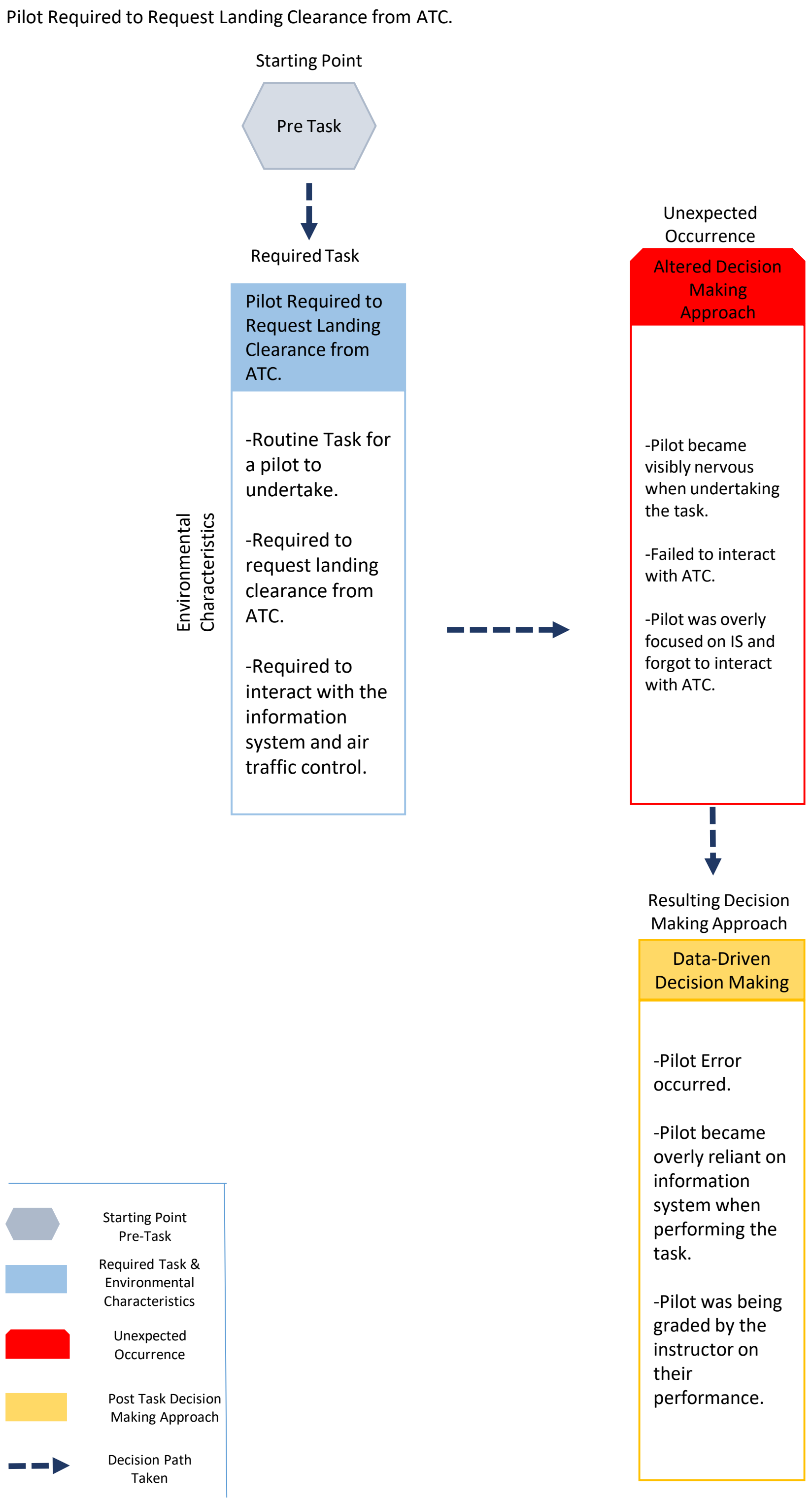

Figure 24. Landing Scenario – System Aided Judgement to Data Driven Approach

A shift towards adopting a data driven approach was also observed in scenarios which were outside the pilots control. Weather conditions a pilot needs to operate in can be extremely volatile. The pilot needs to remain calm in these situations and can receive weather information from the on board information system and also updates from air traffic control. During favourable weather conditions the pilot remained calm, interacting with both the information system and air traffic control when flying the aircraft. The pilot would often receive requests for a status update or on the flight path from air traffic control. Once this request was received the pilot using a combination of their own judgement and the information system would need to interact with the information system, interpret the data, and relay this information to air traffic control. The pilot was generally at ease preforming this task during mild flying conditions and displayed no visible or audible signs of stress or nervousness. During a scenario of severe fog it was observed that the pilot began to become overly focused on their instruments as shown in Figure 25. The pilot's visibility was minimal and the pilot was now reliant on utilising the information system in conjunction with air traffic control for navigational information. However, due to the environmental shift the pilots' decision-making approach also altered.

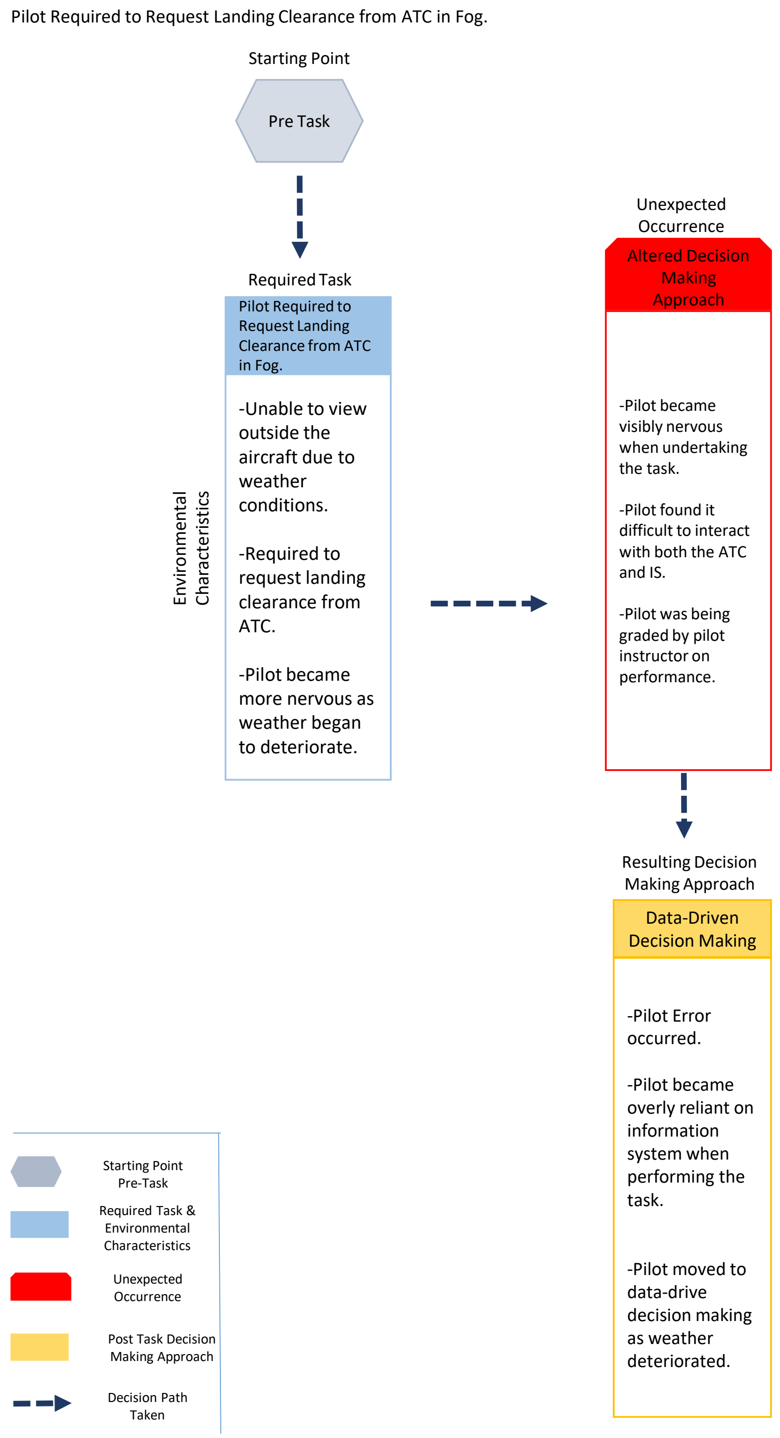

Figure 25. Heavy Fog – System Aided Judgement to Data Driven Decision Making.

The pilot became engrossed in the information system and failed to communicate with air traffic control consistently. The shift of decision-making approach to rely solely on data-driven decision making would result in pilot error. As the pilot was beginning the final approach for landing the aircraft the pilot is expected to relay and interpret information to and from air traffic control. The pilot failed to do this due to the deterioration in weather conditions and subsequent shift to a data driven approach to decision making as shown in Figure 25. The pilot took an incorrect flight path and was unable to land the aircraft. It was found that the pilot relied solely on a data driven approach. This resulted in the pilot filtering out vital information relating to landing coordinates from air traffic control. This shift in decision-making approach would result in a pilot error occurring.

This section has reviewed data collected surrounding a data driven approach for aircraft pilots. It was found that in scenarios with novel, unexpected environmental changes, with high task variety and task difficulty the aircraft pilot will alter their decision-making approach and adopted a data driven approach. This can have negative consequences for the pilot, if the pilot is expected to perform additional tasks such as communicating with air traffic control. Failure to communicate correctly with air traffic control can result in pilot error. Pilot error can include improper flying procedures, controlled flight into terrain, premature descent, excessive landing speed, missed runway, fuel starvation, navigation errors, wrong runway take off/landing, and mid-air collisions caused by the pilot. Any of these errors can have catastrophic consequences for a pilot and all passengers on board.

4.7 Pilot Summary

This section has reviewed data collected from a series of observations at an international flight training academy for pilots which is approved by the European Aviation Safety Agency (EASA). The literature review found that pilots need to operate under conditions of high risk, time pressure, and uncertainty. The data collected through observation confirmed these findings by looking at characteristics of the environment, the task characteristics, and the decisions making approach adopted by the pilots. Operating environments such as those aircraft pilots operate in are very dynamic. These environments require a decision maker to compute large amounts of complex information rapidly. Information systems within the aviation field greatly extend the range of human potential but this can lead to catastrophic errors if the incorrect decision is undertaken when utilising the information system. Due to this it is vital that an aircraft pilot adopts the correct decision-making approach for a given scenario.

It was found that the pilot would alter their decision-making approach as the operating environment the pilot found themselves in shifted. During scenarios of high pressure, high stress, and uncertainty the pilot would shift their decision making to a data-driven decision-making approach. Although the information system is an invaluable tool for the aircraft pilot, relying solely on the information system can be an incorrect approach. This results in the pilot missing key information being provided to them by air traffic control. A pilot missing vital information being provided by air traffic control can result in safety issues occurring and ultimately pilot error.

The next section will look at a case study in another dynamic environment, an air-traffic control centre.

4.8 Air Traffic Controller Introduction

This chapter is a case study involving an air traffic controller manager in a live air traffic control tower. As discussed in chapter 2, adopting the correct decision-making approach can improve decision outcome. In highly dynamic environments, the contextual familiarity of a task can alter rapidly, which may affect decision making performance if the decision-making approach is not amended to reflect the changes in the environment. This chapter will look at an air traffic controller manager's decision-making approach through the lens of environmental dynamism, contextual task familiarity, and the decision-making approach utilised by the decision maker for specific tasks.

This case study took place at an international air traffic control tower which handles over two million passengers annually. Air traffic controllers at this facility are expected to interact with international flights, domestic flights, personal flights, and training flights. Air traffic controllers were viewed as ideal candidates for this study as they operate in dynamic environments, often under situations of high risk, time pressure, and uncertainty. Observation for this case study took place in a live air traffic control tower which was operated by three air traffic controllers. These three operators consisted of a surface movement operator, an assistant surface movement operator, and an approach station operator.

The manager of this air traffic control tower at an international airport was the unit of analysis. The manager of the air traffic controller had over 20 years' experience of being an air traffic controller. The air traffic control manager had a high level of understanding with regards to operating modern information system driven air traffic control and the interpersonal skills needed to communicate with fellow colleagues and aircraft pilots. Figure 26 shows the information system the air traffic controller used in a live environment. As well as interact with the nine information systems shown in Figure 1, air traffic controllers need to be in continuous communication with their colleagues and aircraft pilots. This includes at pre take off, take-off, during flight, and when landing the aircraft. The air traffic control manager observed in this study was the manager of a team of 3 individuals, including the air traffic control manager. The air traffic control tower team is made of a ground movement manager (unit of analysis), an assistant to the ground movement manager, and an individual who monitors the approach desk. The ground movement manager works with aircraft which are due to take off, aircraft which are airborne, aircraft which are due to land, aircraft which are taxing, which runway should be used, and will have seniority on decision making for any unexpected scenarios which occur. The ground movement manager communicates with pilots verbally. The assistant to the ground movement manager works on specific tasks that the ground movement manager assigns them. The assistant to the ground movement manager also works with current flight schedules for departing and arriving commercial, private, and training aircraft. From these flight schedules the assistant ground manager creates flight schedule strips for the ground movement manager as can be seen in Figure 26. The ground movement manager uses the flight progress strips to keep track of flights that need to be worked with. The final position in the air traffic control tower is the approach desk which is used to monitor aircraft which enter the air traffic control towers jurisdiction. The approach desk monitors aircraft that are following the correct flight path and any potential mid-air collisions that may occur. The ground movement manager, assistant to the ground movement manager, and the approach desk use an individual version of the information system shown in Figure 26. The next sections will explore the air traffic controller manager case study in depth. How the environment and contextual task familiarity affect the decision-making approach adopted by the manager of the air traffic control facility will be reviewed. A summary of the findings will then be presented.

4.8.1 Information System

Each operator interacted with two screens displaying data from various information systems, and also used flight progress strips which were written on strips of paper. Air traffic controllers need to be comfortable operating a range of information systems.

The systems the air traffic controller manager was required to use are listed below and can be seen in *Figure 26*;

1. Radar of all aircrafts in the airports operating range

2. Global departure list which shows Visual Flight Rule (VFR) and Instrument Flight Rule (IFR) aircraft

3. Section list which gives detailed information on IFR flights

4. Weather data system which gives the operator detailed information on weather patterns

5. Airfield data which contains weather information the aircrafts are using

6. Secondary radar which displays radar data from other air traffic controls in the country

7. Uncontrolled list which contains data on VFR flights

8. Flight Progress Strips

9. System Control Panel

These information systems will be discussed in more detail in the subsequent sections.

Figure 26 is a photograph of the air traffic control managers' information system. Label 1 refers to the air traffic controller managers' primary radar information system. The primary radar system can provide the air traffic controller with numerous data points such as the flight number of the aircraft, the type of aircraft, the destination of the aircraft, the starting point of the aircraft, the speed the aircraft is travelling at, the altitude the aircraft is travelling at, the orientation the aircraft is taking, the current pressure of the aircraft, and all aircraft in the vicinity of the airport. The primary radar also has a filter which allows the air traffic controller to view all aircraft travelling at a national level, however, the default view for the primary radar system is localised to the airport. Label 2 refers to the global departure list for both VFR and IFR aircraft. The global departure list shows both VFR and IFR aircrafts which are the two sets of regulations which govern all aspects of civil aviation aircraft operations. VFR aircrafts are Visual Flight Rule aircraft which are a set of regulations which allow a pilot to operate an aircraft in favourable weather conditions. This allows the pilot to fly the aircraft by using visual cues in the landscape such as location of bridges, roads, and mountain ranges. Pilots who operate an aircraft under VFR rules do not typically utilise an on-board information system. Due to the lack of information systems on board, VFR pilots are only permitted to operate the aircraft in clear weather conditions, when visibility is high. Pilots operating under VFR regulations are not typically allowed to operate an aircraft at night due to the lack of visibility.

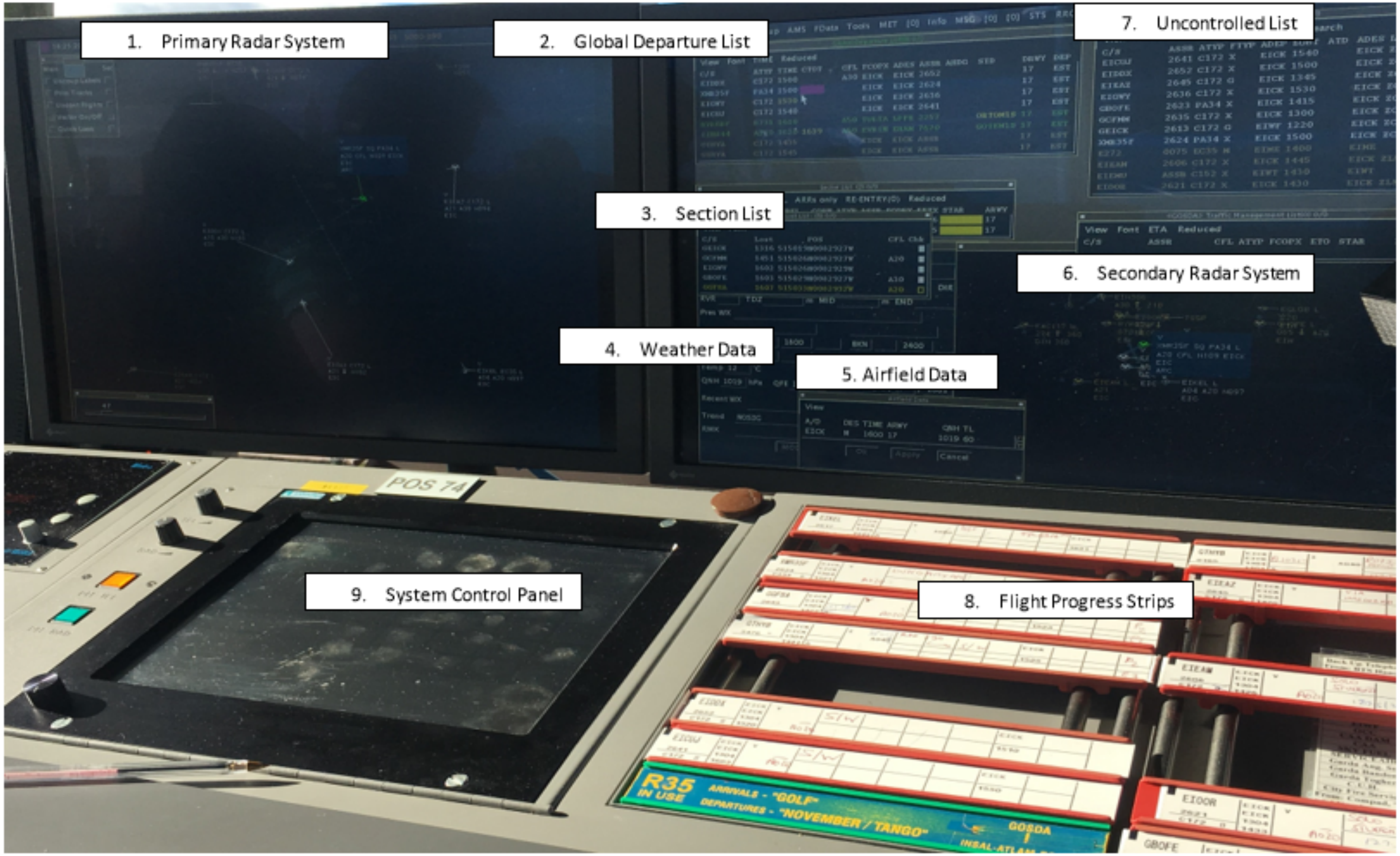

Figure 26 - Air Traffic Control Information System

In contrast to VFR regulations an aircraft may also be operated under IFR regulations. IFR regulations refer to Instrument Flight Rules and are defined by the U.S. Federal Aviation Administrations (FAA) instrument flying handbook as the following:

“Rules and regulations established by the FAA to govern flight under conditions in which flight by outside visual reference is not safe. IFR flight depends upon flying by reference to instruments in the flight deck, and navigation is accomplished by reference to electronic signals.”

Pilots must operate under IFR regulations when it is not safe to operate an aircraft under VFR. This is typically due to visual cues outside the aircraft being obscured or it being night-time when the flight is occurring, in such instances a pilot must fly using IFR. A pilot must operate under IFR when flying in a “Class A” airspace. Class A airspace extends from 18,000 feet (5,500m) above mean sea level (AMSL) to 60,000 feet. A VFR aircraft is allowed to operate in “Class C” airspace which is 500 feet below and 2000 feet horizontal distance from the clouds and as long as there is at least three miles of visibility. A commercial airline will typically operate under IFR regardless of airspace and a private light aircraft will normally operate under VFR. As IFR and VFR operate under different aircraft regulations the air traffic controller will have different responsibilities for both. An air traffic controller will need to provide a VFR pilot with more information which is not available from the information system such as, traffic advisory and weather information. This information is available to an IFR pilot through the on-board information system on the aircraft.

Label 3 is the section list which gives the air traffic controller a specific breakdown of all IFR aircraft currently travelling through the air traffic control towers airspace. Label 4 shows the weather information system for the air traffic control manage. This information system will provide detailed weather information for the surrounding airfield but can also be utilised to view weather information from other parts of the country. The air traffic controller will use the weather information system to view weather patterns which could affect a pilot or the aircrafts performance such as severe turbulence, wind shear, mountain wave, poor visibility, heavy rain, severe winds, icing, thunderstorms, and lightning strikes. Label 5 shows the airfield weather data system which contains the correct signal and setup that nearby aircraft should adhere to ensure they are receiving the most update weather information on board the aircraft. Label 6 is a secondary radar system for the air traffic controller which is utilised if the primary radar system fails. The secondary radar system also allows the air traffic controller to view detailed radar information which is outside the jurisdiction of the air traffic controller tower. This allows the air traffic controller to view detailed radar information on air traffic travelling in other areas of the country. It also allows the air traffic controller to provide assistance in case of an emergency at a different location. Label 7 shows the uncontrolled list which gives the air traffic controller a specific breakdown of all VFR flights which are currently airborne. The aircraft are labelled with a white colour are under the control of this specific air traffic control tower, whilst the aircraft labelled with a gold colour are under the control of the next nearest air traffic control tower. The air traffic controller can view information such as the aircraft type (ATYP), the airport of departure (ADEP), the airport of destination (ADES), and the call-sign.

Label 8 refers to the air traffic control managers flight progress strips. The air traffic control manager described these strips as being “tailored to the individual” and “all air traffic controllers will set theirs up differently”. The flight progress strips are a small strip of paper which are used to keep track of a flight that the air traffic controller is working on. The flight progress strips are used to as a quick method of annotating a flight, to keep a record of instructions that were given to a specific flight, to allow other controllers to see what occurred for a specific flight, and in a handover process when a specific work shift has finished. The air traffic control tower had colour coded flight progress strips for different scenarios. A yellow flight progress strip refers to a flight which is due to take off, a blue fight progress strip refers to a flight which is due to arrive, and a red flight progress strip refers to a training aircraft. Once a specific aircraft has either departed the current flight space or arrived the flight progress strip will be taken off the air traffic controllers’ workstation and stored securely. The flight progress strip will contain the following information;

- The aircrafts flight number (identification)
- Aircraft type as the relevant 4-letter ICAO designator (e.g. B744 for a Boeing 747-400)
- The assigned altitude.
- Departure and destination.
- The time.

Label 9 refers to the air traffic control manager's system control panel. From this system the air traffic controller can control the setup and layout of specific functions of the overall information system. For example, zooming in or out of a specific part of the primary radar. The air traffic controller can also contact specific aircraft or specific air traffic control towers verbally using this control panel and a microphone. The next section will now review the different scenarios the air traffic control manager had to work through.

4.8.2 Air Traffic Control Scenarios

The following section will outline and describe a series of scenarios which the air traffic control manager was involved with. These scenarios ranged from the mundane tasks such as engaging with a pilot to ensure their pre-flight routine is correct to more unexpected tasks such as receiving an emergency notification from the approach desk. The air traffic control manager was required to complete 7 distinct tasks. These tasks were performed in a live, real-time, air traffic control tower. The following sections will provide an overview and discuss the specifics of each scenario.

Scenario 1 - Take off request

A take-off request is a routine task the air traffic control manager will be required to complete a number of times per day. Take-off requests are scheduled, and the air traffic controller will know in advance the specific flight details, time, type of aircraft, and its destination before take-off. Flight schedule is provided by Euro control across 41 member states of the European region. It was noted that for a flight take off, the air traffic controller did not interact with the information system but rather used the local environment to help guide the aircraft. The air traffic controller reviewed the local environment from the tower and provided the pilot with local information. These data points included current aircraft on the runway, aircraft which were due to land from the flight progress strips, wind speed, wind direction, cross winds, and aircraft which were due to take off. This information was then relayed to the aircraft pilot which allowed them to take-off safely and on time.

<u>Scenario 2 - Landing request</u>

The air traffic control manager was required to work with pilots who were airborne and requested landing clearance at the airport. Once this occurs the air traffic controller needs to scan the local environment for various data points such as the number of aircrafts on a runway, the number of aircrafts taxing, existing aircrafts in the sky that are scheduled to land, weather conditions which may prove hazards for the aircraft, crosswinds, or any unexpected occurrences in the environment. The air traffic controller will also use their information system to quickly review key data points about the aircraft; these data points can include the aircraft call sign, the actual speed across the ground, the altitude the aircraft is flying at, the flight route, the distance from the air traffic control tower, and the true air speed. The air traffic controller is required to use the data points obtained from the information system in conjunction with the data scanned from the environment.

<u>Scenario 3 - Landing request from VFR aircraft</u>

The air traffic controller will also need to contend with airborne aircrafts which do not conform to the same standards as commercial jet airlines. These are aircrafts that a pilot operates under visual flight rules know as, VFR. An aircraft pilot is permitted to operate this type of aircraft when the weather conditions are clear enough to allow the pilot to see where the aircraft is going. If the weather conditions are not of the correct level the pilot is required to use instrument flight rules, known as IFR. Aircraft which fly VFR are typically light aircraft which are flying at lower altitudes and the pilot in these circumstances will rely on visual references such as buildings and roads to navigate the aircraft. The pilot will not have access to radar information that is found on commercial aircrafts. As a result of this, a pilot flying with a VFR approach is more reliant on the air traffic control manager to guide them to successfully land the aircraft. The air traffic control manager is also missing vital information that is provided by radar in these occurrences. The air traffic controller does not have access to the aircrafts flight plan, distance from the air traffic controller, speed of aircraft on the ground and the true air speed. The air traffic controller is reliant on obtaining and viewing data points from the external environment such as the overall conditions and if there were aircraft on a specific runway. This information is then relayed back to the VFR aircraft pilot who will amend their flight plan accordingly.

Scenario 4 - Emergency notification from approach desk

In addition to the routine tasks outlined above, the air traffic controller also needs to be adept at handling emergency scenarios which can occur at any time. The approach desk is a surveillance display which assists the ground movement position with the use of a secondary radar. At this position the air traffic control manager is expected to monitor airborne traffic which includes a map of the area, position of various aircraft, data tags that include aircraft information, the speed of the aircraft, the altitude of the aircraft, and information specific to the air traffic control manager. The primary focus of an air traffic controller who operates the approach desk is to avoid mid-air collisions of aircrafts. If two aircrafts fly too closely to one another an alarm will sound on the information system and there will also be a flashing red light. The air traffic controller is fully reliant on the information system once this alarm sounds and is required to study the information being presented for a number of seconds. Once the air traffic controller reviews the information, they are required to rapidly contact the aircraft to recommend them to change flight paths.

Scenario 5 - Request for short & long-range forecast from pilot

Pilots are required to contend with dynamic weather conditions which can alter multiple times over the course of a flight. Occasionally the air traffic controller may be asked to assist with this by providing a short range or long range forecast for the pilot to ensure the safe passage of the aircraft. This could include weather information such as turbulence levels, wind shear levels, mountain wave, visibility, rain levels, winds, potential icing, potential thunderstorms, and potential lightning strikes. For immediate weather updates the air traffic controller would look at the external environment for weather patterns relating to wind speed, wind direction, and general weather conditions. This is accomplished by observing the surrounding external environment from the air traffic control tower. The air traffic control manager remarked, "When I get into my car when I'm driving to work, I am continuously scanning for data. I am looking at wind speeds, wind directions, and the weather. I know which direction aircrafts are going to take off from and how I will land airborne aircrafts." The air traffic control manager was able to provide this weather information and subsequent take-off direction instantaneously to the aircraft pilot. For long range forecasts, the air traffic controller would be reliant on the information system to assist with the task. The air traffic controller would utilise the information system to relay long range forecasts that were outside the air traffic controller's visibility to assist the pilot.

<u>Scenario 6 - Unexpected lowering of visibility on the runway.</u>

Although the previous scenario can be described as being routine and common place for the air traffic controller, they also had to complete less routine weather related tasks. These tasks highlight the dynamic environment the air traffic controller was required to operate in with weather conditions changing numerous times throughout the day. In this scenario a nearby farmer began to unexpectedly dust their crops with agricultural lime for pest control. Due to the wind direction and wind speed, the agricultural lime that was being sprayed began to blow back towards the runway. This resulted in lower visibility for the air traffic control manager, the aircraft pilots on the ground, and aircraft due to land. Once realising that the operating environment had altered the air traffic control manager intuitively began to inform aircraft that were due to land and aircraft that were on the runway of the poor visibility. The air traffic control manager also gave the pilots feedback and advice on the best course of action to take due to the unexpected change in the environments weather conditions.

Scenario 7 - Request for aircraft to take off whilst working with an airborne aircraft.

The air traffic controller was also required to work with two separate aircrafts in very quick succession from each other. This was a time sensitive task for the air traffic controller as it is vitally important for a pilot to receive decision critical information in a timely manner. This results in a high time pressure scenario for the air traffic controller as they had specific time windows to deal with both aircraft. The air traffic controller used the information system to briefly check for the aircrafts distance from the airport, but relied on their intuition to scan the environment to direct the aircraft to land at a specific runway. In a matter of seconds, the air traffic controller is expected to factor in the speed the aircraft is travelling at, the distance to the airport, current aircraft on specific runways, aircraft that are due to land, and which runway is available for airborne aircraft. The air traffic controller’s high level of intuition allowed them to cut through vast swathes of information to reach the correct conclusion for the airborne aircraft. Once the air traffic controller had given the airborne pilot the necessary information to land the aircraft, the air traffic controller immediately needs to work with an aircraft on ground for take-off. The air traffic controller is now required to work with a different data set and look for factors such as current aircraft on the runway, aircraft which were due to land, wind speed, wind direction, cross winds, and which aircraft were due to take off.

This section has provided an overview and background of the various task scenarios the air traffic control manager was required to complete. This was a live, real-time environment the air traffic controller was managing; the air traffic controller had a responsibility and duty to ensure the correct flow of information to aircraft in their jurisdiction. The subsequent sections will now review these scenarios through the lens of;

- Aircraft Communication
- Dynamic Weather
- Information Fluctuations
- Time Pressure
- Task Familiarity
- Task Non-Routineness
- Task Interdependence
- Intuition
- System Aided Judgement
- Data Driven Decision Making

Reviewing scenarios through this lens will explore if and how the air traffic control manager oscillated between differing decision-making approaches.

4.9 Operating Environment

4.9.1 Introduction

Air traffic controllers are required to perform tasks in environments of high time pressure, high levels of personal stress, and varying weather conditions. Air traffic controllers face numerous challenges such as interacting with a number of different information systems, interacting with aircraft pilots who will seek guidance both on the runway and in the air, and interacting with their colleagues. Due to the varying operating environment air traffic controllers are expected to perform to a high standard; failure to do so can result in catastrophic consequences for all on board an aircraft. The manager of the air traffic control facility is expected to take on board new information and relay this to aircraft pilots. The subsequent sections will show how the operating environment for the air traffic control manager can be unexpected and novel. This type of operating environment can present challenges to the air traffic control manager. This will be shown in latter sections. The first section will look at how the air traffic control manager communicated with pilots.

4.9.2 Aircraft Communication

In scenario one the air traffic controller was required to deal with a take-off request. This is displayed in Figure 27, which shows the air traffic control manager adopted an intuitive decision-making approach and began to scan the external environment for factors to safely help the aircraft to take off. These included current aircraft on the runway, aircraft which were due to land from the flight progress strips, wind speed, wind direction, cross winds, and aircraft which were due to take off. The air traffic control manager was intuitively able to scan and interpret this data to give the pilot due to take off the best possible instructions. Due to the air traffic control manager adopting an intuitive decision-making approach the pilot was successfully able to take off as the correct information had been provided.

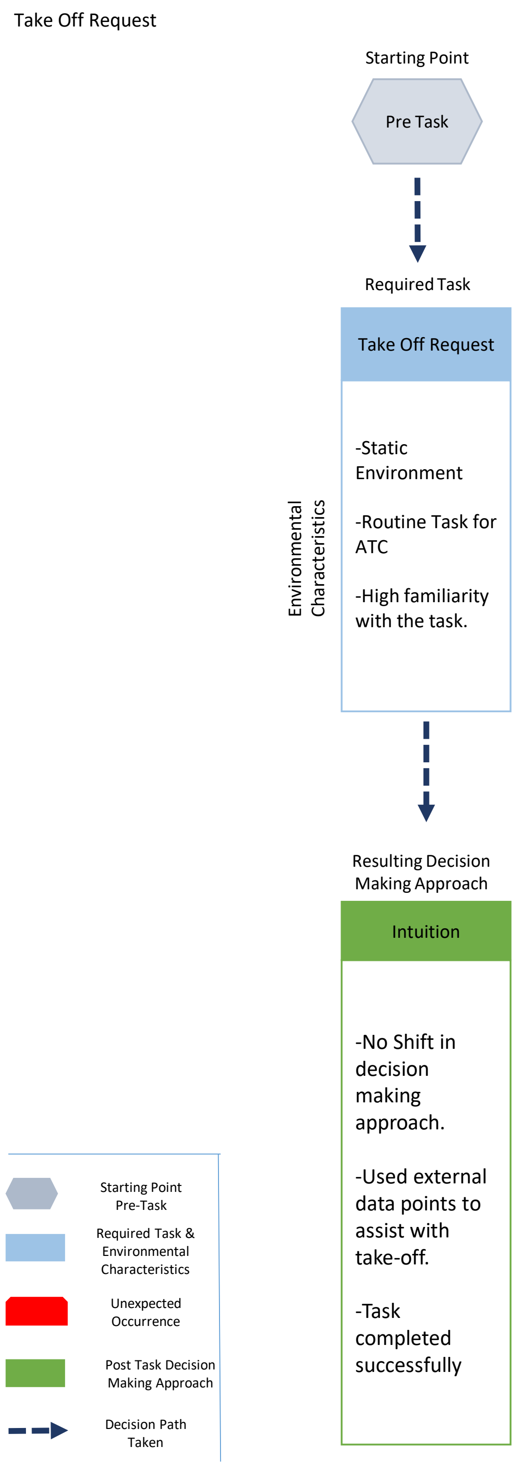

Figure 27. Take off request – Adopts an Intuitive Approach.

Once the above task was complete, the air traffic control manager was required to shift their decision-making approach in scenario 2 and displayed in Figure 28.

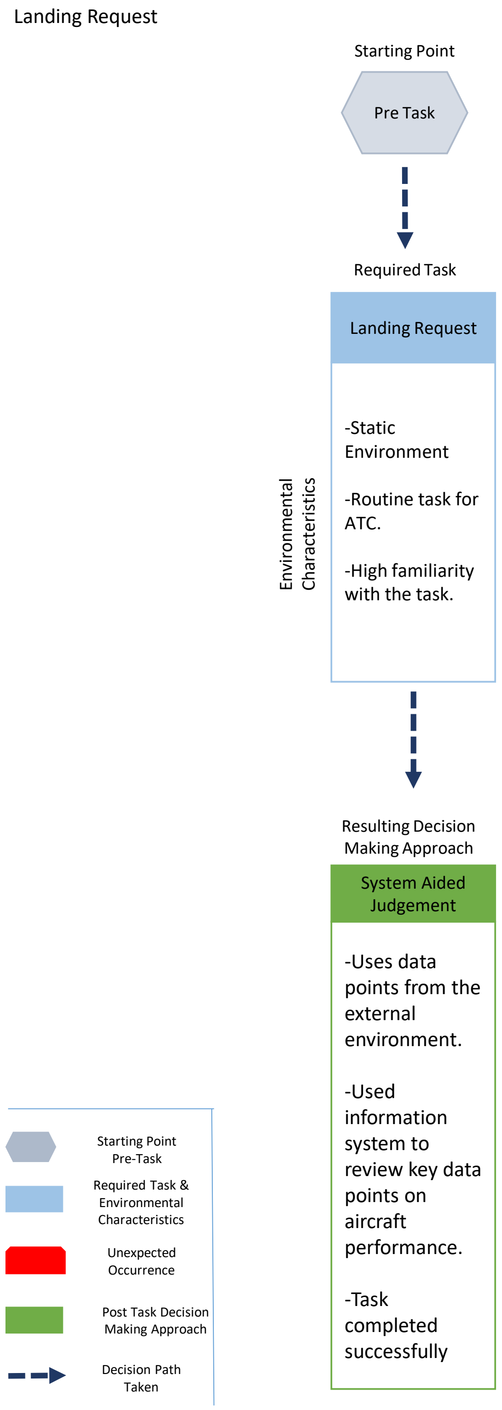

Figure 28. Landing request – Intuitive Approach to System Aided Judgement.

A request from an airborne pilot to land an aircraft can occur at any time and the air traffic control manager needs to remain continuously alert for these requests. Once a request from an airborne pilot is received, the air traffic control manager will briefly move away from an intuitive approach. Once this occurs the air traffic control manager will quickly glance at the information system located in front of them and review data that is being presented to them relating to a number of factors. These include the aircraft call sign, the actual speed across ground, the altitude the aircraft is flying at, the flight route, the distance from the air traffic control tower, and the true air speed. The air traffic controller will quickly interpret this information that is being provided to them by the information system and use it in conjunction with the intuitively scanned information from the surrounding environment. The air traffic control manager will need to determine the when the aircraft can land safely, which runway is best suited to the aircraft, and if there are any unexpected circumstances which may force a delay to this.

To land the aircraft the air traffic control manager will use the intuitively scanned information relating to number of aircrafts on the runway, which runways are free, aircrafts ready to take off, wind speed, and wind direction, but will also factor in data from the information system such as distance to airport, speed of aircraft and travelling direction. The air traffic controller is required to utilise data from the information system to support their intuitively scanned information of the external environment from the air traffic control tower as they are unable to visually find data relating to aircraft distance, orientation, and speed from observation. This can be seen in Figure 28 with the altering operating environmental characteristics the air traffic controller manager was working under. In this scenario, the air traffic control manager was successfully able to provide the airborne pilot with the necessary and correct information to land the aircraft.

The air traffic control manager will also need to contend with airborne aircrafts which do conform to the same standards as the commercial aircraft detailed above. These are aircrafts that a pilot operates under visual flight rules know as, VFR. A VFR landing request was seen in scenario 3 and is displayed in Figure 29. Once the air traffic control manager received a request a VFR aircraft the air traffic control manager needed to alter their decision-making approach. In this scenario, the air traffic control manager did not have specific radar information available to as a VFR aircraft does not carry this technology. The altering of the required task and the environment the air traffic controller had been operating in can be seen in Figure 29.

Once the request from the VFR aircraft had been received, the air traffic control manager had to move away from a system aided judgement decision-making approach and adopt an intuitive decision-making approach. The air traffic control manager was unable to rely on the information system for guidance as a VFR aircraft does not involve flying by an information system. The air traffic control manager now needed to rely on intuitively scanning the environment for a number of factors to help safely land the aircraft. The air traffic control managers intuitively scanned for current runways in use, number of aircrafts on the runway, if there are any crosswinds, the speed of the wind, the direction of the wind, aircrafts which are beginning the final approach, and if there are any unexpected occurrences in the immediate area. This required shift in both the task and the operating environment which was no longer suitable to utilising the information system can be seen in Figure 29.

The air traffic control manager would intuitively scan for information to ensure the safety of both aircraft on the ground and airborne aircrafts by observing the conditions in the surrounding area from the air traffic control tower. The air traffic control manager will then relay this information back to the VFR airborne pilot instantaneously and the pilot will then amend their flying pattern accordingly. In this scenario the pilot successfully landed the VFR aircraft with the assistance of the air traffic control manager who adopted an intuitive approach. This post shift decision-making approach after an altering of the required task and environmental shift can be seen in Figure 29. This scenario shows that that an air traffic control manager needs to be comfortable adopting a range of decision-making approaches depending on the scenarios which arise.

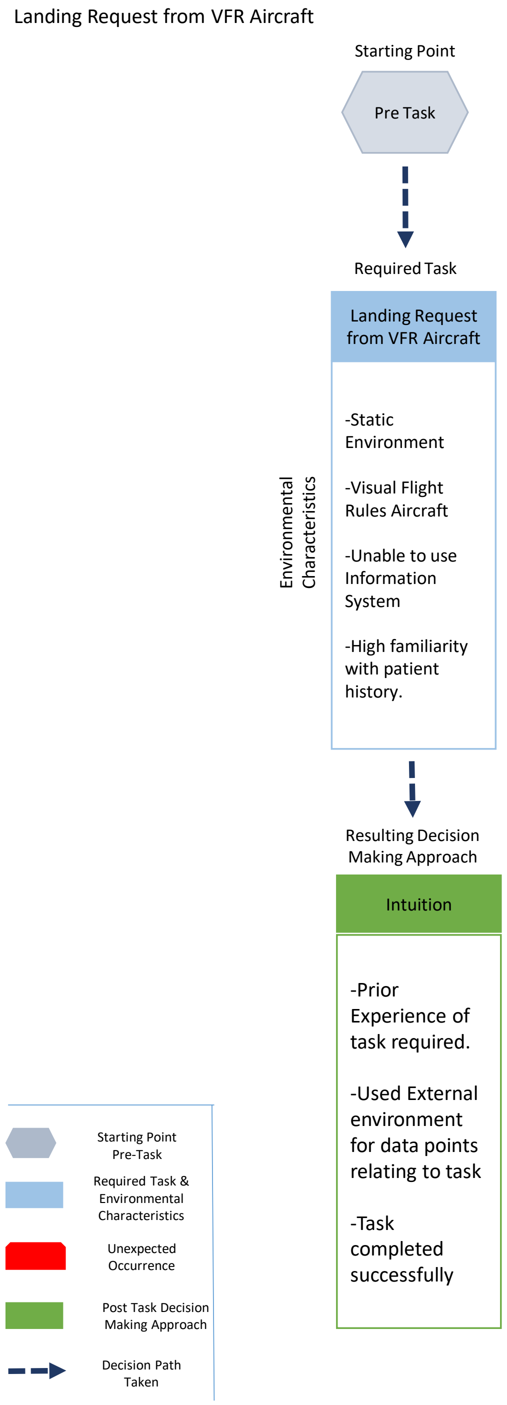

Figure 29. VFR landing request – System Aided Judgement to Intuitive approach.

This section has reviewed the operating environment that an air traffic control manager works in. The operating environment was found to be very dynamic and showed the air traffic controllers need to adopt a range of different decision-making approaches to successfully and safely ensure the departure and arrival of aircrafts. It was found that the air traffic control manager need to intuitively scan the environment when working with aircraft that are on the ground. It was also found that depending on the type of aircraft, IFR or VFR, the air traffic control manager will either need to adopt a system aided judgement or solely rely on an intuitive approach depending on the type of aircrafts information systems. The air traffic control manager is also required to adopt a data driven approach in situations of emergency such as mid-air collision. These varying different roles require alternating decision-making approaches and contribute to the air traffic control manager operating in a very dynamic environment. The next section will review the air traffic control managers decision-making approaches in the context of dynamic weather patterns.

4.9.3 Dynamic Weather

The air traffic control manager was operating in a live environment where weather conditions could vary greatly over the course of a working day. Weather conditions will impact the air traffic controller's decision-making approach but the air traffic control manager also needs to be aware of the effect weather will have on aircraft pilots and relay weather information to them. The air traffic control manager needs to factor in weather conditions into their own decision-making approach as it can have an impact on traffic capacity and aircraft safety. Weather conditions such as rain, ice, or snow on a runway can cause landing aircrafts to take longer to slow down and exit. This will reduce the safe arrival rate and requiring more space between landing aircrafts. Fog will also decrease the landing rate of aircrafts and greatly impacting the visibility levels of the air traffic control manager. The decrease in turnabout speed on the runway will also impact aircraft which are already airborne. This will result in aircraft which are airborne being delayed and resulting in potential safety issues occurring. The air traffic control manager is also required to inform aircraft pilots on the ground and airborne pilots of any potential weather issues. The weather conditions that airborne pilots need to contend with can be extremely volatile. Weather conditions can affect aircraft pilots at all times when operating the aircraft, including pre-flight, take-off, mid-flight, and landing the aircraft. Weather conditions which can alter aircraft pilot performance can include mild conditions, severe turbulence, wind shear, mountain wave, poor visibility, heavy rain, severe winds, icing, thunderstorms, and lightning strikes. The aircraft pilot relies on information being provided to them from air traffic control to ensure the safe arrival of the aircraft. The air traffic control manager needs to remain continuously aware of the varying weather conditions which can occur. The air traffic control manager can use visually cues to look for signs in changing weather patterns from observing the outside environment from the air traffic control tower and also review detailed live weather reports on a dedicated information system.

The air traffic control manager is required to relay weather information to the aircraft pilots before take-off would occur. During these scenarios air traffic control would make the aircraft pilot aware of weather information that would impact the take-off of the aircraft. This could include weather information such as turbulence levels, wind shear levels, mountain wave, visibility, rain levels, winds, potential icing, potential thunderstorms, and potential lightning strikes. At this stage the air traffic control manager would intuitively scan the environment for weather patterns relating to wind speed, wind direction, and general weather conditions. This is accomplished by observing the surrounding external environment from the air traffic control tower. The air traffic control manager remarked, *"When I get into my car when I'm driving to work, I am continuously scanning for data. I am looking at wind speeds, wind directions, and the weather. I know which direction aircrafts are going to take off from, and how I will land airborne aircrafts".* The air traffic control manager was able to provide this weather information and subsequent take-off direction instantaneously to the aircraft pilot.

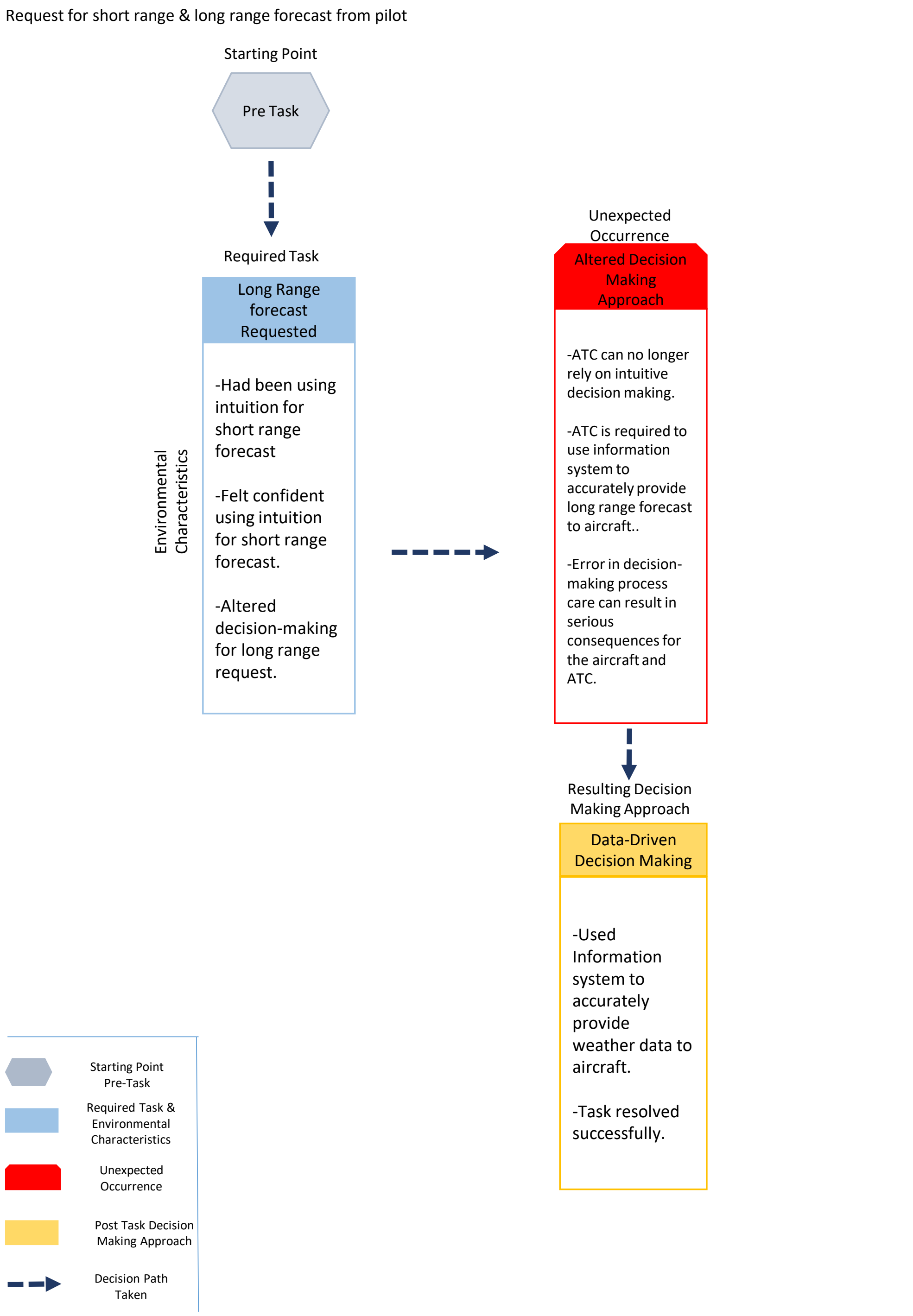

Figure 30. Long range weather request – Intuitive approach to System Aided Judgement.

It was noted in the observation that the air traffic control provides the aircraft pilots with weather updates including wind speed, current visibility, temperatures, fog, cloud cover and that, the visualisation levels of the runway.

Although the air traffic control manager would rely on an intuitive approach to guide the aircraft pilot in relation to weather conditions for take-off, the air traffic control manager was unable to rely on this method for long range forecast which was outside the air traffic control managers' vision. During scenario 5, a pilot requested long range weather information from air traffic control as shown in Figure 30.

Once this request was received the air traffic controller was no longer able to rely on the intuitive decision-making approach they had adopted to this point. The changing of the required task can been seen in Figure 30. The air traffic control manager was unable to use the data they have been on boarding throughout the day and were required to interact with the information system to find long range weather information for the pilot. It was clear that the air traffic control manager was highly experienced in dealing with this scenario and felt at ease navigating the information system to find the specific weather information for the specific route the pilot was undertaking. The air traffic controller had shifted from an intuitive decision-making approach to adopting a data-driven approach to decision making (depicted in Figure 30). The air traffic control manager was successfully able to rely the correct weather information requested by the pilot and the pilot successfully took off.

Although the above was quite a common scenario for the air traffic control manager to encounter there were also unexpected and novel tasks the air traffic control manager would need to complete. Scenario 6 is an example of a novel and unexpected event occurring for the air traffic controller.

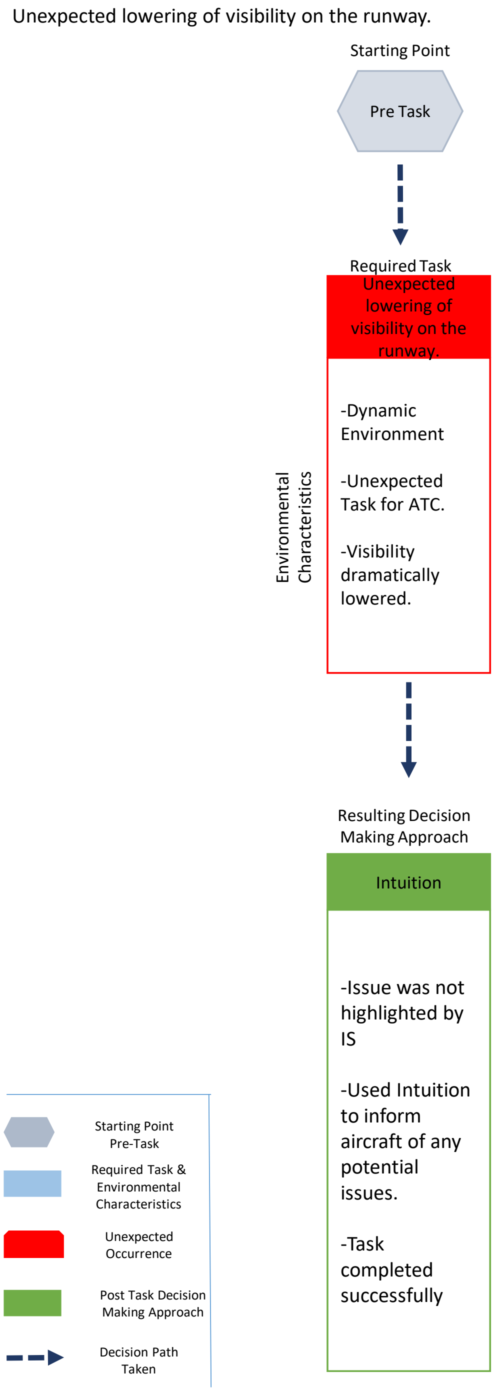

Figure 31. Agricultural Lime Sprayed – System Aided Judgement to Intuition

In scenario 6, the air traffic control manager was able to give clear and concise instructions to the aircraft pilots. As the unexpected event of agricultural lime began to blow onto the runway the air traffic control manager's decision-making approach oscillated. This can be seen in Figure 31 whereby the unexpected shifts in the environment in conjunction with the novel task facing the air traffic control manager altered their decision-making approach. Once realising that the operating environment had altered the air traffic control manager intuitively began to inform aircraft that were due to land and aircraft that were on the runway of the poor visibility. The air traffic control manager also gave the pilots feedback and advice on the best course of action to take due to the unexpected change in the environments weather conditions.

The air traffic control managers experience of over twenty years allowed them to react intuitively to an unexpected event which arose. The air traffic control manager knew intuitively how to react and which course of action to take. Due to this the aircraft pilots were able to receive instructions rapidly and it gave the pilots time to react to this unexpected scenario. As aircraft pilots operate in such a time pressure environment, information being provided to them in relation to unexpected events when landing can ensure that an aircraft will land safely for all those aboard. Failure for information such as this to be provided to the aircraft pilots in a timely manner can have catastrophic consequences for all those involved.

This section has reviewed the effects weather conditions can have on an air traffic control managers' decision-making approach. It was found that the weather conditions an air traffic control manager needs to contend with are not static but dynamic. The dynamic weather patterns can often be unpredictable as seen with the agricultural lime which was being sprayed by a local farmer close to the runway. The next section will look at information challenges and review its influence on the decision-making approach adopted by air traffic control managers.

4.9.4 Information Challenges

In addition to the operating environment and dynamic weather as outlined in the previous sections, information fluctuations are also a factor in altering the characteristics of an environment and will be discussed in this section. Information flow for the air traffic control manager was continuous throughout the day including flights at pre-take off, taxing, mid-flight, pre-landing, and whilst landing. Information was provided to the air traffic control manager though various information systems that would provide detailed information for specific flights. These information systems include a radar of all aircrafts in the airports operating range, a secondary radar which displays radar data from other air traffic controls in the country, airfield data which contains weather information the aircrafts are using, a global departure list which shows VFR and IFR aircraft, a section list which gives detailed information on IFR flights, an uncontrolled list which contains data on VFR flights, and a weather data system which gives the operator detailed information on weather in the surrounding area. In addition to the data being relayed to the air traffic control manager via information systems, the air traffic control manager also would take on board information using an intuitive scanning of the surrounding area. The intuitive scanning allowed the air traffic control manager to infer data for various scenarios such as current flights on due to depart, number of aircraft on the runway, aircraft due to land, distance from airport of aircraft due to land, speed of aircraft, and direction aircraft was landing. Due to this, there will be scenarios when the air traffic control manager can gain more information from the using the information system and not relying on their intuition, using a combination of both, or relying on their intuition more.

As discussed above there are scenarios when the air traffic control manager will be more reliant on the information system or their own intuition, depending on the information fluctuations as a result of shifts in the environment. This shift from using a combination of the air traffic control managers' intuition and the information system to adopting a data driven decision-making approach was observed in a situation of potential crisis (as shown in *Figure 32*).

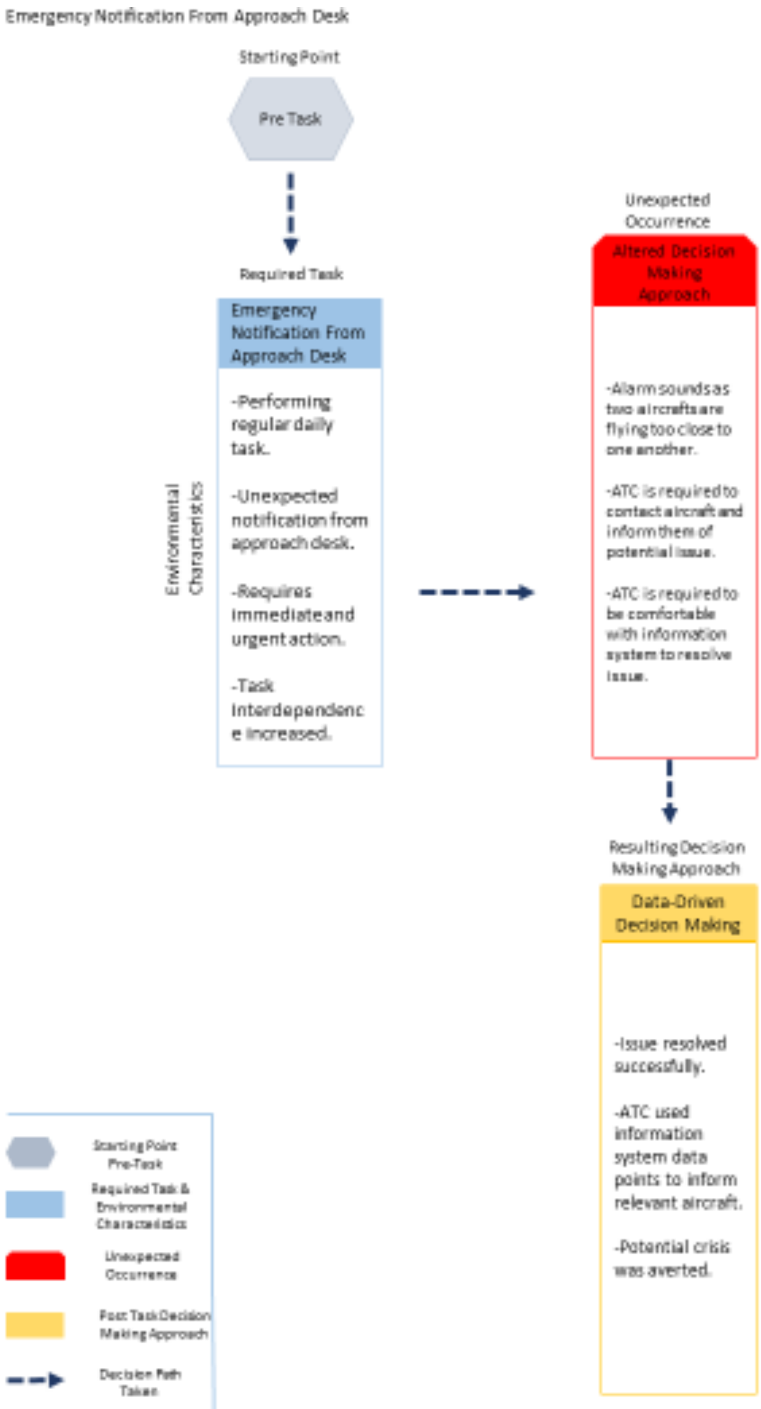

Figure 32. Potential crisis alters information source – System Aided Judgement to Data Driven Decision Making

Scenario 3 is an example of a potential crisis occurring which the air traffic controller needed to react to. Using the system aided judgement approach, the air traffic control manager used a combination of the information system for gauging where the aircraft was, the distance it was travelling, and any other aircraft in that vicinity. The air traffic control manager also used their intuition to scan the external environment outside the air traffic control tower for data relating to air traffic on the ground, aircraft which were due to take off, and to ensure the surrounding area was safe for aircraft to land. This decision-making approach would alter as the environment shifted and the air traffic control manager needed to adopt a different decision-making approach for a different task. As two airborne aircrafts began to fly close to one another, the approach desk would begin to alarm visually and audibly. The air traffic control manager now shifted their decision-making approach to a data driven approach. This shift occurred due to the environmental conditions and the task the air traffic control manager was required to complete altering. These shifts can be seen in Figure 32. The air traffic control manager was unable to use an intuitive approach to scan the environment for data relating to this task as the aircraft were travelling outside the visibility of the air traffic control tower. The air traffic control manager using the data provided by the information system would then contact the airborne aircraft pilot and request them to amend the current flight trajectory. The air traffic control manager became solely reliant on data being provided to them from the approach desk information system which can be seen in Figure 32. Once the aircraft pilot confirmed the course of action provided to them by the air traffic control manager and amended the flight trajectory, the warning signals would stop occurring from the approach desk. This scenario highlights the fluctuations in information air traffic control managers can face as the operating environment alters. In this scenario the air traffic control manager adopted the correct course of action by utilising a data driven approach to decision making and the issue was resolved.

4.9.5 Time Pressure

The previous sections have highlighted factors which contribute to air traffic controllers operating in a dynamic environment. From an operating environment perspective, it was shown that air traffic controllers need to conduct varying, interrelated tasks under constraints of time and information.

These factors increase the dynamism within the operating environment of an air traffic controller. Air traffic controllers need to remain continuously aware such factors that are in their control and factors that are outside their control such as altering weather patterns. Chapter 2 concluded that time pressure has been shown to reduce the quality of decisions made, reduce propensity to take risks, and increase the stress an individual is under. The previous sections have reviewed air traffic controller's decision-making approaches from differing perspectives.

The commonality between these perspectives is that air traffic controllers need to operate in scenarios when time is of a premium. It has been shown that air traffic controllers are required to operate with differing parties such as airborne pilots, pilots on the runway, commercial aircraft, training aircraft, and personal aircraft. The air traffic control manager also needs to operate, monitor, and interpret various different information systems within the air traffic control tower which have been detailed in a previous section. An air traffic control manager has a high level of responsibility to ensure the safe departure of aircraft, the safety of airborne flights, and the safe arrival of aircraft. An air traffic control manager needs to remain aware of their operating environment whilst working under high time pressure. Failure to contend with these environmental pressures could lead to catastrophic consequences including fatalities for numerous passengers and staff.

Scenario 7 was found to be an example of the air traffic controller being required to operate under time pressure. In a matter of seconds, the air traffic controller is expected to factor in the speed the aircraft is travelling at, the distance to the airport, current aircraft on specific runways, aircraft that are due to land, and which runway is available for airborne aircraft. The air traffic controller's high level of intuition allowed them to cut through vast swathes of information to reach the correct conclusion for the airborne aircraft (as shown in *Figure 33*).

Request for aircraft to take off whilst working with an airborne aircraft.

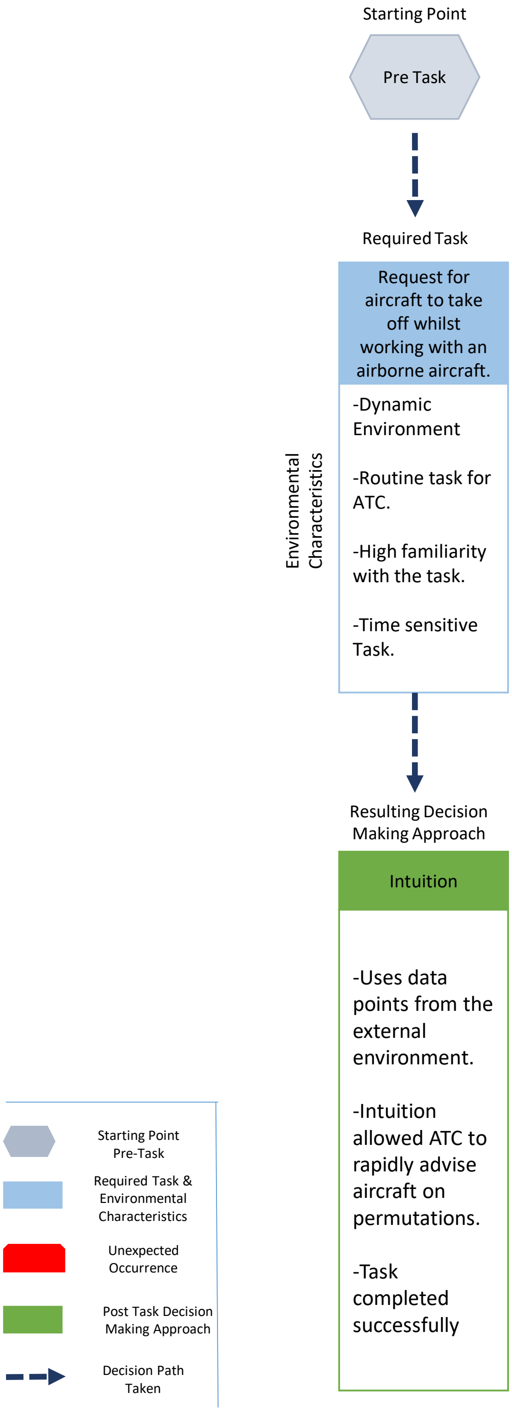

Figure 33. Take off request under time pressure – System Aided Judgement to Intuitive Approach.

The air traffic controller utilised the information system as a secondary data source but relied on their intuition to take the best course of action. The use of the information system and their intuition as a decision-making approach can be seen in Figure 33. Once the air traffic controller had given the airborne pilot the necessary information to land the aircraft, the air traffic controller immediately needs to work with an aircraft on ground for take-off. This shift in the specific task the air traffic control manager was working on can be seen in Figure 33. The air traffic controller began to intuitively scan current aircraft on the runway, aircraft which were due to land, wind speed, wind direction, cross winds, and which aircraft were due to take off. The air traffic controller had the ability to take on board these various pieces of information and instantaneously give the pilot feedback on which take-off procedures to take. The air traffic controller no longer required the use of the information system for the specific task of assisting an aircraft with taking off. As a result of the altering in the task and the operating environment the air traffic control manager changed their decision-making approach to intuition, as can be seen in Figure 33.

A change in decision-making approach was also evident when a warning signal began to sound from the approach desk in the air traffic control tower. The approach desk is a surveillance display which assists the ground movement controller with the use of radar. Whilst at the approach desk the air traffic controller is expected to monitor airborne traffic for any potential issues that may arise. To assist with this the approach desks offers the air traffic controller a map of the area, position of any aircraft in that airspace, data tags which include aircraft information, the speed of the aircraft, and the altitude of the aircraft. The approach desk also has a hotline which allows the air traffic controller to instantly speak to a member of staff from another air traffic control tower. The primary focus of the approach desk is to avoid mid-air collisions of aircrafts. Scenario 4 involved a potential mid-air collision was observed at the approach desk. Prior to the potential mid-air collision occurring, the air traffic controller had been guiding a commercial aircraft to land.

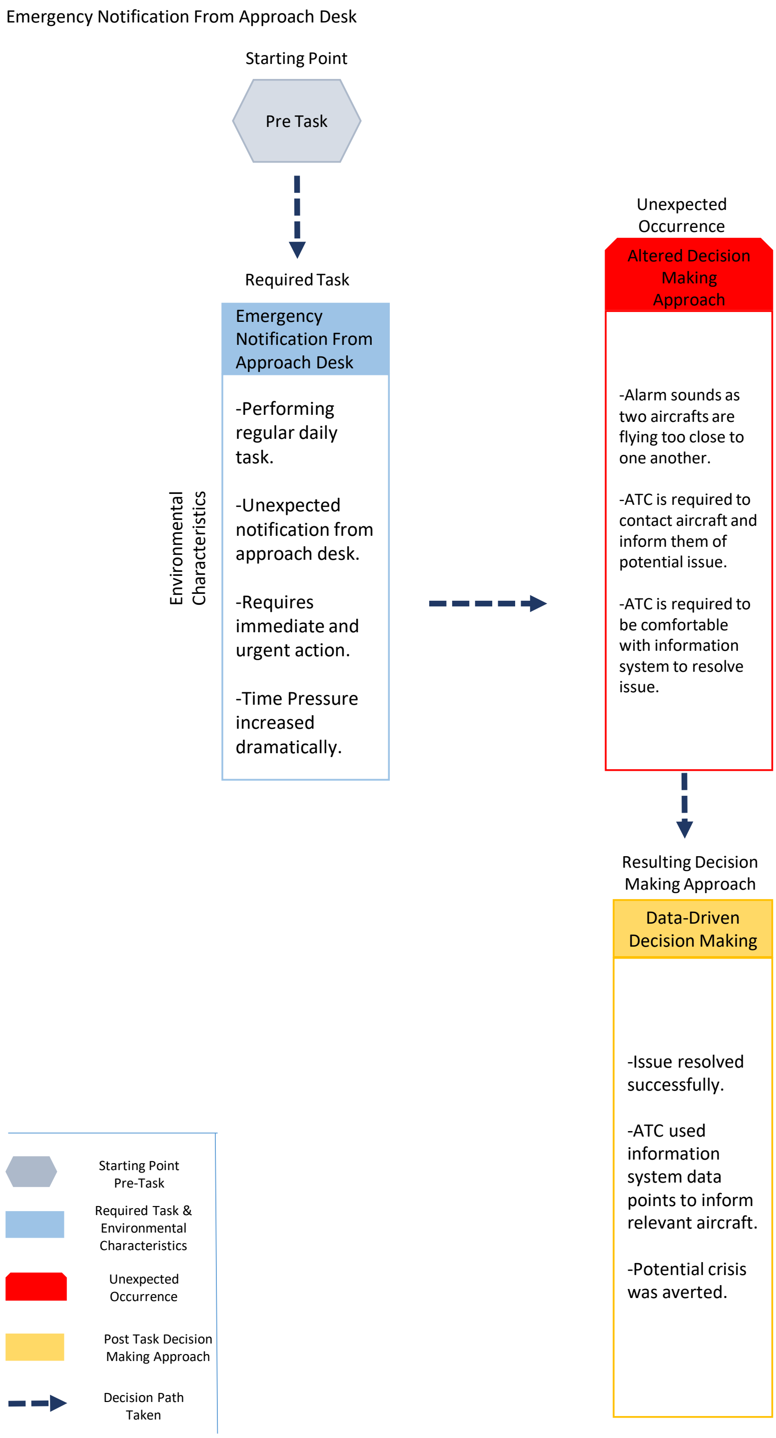

Figure 34. Approach Desk Alarm increases time pressure – System Aided Judgement to Data Driven Decision Making.

As can be seen in Figure 34, whilst assisting the airborne aircraft to land the air traffic controller adopted a system aided judgement approach. The air traffic controller utilises the information system to gain insight into a number of data points such as the actual speed across ground, the altitude the aircraft is flying at, the flight route, the distance from the air traffic control tower, and the true air speed. In conjunction with the information system, the air traffic control manager utilised their intuition to scan the external environment for when the aircraft can land safely, which runway is best suited to the aircraft, and if there are any unexpected circumstances which may result in the aircraft being delayed. Whilst working with the airborne aircraft, the approach desk warning signal began to sound and flash indicating that two aircraft were too close to one another. The operating environment and the task the air traffic controller manager had been working on had now altered. This can be seen in figure Figure 34. As a result of the task and operating environment altering, the air traffic control manager was required to adopt a data driven decision-making approach. Utilising data from the information system, the air traffic control manager would then contact the aircraft pilot to amend the flight trajectory. The aircraft pilot successfully amended the flight trajectory and the approach desk warning signals stopped sounding. In this scenario, the air traffic controller was obligated to adopt a data driven decision-making approach (Figure 34) as it was not possible to view the aircraft which were travelling a great distance away from the air traffic control. The air traffic controller adopted the correct decision-making approach for the task, and the situation was resolved successfully.

This section has reviewed the effects of time pressure on air traffic controller's decision-making process. It was found that due to the environment air traffic controllers operate in time pressure can fluctuate. The fluctuations in time pressure can alter the decision-making approach adopted by the air traffic controlled depending on the scenario. The next section will review data collected in relation to task familiarity.

4.10 Task Familiarity

The previous sections have identified that air traffic controllers operate in a highly dynamic environment. Factors including the operating environment, information fluctuations, and time pressure were found to be contributing factors which can alter the environment an air traffic controller operates in.

The environment was found to dynamic rather than static, which can lead to an increase in uncertainty and raise the ambiguity air traffic controllers need to face in conducting daily tasks. The environment the air traffic control manager operates in was shown to be unexpected, constantly changing, and difficult to analyse. Chapter 2 concluded that when the decision-making approach utilised is aligned with the task characteristics of the scenario decision-making performance can be improved. The following sections will present the findings from data collected in relation to task non routineness, and task interdependency

4.10.1 Task Non-Routineness

As discussed in Chapter 2 low task variety infers that decision makers will have less uncertainty about the task at hand and future activities. High task variety infers that a decision maker will find it increasingly difficult to predict problems and future activities arising. As task variety begins to increase a decision maker will find it increasingly difficult to predict problems and future activities before they arise. This can result in a decision maker becoming more reactive rather than proactive. This can have negative consequences when operating as an air traffic controller.

The previous section identified that air traffic controllers operate in a highly dynamic environment and as a consequence high task non-routineness occurs. High task non-routineness was observed in situations which are outside the air traffic controllers which can be difficult to predict and difficult to react to. One such scenario of high task non-routineness which occurred due to the dynamism of the environment was an incident involving agricultural lime being sprayed on a nearby farm by a local farmer. This scenario was discussed in scenario 6 and is displayed in Figure 35. Prior to the environment shifting and task non-routineness increasing the air traffic controller was at ease interacting with both the information system and the aircraft pilots. It was noted in the observation that the air traffic controller was able to give clear and concise instructions to the aircraft pilots.

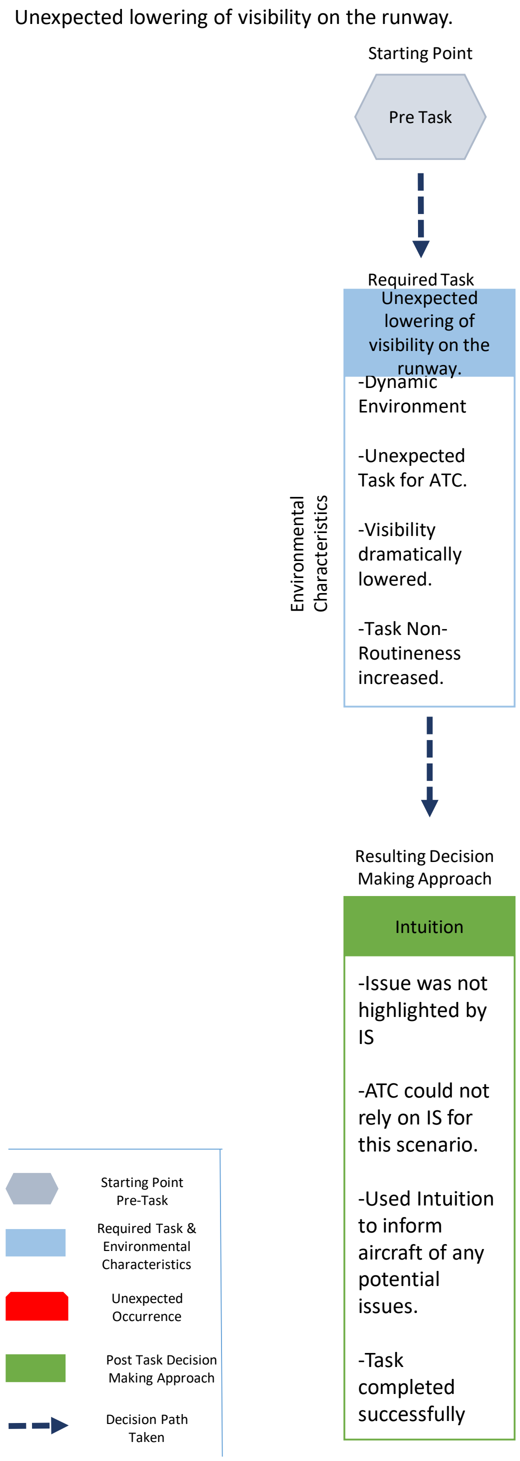

Figure 35. Agricultural Lime Sprayed Task non-routineness increases - System Aided Judgement to Intuition

The initial use of a system aided judgement approach can be seen in Figure 35. This would begin to alter as the environment and task non-routineness shifted due to the agricultural lime being sprayed. Immediately upon seeing that the agricultural lime was being sprayed the air traffic controller began to intuitively inform airborne aircrafts which were due to land and aircraft that were on the runway of the situation facing them. The change in decision-making approach due to the task non-routineness altering can be seen in Figure 35. The air traffic control manager was now utilising their intuition to give the aircraft pilots feedback and advice on the best course of action to take due to the unexpected change in the environments weather conditions.

In this scenario, the high level of task non-routineness was mitigated by the air traffic control managers' vast levels of experience which allowed them to react intuitively to an unexpected event which arose. The air traffic controller knew intuitively how to react and which course of action the aircraft pilots needed to adopt to ensure a safe journey. This change in decision-making approach can be seen in Figure 35. The aircraft pilots were able to receive these instructions rapidly. This is advantageous as aircraft pilots operate in a highly time sensitive environment.

In contrast to the above scenario, it was also observed that the air traffic control manager had a formal and well-defined procedure to problem solving when task non-routineness was lower. A lower task non-routineness was observed in scenario 3 and is shown in Figure 36. In these instances, the task non- routineness the air traffic controller was subjected to was considerably lower than the previous scenario.

In such a scenario, the air traffic controller began to scan the external environment outside the air traffic control tower intuitively to assist with landing the aircraft. The air traffic controller will intuitively scan for a number of data points such as the current runways in use, number of aircraft on the runway, level of crosswinds, the speed of the wind, the direction of the wind, additional aircrafts which are beginning their final approach, and if there are any unexpected occurrences in the immediate area. The shift to an intuitive decision-making approach can be seen in Figure 36. The air traffic controller had an intuitive well defined search procedure to solve the problem that they were facing. These well learned rules had been hardwired to the air traffic controller over a number of years. The air traffic controller was successfully able to land the aircraft due to the information they obtained from the intuitive scan of the external environment from the air traffic control tower. These intuitive scans developed over time allowed the air traffic controller to lower the task variety and task difficulty they were facing for this task.

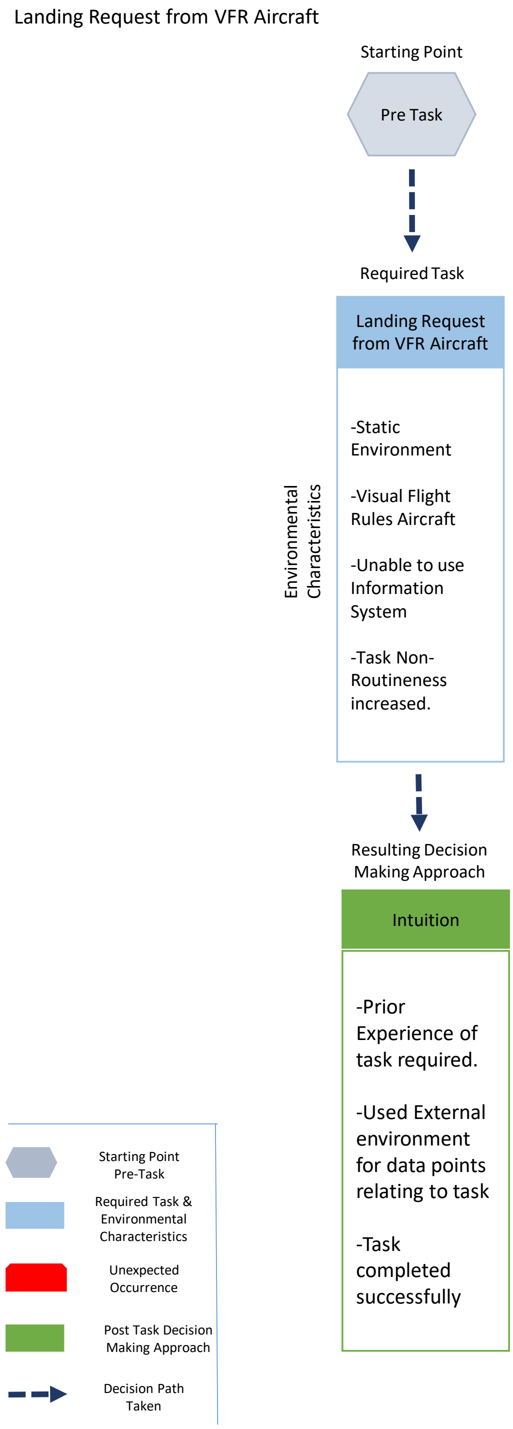

Figure 36. VFR landing request – System Aided Judgement to Intuitive approach.

This section has discussed task non-routineness for the air traffic controller. It was found that shifts in the environment can alter both the task variety and task difficulty facing the air traffic control manager. The altering of the task non-routineness can create scenarios were the air traffic control manager is experienced with or inexperienced in dealing with. The next section will review data collected from a task interdependence perspective.

4.10.2 Task Interdependence

The previous viewed data collected from a task difficult and task variety perspective. Chapter 2 found that in dynamic environments such as those air traffic controllers operate in, interdependent tasks become more important due to the increased need for coordination to resolve ambiguity. This section will review data collected from a task interdependence perspective. Task interdependence is required between the air traffic controller and aircraft pilots to safely ensure the departure and arrival of aircraft. The aircraft pilot is reliant on the air traffic control manager to provide information whilst on the ground, at take-off, mid-flight, and when gaining clearance to attempt landing the aircraft. The air traffic control manager is expected to interact with the aircraft pilot, interpret any information being relayed to them, and give the aircraft pilots the final clearance.

The heightened interdependency of tasks was apparent in a situation of potential crisis such as a mid-air collision between airborne aircrafts. As outlined in previous sections, if a potential mid-air collision arises the air traffic controller is placed under high levels of time pressure to inform airborne pilots to immediately alter the flight trajectory to avoid a potential mid-air collision with another aircraft. If such a scenario occurs, there is a designated alarm and warning system which will notify the air traffic controllers of this potential crisis. This information system is known as the approach desk. It is a radar information system which will assist the ground movement controller if any potential mid-air collisions are potentially arising. The approach desk will give the air traffic controller detailed information on a radar map of the area, the position of any aircraft in the designated airspace, data tags which include aircraft information, the speed of the aircraft, and the altitude of the aircraft. The approach desk also allows the air traffic controller to communicate directly with any aircraft in the vicinity of the area. A scenario involving a potential mid-air collision was observed at the approach desk. Prior to this potential crisis emerging, the air traffic controller had been adopting a system aided judgement approach to assist guiding an airborne aircraft to land safely which can be seen in Figure 37.

The air traffic control manager had over twenty years of experience in landing aircraft and was comfortable assisting an aircraft to land using both the information system and their own intuition. As the environmental uncertainty began to increase the task non-routineness and task interdependency also increased. As the two airborne pilot began to fly in close proximity to one another the approach desk would begin to alarm with warning sounds and lights. The task interdependency in this scenario was now critical as the airborne aircraft needed to be made aware of a potential life-threatening scenario. The airborne aircraft pilots were reliant on the air traffic controller to provide them with the correct course of action to take in this scenario. Due to the altering of the required task to complete and the increasing of environmental dynamism the air traffic control manager was required to alter their decision-making approach. The air traffic controller now altered their decision-making approach to adopt a data-driven approach to decision making as can be seen in Figure 37. The air traffic controller using the data provided by the information system would then contact the airborne aircraft pilot and request them to amend the current flight trajectory. Once the aircraft pilot confirmed the course of action and amended the flight trajectory, the warning signals would stop occurring from the approach desk. This scenario highlights the increasing interdependency between parties when environmental uncertainty increases. In this scenario the air traffic controller adopted the correct course of action by utilising a data driven approach to decision making as seen in Figure 37. This allowed the airborne aircraft pilots to amend their flight trajectory and safely allow both aircrafts to pass.

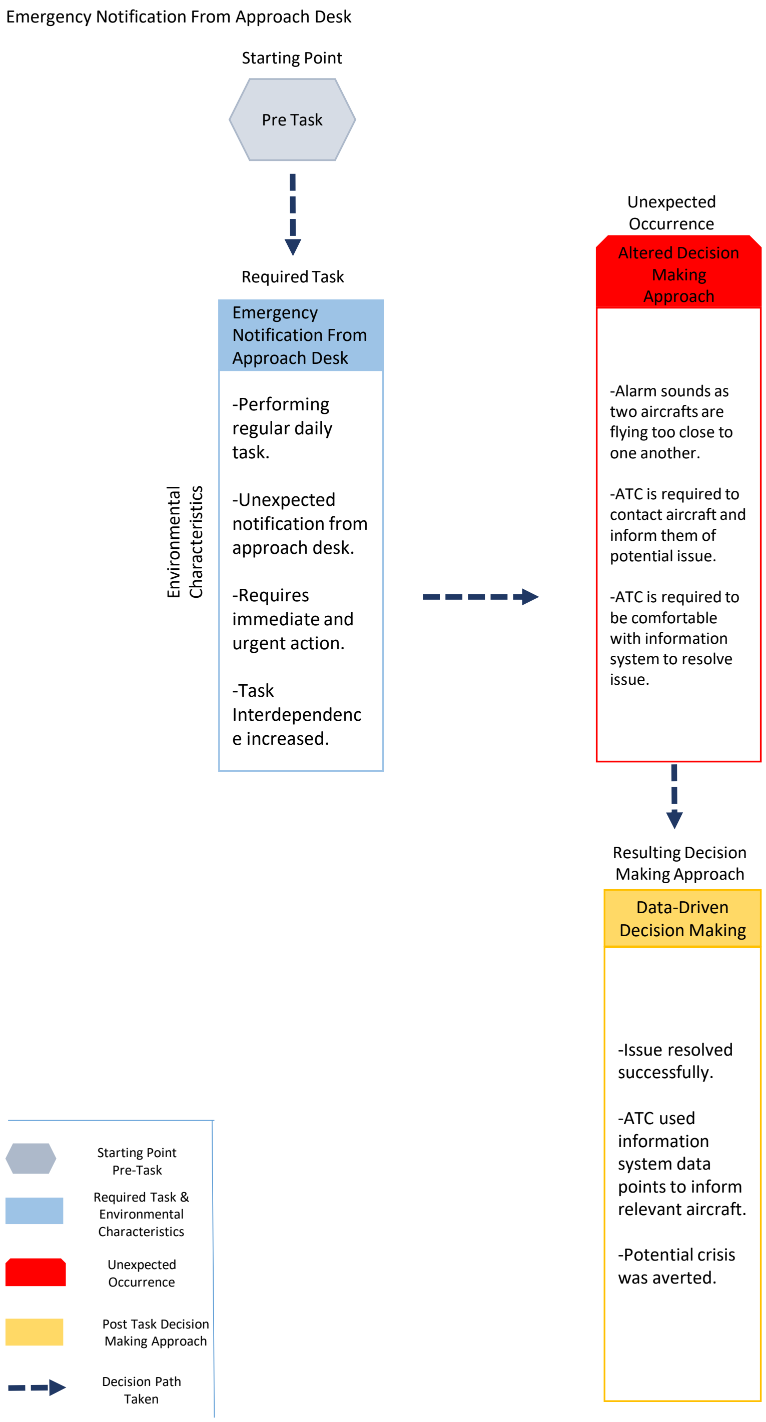

Figure 37.Potential crisis increases task interdependency – System Aided Judgement to Data Driven Decision Making.

This section has reviewed data collected involving air traffic controllers and task interdependency in dynamic environments. It was found that as the environment would become more dynamic, a greater level of dependency between air traffic control and the pilot was required. The next section will review data collected from an intuitive perspective.

4.11 Intuition

Chapter 2 showed that intuition is an associative and rapid decision-making approach adopted by domain experts. It was also shown that in situations when the decision maker is placed under high stress and high time pressure that intuitive decision making can be an advantageous decision-making tool. An intuitive decision-making approach is advantageous in domains of high time pressure as it allows the decision maker to cut through vast quantities of data and make an informed decision rapidly. It was shown in Chapter 2 that as environmental uncertainty increases standard operating procedures are less effective. In these scenarios, it is advantageous to adopt an intuitive decision-making approach. The previous sections have shown the air traffic control manager operates under conditions of high time pressure, high stress, and information fluctuations all within a dynamic environment. In such a dynamic environment it is advantageous for the air traffic control manager to utilise an intuitive decision-making approach.

An intuitive decision-making approach was most commonly used by the air traffic control manager when working with aircraft for ground management. These tasks could include take-off clearance, trafficking of aircraft, runway scheduling, and any potential unexpected occurrences on the runway. When the air traffic control manager had prior experience of a scenario and could view the task in front of them from the air traffic control tower the air traffic control manager would adopt an intuitive decision-making approach.

This was observed in scenario 1 when the air traffic controller is required to assist with an aircraft taking off.

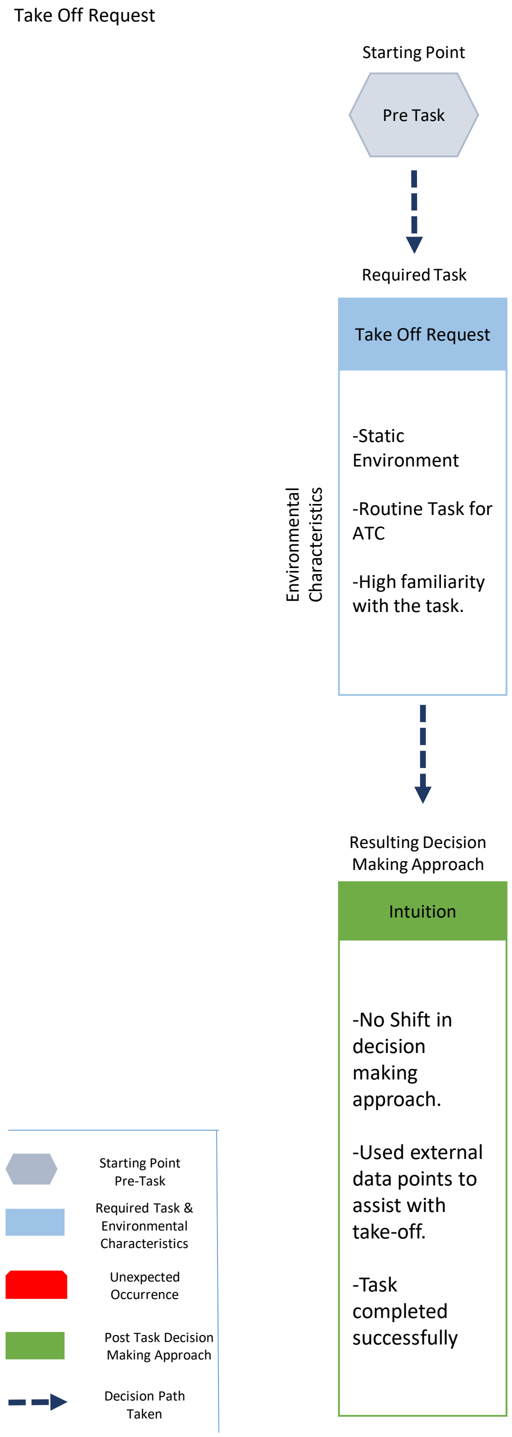

Figure 38. Take off request – System Aided Judgement to Intuitive Approach.

The air traffic controller is required to work with an aircraft which was on the runway requesting permission to take off. This task required a different skillset and the air traffic controller is required to move away from the system aided judgement approach they had been adopting. The air traffic control manager would scan for specific data points in the external environment from the air traffic control tower which would assist the pilot with take-off of the aircraft. These factors include the current number of aircraft of the runway, aircraft which were currently due to land, the wind speed, wind direction, and additional aircraft which were due to take off. The air traffic controller was able to intuitively scan the environment rapidly and cut through vast quantities of data in order to recommend to the pilot the correct take-off procedure. This intuitive decision-making approach as a result of altering the task environment and changes in the environment can be seen in Figure 38. The pilot successfully took the information on board that was provided by the air traffic controller and took off correctly.

This section has reviewed data collected from an intuitive decision-making approach. It was found that the air traffic controllers would use an intuitive decision-making approach in scenarios when they had experience of performing the task previously. It was also found that in situations of potential crisis, an intuitive response can alter aircraft to any dangers they may encounter in the environment. The next section will look at data collected from a system aided judgement perspective.

4.12 System Aided Judgement

Chapter 2 showed that intuition and a data driven decision-making approach are becoming of increasing importance and viewed as beneficial to decision makers in organisations. This skill set is also required by air traffic controllers who are required to use their own judgement in conjunction with an information system. Air traffic controllers are required to interpret, compute and relay information between themselves and aircraft pilots. It is vital for air traffic controllers that they acquire the skillset to utilise both an information system and the human intuitive response system. A breakdown in an air traffic controllers decision-making process can lead to catastrophic and fatal consequences for an aircraft pilot.

System aided judgement was the most observed decision-making approach adopted by the air traffic control manager. System aided judgement was observed to be the default decision-making approach for the air traffic control manager. The air traffic control manager was generally in a relaxed and calm position when adopting a system aided judgement approach. Scenario 2 was identified as a scenario were the air traffic controller was required to use a system-aided judgement approach.

The landing request will be communicated verbally from the airborne pilot to the air traffic controller. Once this verbal request is received it was observed that the air traffic control manager will shift to a system aided judgement approach. The air traffic control manager will gather data relating to the airborne flight from the information system located in front of them. The air traffic control manager will gather data from this information system relating to the aircraft call sign, the actual speed across ground, the altitude the aircraft is flying at, the flight route, the distance from the air traffic control tower, and the true air speed. The air traffic control manager will then use this data they've gathered from the information system in conjunction with data gathered by intuitively looking at the external environment from the air traffic control tower. The use of a system aided judgement approach as a result of changes to the task required and the external environment can be seen in Figure 39. The air traffic control manager will then use both data sets to make decisions surrounding when the aircraft can land safely. These data sets include which runway is best suited to land the aircraft, if there are any unexpected circumstances occurring, which specific runway is free, aircrafts which are due to take off which may impact landings, wind speed, wind direction, speed of the airborne aircraft, and distance of the airborne aircraft to the airport. The air traffic controller successfully combined both data intuitive knowledge of the environment and the information system to assist the airborne pilot with a successfully landing of the aircraft.

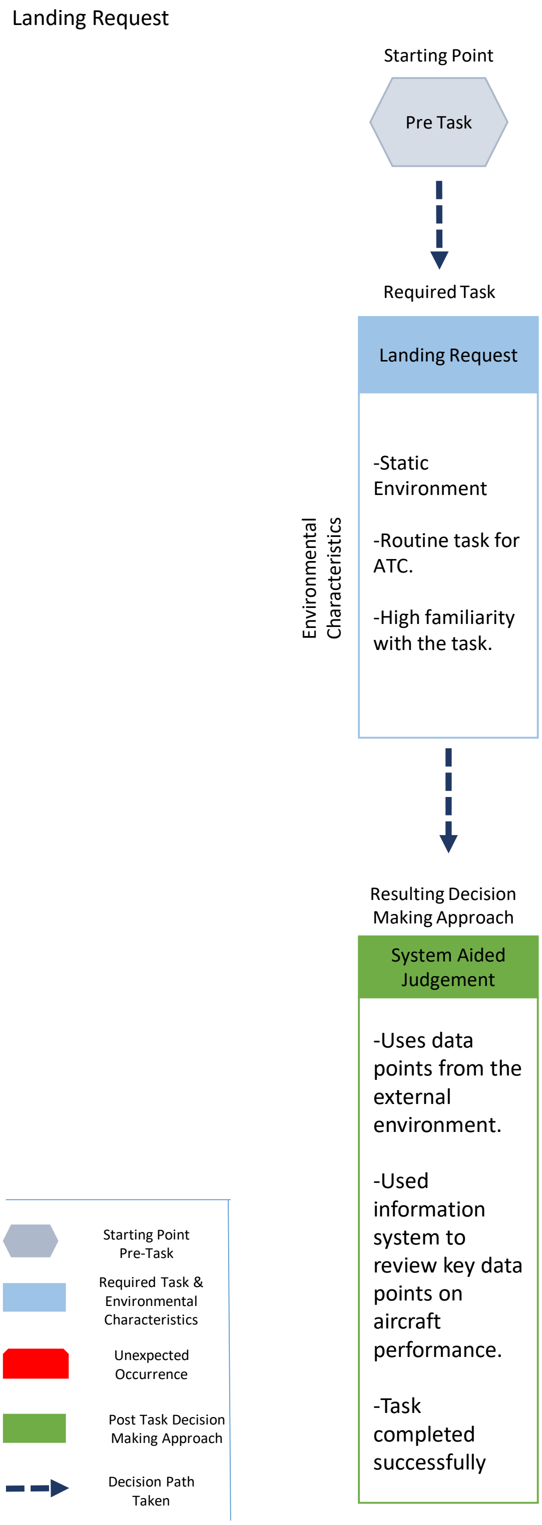

Figure 39. Landing request – Intuitive Approach to System Aided Judgement.

This section has reviewed data observed from a system aided judgement perspective. It was found that this was the most common form of decision-making approach used by the air traffic controllers, however in scenarios were the environment would shift to novel or unexpected occurrences the air traffic controllers would alter their decision-making approach. The next section will review data observed from a data driven decision making perspective.

4.13 Data Driven Decision Making

Chapter 2 detailed how organisations in differing organisations are moving towards a data driven approach to decision making. Data driven decision making is now seen as a key differentiator in organisations, and employees are being hired specifically for their expertise with analytical tools. An air traffic control manager is expected to have a high level of competence for analytical systems and to utilise information systems for various tasks.

The air traffic control manager relying on a data driven approach to their decision making was found to be the least common decision-making approach from the data collected. Despite air traffic controllers needing to be comfortable across a range of decision-making approaches, it was found that the air traffic control manager relied on a purely data driven approach during a potential crisis. A potential crisis was seen and detailed in scenario 4 and is displayed in Figure 40.

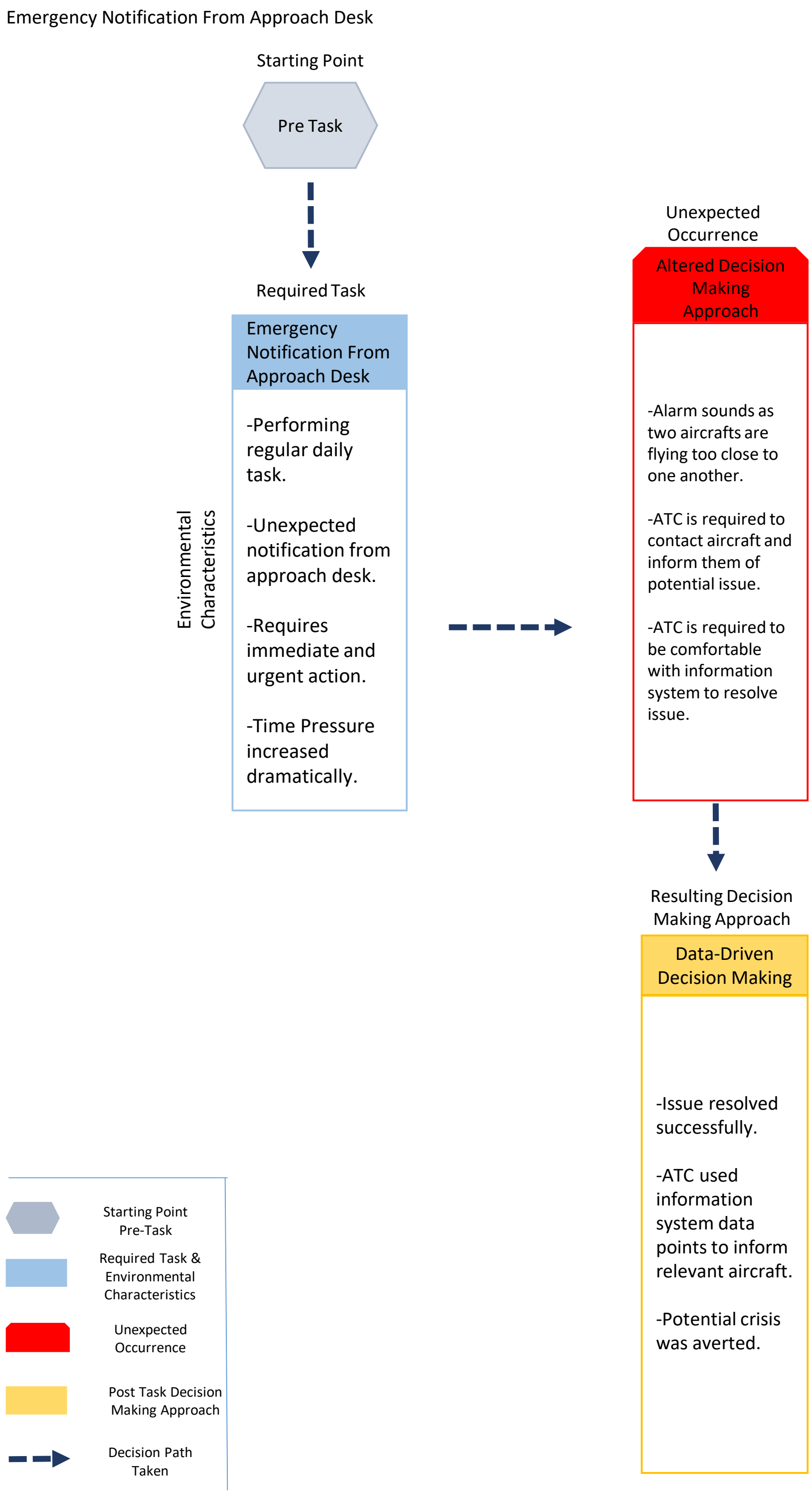

Figure 40. Approach Desk Alarm – System Aided Judgement to Data Driven Decision Making.

Once the alarm and warning signal began to display at the approach desk the air traffic control manager was required to immediately alter their decision-making approach to a data driven decision-making approach. The air traffic control manager was now fully focused on using the data being provided to them by the information system to attempt to resolve the issue. The air traffic control manager was analysing data being provided to them by the information system such as aircraft orientation and travelling speed. The air traffic control manager was now focused and required to use the data from the information system to resolve the issue being displayed. The air traffic control manager would analyse the data for a moment and rapidly contacted the aircraft to recommend the correct course of action for the pilot to take. The pilot then confirmed the course of action and amended the aircrafts flight trajectory. This successfully resulted in the issue being resolved.

4.14 Air Traffic Control Manager Summary

This section has reviewed data collected from a series of observations at an international airports air traffic control tower. Chapter 4 shows that air traffic controllers operate under conditions of high risk, time pressure, and uncertainty. The data collected from the observation sessions confirms these findings by reviewing the data from the perspective of the environment, the task characteristics, and the decision-making approach adopted by an air traffic control manager with over twenty years' experience. The operating environment the air traffic control manager works in can be classified as very dynamic requiring the decision maker to compute large quantities of complex information rapidly. The air traffic control manager is required to ensure the safe departure and arrival of aircraft and to relay the most up to date information available to the pilots. Failure for the air traffic controller to successfully provide pilots with the correct information can lead to catastrophic consequences for all those on board an aircraft.

The air traffic control manager was found to display an intuitive decision-making approach for a number of tasks. An intuitive decision-making approach was most commonly observed when the air traffic control manager was working at the ground movement position dealing with tasks including take-off clearance, trafficking of aircraft, runway scheduling, landing aircraft and unexpected occurrences which may be in sigh of the air traffic control tower. When the air traffic control manager had prior experience of a scenario and could view the task in front of them from the air traffic control tower the air traffic control manager would adopt an intuitive decision-making approach. This was seen when the air traffic control manager was required to work with an aircraft which was due to take off. In this scenario, the air traffic controller would move away from utilising the information system and use an intuitive decision-making approach. The air traffic control manager would look for data points in the external environment from the air traffic control tower such as current number of aircraft of the runway, aircraft which were currently due to land, the wind speed, wind direction, and additional aircraft which were due to take off. The air traffic controller successfully relayed information from the external environment to the aircraft pilot who successfully took off. The air traffic control manager who had over twenty years of experience in this role was quite comfortable not utilising the information system for this task and commented on this stating *"When I get into my car when I'm driving to work, I am continuously scanning for data. I am looking at wind speeds, wind directions, and the weather. I know which direction aircrafts are going to take off from, and how I will land airborne aircrafts."*

The air traffic controller would also adopt a system aided judgement approach when working with aircraft who submitted a landing request or requested detailed long-range weather forecast information. Whilst working with an aircraft which requested to land the air traffic controller was seen to use a combination of the information system but also their intuition. The air traffic control manager will gather data from this information system relating to the aircraft call sign, the actual speed across ground, the altitude the aircraft is flying at, the flight route, and the distance the aircraft is from the air traffic control tower. The air traffic control manager also needs to be aware of aircraft which are currently on the runway either arriving or departing before giving the airborne aircraft permission to land. The air traffic control manager would intuitively scan the external environment from the air traffic control tower for the current runways in use, the number of aircrafts on a specific runway, if there are any crosswinds, the speed of the wind, the direction of the wind, any aircraft which are beginning their final approach, and if there are any unexpected occurrences within visibility of the air traffic control tower. The air traffic control manager will then use this data they've gathered from the information system in conjunction with data gathered by intuitively scanning the external environment from the air traffic control tower to either give the airborne aircraft allow or deny them permission to land.

The final observed decision-making approach adopted by the air traffic control manager was a data driven decision making approach. Despite the numerous information systems available to the air traffic control manager as seen in Figure 26 a data driven decision making approach was found to be the rarest form of decision making approach utilised by the air traffic control manager. It was found that the air traffic controller would adopt a purely data driven approach to decision making in times of potential crisis when there would be a high potential of a negative outcome to the aircraft and personally to the air traffic control manager. An error in decision making by the air traffic control manager could result in numerous fatalities. The air traffic control manager would also adopt a data driven decision making approach when it was required to use the information system and the air traffic control manager had no alternative. An observed scenario of potential crisis when two aircraft began to fly too close to one another resulted in the air traffic controller shifting to a purely data driven approach. Such a potential crisis as a mid-air collision is a high-risk scenario with a potential high personal cost to the air traffic controller and the passengers of the aircraft if there are any errors in guidance from the air traffic controller. The air traffic controller is under a high level of pressure to advise the aircrafts to adopt the correct course of action. It was observed that when the alarm would sound from the approach desk for a potential mid-air collision occurring between two aircrafts that the air traffic control manager would immediately adopt a data driven approach to decision making. The air traffic control manager would analyse the data being displayed by the approach desk for a moment and rapidly contact the aircraft pilots to amend their current flight path. This was a high-risk scenario for the air traffic control manager of which any potential error in decision making would result in a high personal negative outcome for the air traffic control manager and catastrophic consequences for the aircraft. The approach desk is also required to analyse aircraft which are out of the range of human vision. These aircraft can be commercial, private and training aircraft which are be travelling thousands of feet in the air and travelling hundreds of miles away from the air traffic control tower. The air traffic control tower is expected to monitor these aircraft at the approach desk to ensure the airborne aircraft are adopting the correct flight trajectories. Whilst working at the approach desk the air traffic control would not alter their decision making approach away from a data driven approach (see Figure 40). This was a necessity for the air traffic control manager as the aircraft were out of human vision and the use of an intuitive or system aided judgement approach to decision making would be incompatible for this task. This was a highly sensitive task for the air traffic controller to manage and any errors would result in catastrophic consequences for the aircraft and have a high personal impact on the air traffic control manager.

In conclusion it was found that air traffic controllers operate in a highly dynamic environment and are required to adopt differing decision-making approaches depending on how the task is framed in the dynamic environmental context. The air traffic control manager that was observed for this study was found to utilise an intuitive or system aided judgement when the aircraft was visible from the air traffic control tower or the air traffic control manager had a high level of experience of dealing with the task. The air traffic control manager was found to utilise a data driven approach to decision making in scenarios when an aircraft was out of range of human vision and in times of potential crisis. Underlying reasons for this phenomenon could potential be that these scenarios are of high risk and high personal cost to the air traffic controller, as well as being required to utilise the information system as the aircraft is out of the limits of human vision. These underlying reasons will be explored in further detail in Chapter 6.

4.15 Chapter Conclusion

This chapter has discussed two case studies which were classified as being in a dynamic environment. A dynamic environment was classified as having increasing time pressure and information challenges which caused varying task familiarity for the decision maker. The first case study involved aircraft pilots at a European Aviation Safety Agency (EASA). The second case study involved an air traffic control manager of an international airport. The unit of analysis in each case study was the key decision maker or manager. Across both case studies, it was found that the key decision maker would oscillate between differing decision-making approaches. Unexpectedly it was also found that the pilot would oscillate their decision-making approach to a data-driven approach when under examination. This was unexpected as they had previously completed the task successfully when not under examination. In addition, it was also found that the air traffic control manager would be required to oscillate their decision making due to organisational processes. Further analysis of these emerging concepts will be conducted in a cross-case analysis in Chapter 6.

The next Chapter will discuss two further case studies which were classified as being in an undynamic environment.

Chapter 5: Undynamic Environment

The previous chapter discussed two case study sites a European accredited flight school and international air traffic control. In both case studies, the unit of analysis was the key decision maker. Due to considerations such as time pressure, information challenges, and task familiarity these case study sites were classified as being in a dynamic environment. This chapter will now discuss two further case study sites, a pharmacy and national grid control room. In both of these case studies, the unit of analysis is the key decision maker. The chapter will begin by discussing the pharmacist and will subsequently discuss the national grid controller. The chapter will conclude with a summary.

5.1 Pharmacist Introduction

This chapter presents a case study of a pharmacist who was working in a local pharmacy store. As discussed in chapter 2, utilising the correct decision-making approach can improve decision making effectiveness. In highly dynamic environments the contextual familiarity of a task can alter rapidly. This may affect decision making performance if the decision-making approach is not applicable to reflect the changes in the environment. This chapter will review the pharmacists decision-making approach through the lens of cognitive continuum theory. Cognitive continuum theory identified environmental dynamism and the contextual task familiarity as contributing factors which influence the decision-making approach utilised by the decision maker for specific tasks. The literature review detailed the importance of using the correct decision-making approach in a given context and this chapter will discuss in further detail the emergent themes from the conceptual model which has been inferred from the data.

This case study took place at a public pharmacy store located which would have up to twenty patients per hour. The pharmacist manager studied is expected to interact with patients who may require urgent assistance, co-workers who were seeking direction on which quantity of drugs to administer and use a health information system located in the store. The pharmacist manager was identified as an ideal candidate for this study. A pharmacist must work under conditions of high risk, with pressures such as patient well-being and occasional time pressure. Observation for this study took place at a pharmacy which was operated by a senior pharmacist manager and two junior pharmacists. The unit of analysis was the senior pharmacist manager. The unit of analysis was in charge of the two other pharmacists who would support him in his role. The senior pharmacist was the key decision maker and only member of staff who would interact with both the patients and the information system; they were thus deemed the most suitable candidate to be studied.

The literature review detailed the importance of utilising the correct decision-making approach in a given context; this chapter will seek to further understand and build upon this concept by reviewing data collected of factors which influenced the pharmacists decision-making approach in a dynamic environment. As a result of this, this chapter will address the research questions outlined below:

5.1.1 Pharmacist Scenarios

The following section will outline and describe a series of scenarios which the pharmacist was required to conduct. The pharmacist generally had to undertake routine tasks they would complete on a daily basis, but they would occasionally have to complete rarer, high intensity, tasks. The pharmacist was found to be required to complete 8 distinct tasks. The tasks were performed in a live pharmacy. The following sections will provide an overview and discuss the specifics of each scenario.

<u>Scenario 1 - Older female regular patient</u>

The pharmacist would on a weekly basis interact with regular customers which resulted in the pharmacist having a high familiarity with a specific scenario, patient, medication, and the intricacies of the task at hand. When the pharmacist was interacting with the older, female, patient the environment was considered static. The pharmacist felt comfortable and relaxed whilst working through the solution to the task; this was seen by the way the pharmacist interacted, often making jokes and/or small talk with the patient. The regularity at which the older female patient visited the pharmacy meant the pharmacist was not subjected to any high time pressure or other stressors. As the prescription was handed to the pharmacist by the patient, the pharmacist was able to recall previous health conditions, previous medications, and previous medical complications caused by incompatible medication the patient had. In such a scenario it was seen that the pharmacist would ignore or not utilise the information system as they felt they had sufficient knowledge for the situation when interacting with regular patient. The pharmacist had the opportunity to utilise the work-flow manager application on the information system but decided to forego this. This was seen when the pharmacist was required to check for alternative medications. If a specific brand was not available, the pharmacist was able to instantaneously recommend and provide alternative medication products to the patient.

<u>Scenario 2 - Younger female regular patient with new medication</u>

The pharmacist in this instance was required to interact again with a regular patient. It was seen that the pharmacist had an in-depth knowledge of the patient by being able to recall their medication history from memory and also knowing the patient by name. Once the pharmacist was handed a prescription by the patient for a new medication, the pharmacist began to question the prescription to ensure it was valid. Once the prescription was found to be valid, the pharmacist then began to utilise the information-system to search for details on the new medication. The pharmacist would take the medication name from the prescription and search for the medication via the work-flow manager. The information system would then return information regarding dosage amount and any potential complications by consuming this medication. The pharmacist would use the information from the information system in conjunction with the in-depth patient knowledge they had accrued over time to best advice the patient on how to proceed with their medication.

Scenario 3 - Young male patient new to the pharmacy

The pharmacist was also required to interact with new patients who had no previous record of receiving any medication at the pharmacy. This was problematic for the pharmacist as they were unable to rely on previous interactions and the medical history of the patient. It was seen that the pharmacist would seek guidance from the information system if the pharmacist had no previous interactions with the patient and the patient was new to the pharmacy. This was achieved by taking the prescription from the patient, inputting the details into the system, and taking on-board the data relating to a specific medication. The pharmacist would then relay this information to the patient to ensure they would not have any adverse effects from the medication.

Scenario 4 - Regular patient with a child.

The pharmacist was also required to work with medication for children who were regular patients to the pharmacy. Similarly, to scenario 1, it was seen that the pharmacist was able to recall previous aliments and the specific medications that had been used by the child in the past. This was advantageous to the pharmacist as the pharmacist was instantaneously able to use the information they had about the patient's medical history and the requested medication to guide the patient on the best course of action. The pharmacist had the option of utilising the work-flow manager functionality of the information system but decided to forego this option.

Scenario 5 - Older female regular patient and no time pressure

Throughout the series of observations, it was noted that there was minimal time pressure exerted on the pharmacist. The lack of time pressure was seen across all scenarios and for this reason only one scenario will be discussed from a time pressure perspective. Time pressure was found to not impact or alter the pharmacist's decision-making process in any circumstances. The negligible time pressure was evident from the pharmacist who displayed no characteristics of time pressure as outlined in the literature review and remained calm and jovial throughout the process. It was found that when the pharmacist was interacting with a patient whom they had a high familiarity with their personal medical background, past medication use, and current medication usage; the environment was static overall and no time pressure was evident for the pharmacist to complete the task. This was observed when the pharmacist interacted with an older regular female patient. In addition, these results were replicated even when the pharmacist was interacting with a patient who was new to the pharmacy or required new medication the pharmacist was unfamiliar with. It can therefore be stated that time pressure was not a factor which influenced or altered the pharmacists decision-making approach across all scenarios.

<u>Scenario 6 - Older male regular patient with new medication</u>

Despite the low level of time pressure as outlined in scenario 5, the environment would occasionally become dynamic. Such an incident occurred in scenario 6 when the pharmacist was required to interact with an older male regular patient who required new medication. Once this scenario is presented to the pharmacist, they are unable to on their pervious knowledge of administering this specific medication and would need to utilise the information system to seek guidance on how best to administer the medication. This is an important step as If the pharmacist administered medication incorrectly it could have negative consequences for both the patient and the pharmacist. The patient could have their symptoms aggravated or be given a fatal dose of the incorrect medication. The pharmacist could also face financial consequences and be struck off the register due to poor decision making. The pharmacist in this instance utilised the work-flow manager application to search for information relating to dosage amount and allergies to a specific medication. The pharmacist would then use this information in conjunction with their knowledge of the patient's history to successfully administer the correct medication to the patient.

<u>Scenario 7 - Female patient new to the pharmacy requiring new medication for a child.</u>

The pharmacist also had to work with patients who were new to the pharmacy and requested medication the pharmacist was unfamiliar with. Although this scenario was rare, it was important for the pharmacist to correctly administer the medication as there could be negative consequences for both the patient and the pharmacist. In such instances it was seen that the pharmacist would rely solely on the information system to assist with their decision-making. The pharmacist would take the prescription from the patient and search the work-flow manager application for the requested medication. The pharmacist searched the work-flow manager by entering the medication name into a text box and clicking search. Once the medication was found in the work-flow manager, the pharmacist would study the system for information regarding correct selection, dosage amount of the medication, and any potential side effects the medication may cause. The pharmacist would also add the customer as a new patient to the pharmacist, by creating a new patient record and adding the patient's personal information. The pharmacist would then make the patient aware of any side effects or complications the medication would cause the patient.

This section has provided a high level overview and background of the various scenarios a pharmacist needed to undertake to successfully complete their daily tasks. There was a latent pressure on the pharmacist to successfully resolve the patients issue as any error in decision making could have very serious ramifications for both the patient and pharmacist. The next section will provide an overview of the information system used by the pharmacist.

5.1.2 Information System

The pharmacist had the option of interacting with an information system to assist and aid the pharmacist's decision-making process. This system is known as the Clan William Qicscript Plus information system and is utilised by 20,000 clinical users across Ireland and the UK to deliver safer, more efficient, and cost-effective patient services. The Qicscript plus information system offers a number of tools for the decision maker:

(i) Activity summary homepage
(ii) Work-flow manager
(iii) Order and stock control management
(iv) Electronic document scanning.

The activity summary homepage allows the pharmacist to view outstanding tasks and activities with the goal of improving efficiency and organisation within the pharmacy. The pharmacist is provided information regarding appointments scheduled, recent patients, repeat patients due, orders due to check-in, and to do list reminders. The pharmacist may also communicate with a patient directly via an SMS message if a patient needs to be reminded about a medical issue. The work-flow manager allows the pharmacist to view patient information. The pharmacist can use this tool to search for a customer name, address, date of birth, previous associated prescriptions, individual patient medical history, current prescriptions in date, and also view information on specific drugs. The pharmacist can view information regarding recommended drug dosage, how often the drug should be taken, and any particular side effects from this medication. An example of the work-flow manager used by the pharmacist can be seen in Figure 41.

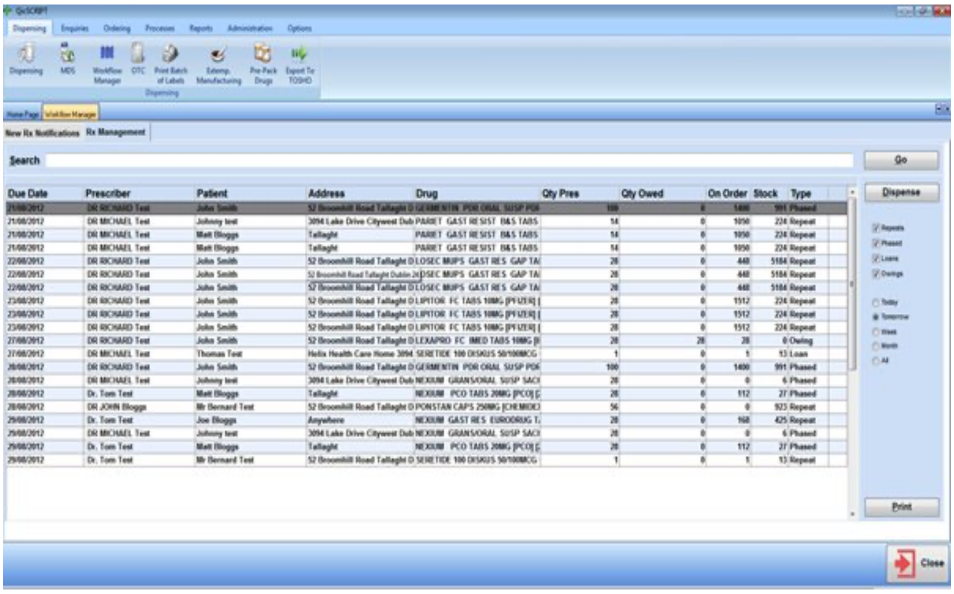

Figure 41 - Qicscript Plus Work-Flow Manager

The pharmacist would utilise the work-flow manager to search for a patient's medical history or log information regarding the patient's current medical diagnosis. The system could then give the pharmacist feedback on which medications had been previously used and which dosage to prescribe the patient with. If the pharmacist chose to ignore this information and dispense a different drug, the system would provide further information about this medication. Information relating to dosage amount, potential side effects, and the patient's medical history would be provided. The work-flow manager allowed the pharmacist to search for detailed information regarding specific medication via a text box and search function. The pharmacist would input the medications brand name and click search. Information would be returned regarding the stock quantity, the correct medication dosage, and any potential complications which may occur by taking the medication. This information allowed the pharmacist to gain a complete picture of potential outcomes that may impact the patient's well-being. In addition, the pharmacist could also add new patients to the information system. The pharmacist had the option via the work-flow manager to add a new patient record; the pharmacist would then be required to enter personal information about the patient such as name, address, and current GP to the information system. This allowed the pharmacist to create a record and treat any new patients who visit the pharmacy.

The information system also allowed the pharmacist detailed stock management assistance. The system allowed the pharmacy to replenish stock levels from the information system and record which medication has been dispensed. The aim of this functionality is to improve profit margins for the pharmacy and increase efficiency of medication being available.

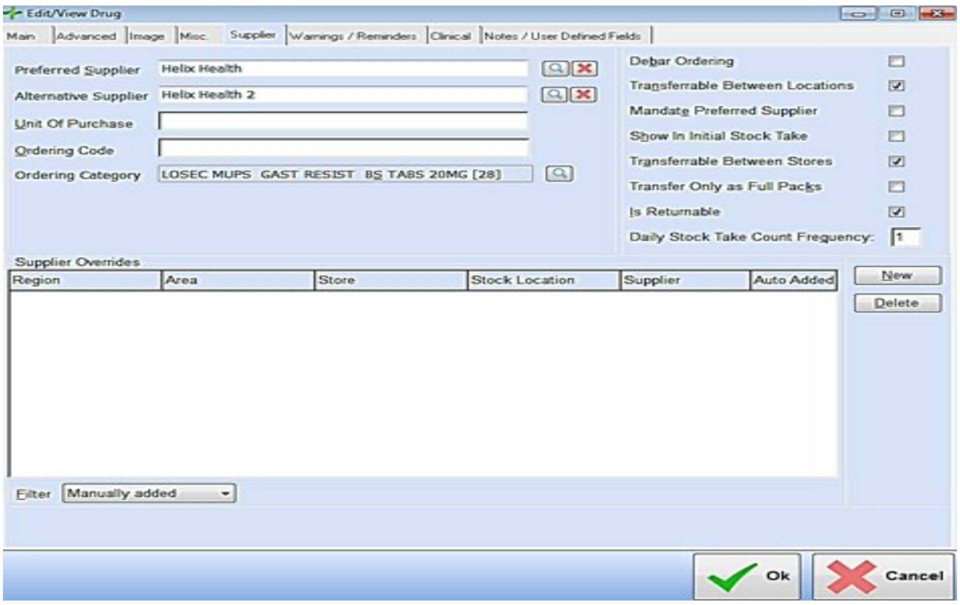

Figure 42 - Qicscript Stock Control Management

The information system also allowed the pharmacist to electronically scan documents. The aim of this functionality is for the pharmacist to go paperless with regards to patients and stock documents. The pharmacist can use this functionality to scan a patient's prescription, assign the scanned prescription to the patient's record, and create a permanent digital record. This is advantageous for the pharmacist as they can quickly review a patient's prescription if there is any ambiguity surrounding it or review past medication a patient has been prescribed.

This electronic scanning functionality can be seen in Figure 43. The pharmacist can scan a number of documents and assign them to a specific record in the information system.

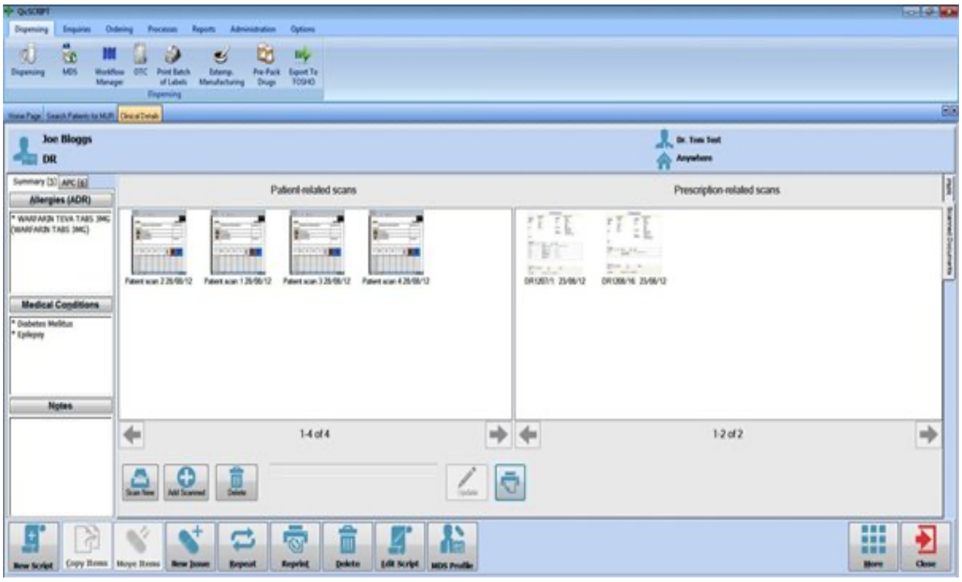

Figure 43 - Qicscript - Electronic Scanning Software

This section has given an overview of the Qicscript information system utilised by the pharmacist. It was found that the information system offers the pharmacist a range of functionality with the overall aims of improving efficiency, quality in the decision-making, and overall productivity of the pharmacy. The next section will review the pharmacists overall operating environment with subsequent sections focusing on the patient interactions, information fluctuations, and time pressure.

5.2 Operating Environment

A senior pharmacist is normally required to perform tasks in a static environment but there may also be circumstances when time pressure, high personal stress, and varying patient dynamics alter this. Despite the static environment, a pharmacist must interact with numerous different types of patients throughout the day whilst also interacting, instructing, and giving feedback to their co-workers. The pharmacist must also interact with a healthcare information system which will provide feedback on specific medications and give recommendations for specific patients. Pharmacists are expected to preform to a high standard and failure to do so can result in catastrophic consequences involving health issues or fatalities for the patients. The incorrect distribution of medication can have high personal cost for the pharmacist from a professional and personal perspective. The subsequent sections will outline how the operating environment for the senior pharmacist was mostly static but with occasionally less common variances. This type of environment resulted in the senior pharmacist feeling comfortable and in control but as the environment became more volatile the pharmacist would need to rely on varying decision-making approaches such as system aided judgement or a data-driven approach to decision making. These differing decision-making approaches were visible in this study of the senior pharmacist.

5.2.1 Patient Interactions

Whilst interacting with a patient the senior pharmacist is expected to input the patient's details into the information system, review key information about the patient, and take in any new information. The failure of the pharmacist to provide the correct medication for a patient could have fatal consequences for the patient. This would also have a high personal cost to the pharmacist with possible criminal proceedings placed against them if a fatal scenario occurred. When the environment the pharmacist was operating in was static, the pharmacist had ample time to review key information from the information system and prescribe the correct medication to a patient for their criteria. Scenario 1 as shown in *Figure 44* is an example of the pharmacist working with a patient.

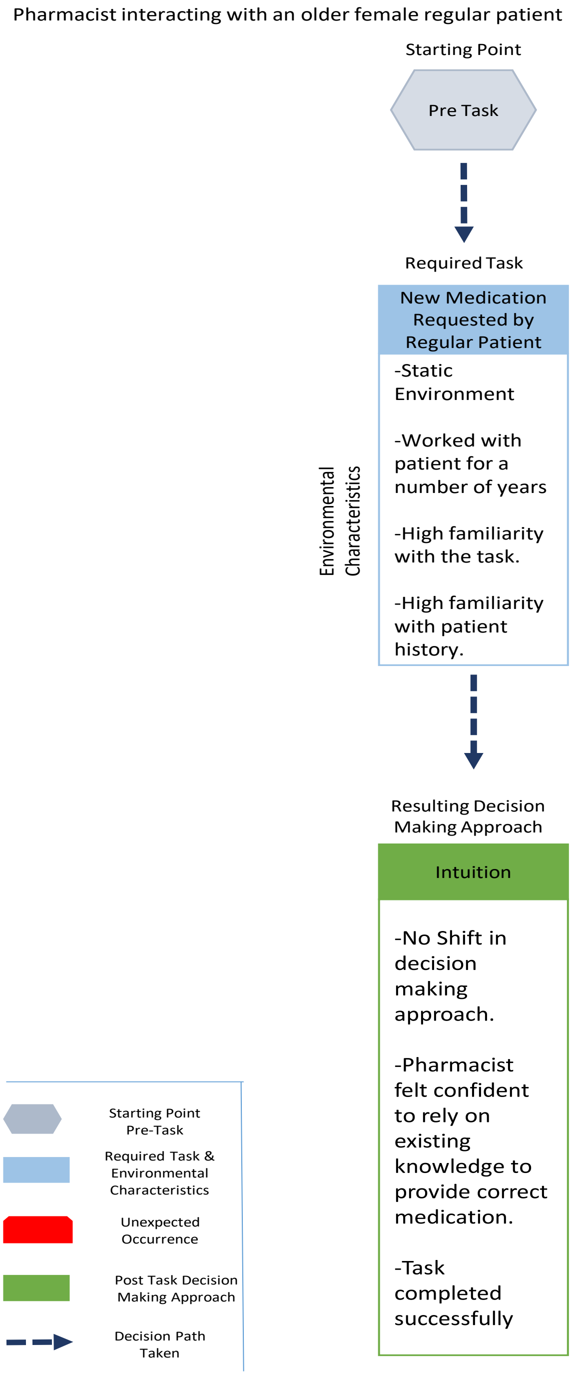

Figure 44 - Pharmacist interacting with an older female regular patient

In scenario 1, it was seen that the pharmacist would ignore or not utilise the information system as they felt they had sufficient knowledge for the situation when interacting with regular patient. The pharmacist commented that the "computer would slow them down". The pharmacist had the opportunity to utilise the work-flow manager application on the information system but decided to forego this. This was seen when the pharmacist was required to check for alternative medications if a specific brand was not available. The pharmacist was able to instantaneously recommend and provide alternative medication products to the patient. It was seen that the pharmacist's high level of medical knowledge, high individual patient experience, and static environment allowed the pharmacist to remain calm and utilise an intuitive decision-making approach.

Scenario 2 outlines the pharmacist working with a regular patient who required a new medication the pharmacist was unfamiliar with and is shown in *Figure 45*.

As the pharmacist was unfamiliar with the specific type of mediation, the pharmacist would take the medication name from the prescription and search for the medication via the work-flow manager. The information system would then return information regarding dosage amount and any potential complications by consuming this medication to the pharmacist. Once this information was obtained from the information system the pharmacist would use it in conjunction with the intuitive knowledge of the individual patient they had gained over the years. The pharmacist later disclosed to the researcher how they were required to double check the information system as they were unfamiliar with the medication and providing the patient with the incorrect medication could result in serious consequences for both the patient and the pharmacist. These consequences could have included illness or a fatal dosage to the patient, whilst the pharmacist may have had their license revoked or faced criminal proceedings. It was seen that when there was ambiguity surrounding a task for the pharmacist they would utilise the information system to reassure themselves of the correct approach. This was an unexpected occurrence and not a factor which was found in the literature review. It was seen that the pharmacist had oscillated from an intuitive decision-making approach to a system aided judgment approach and successfully completed the task.

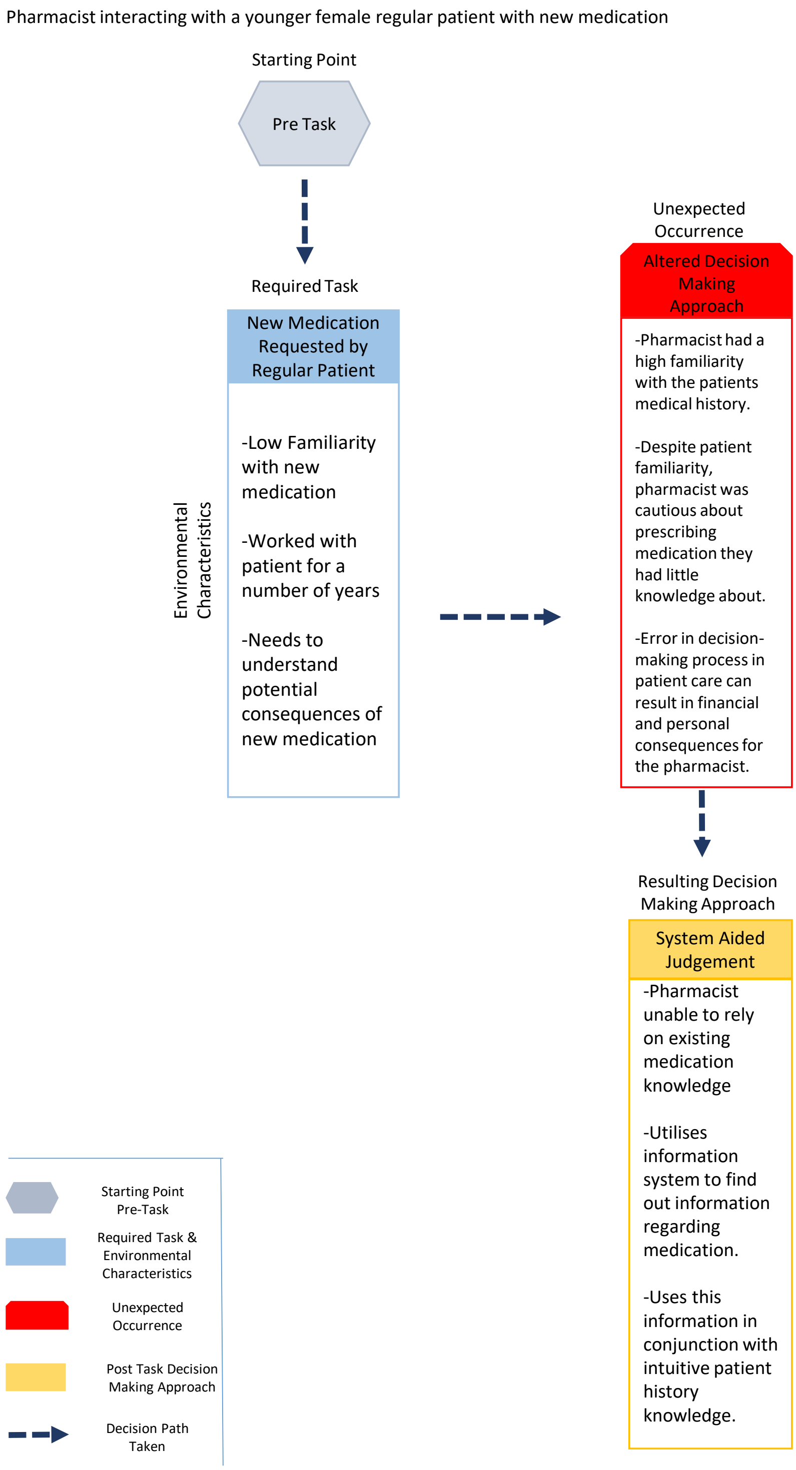

Figure 45 - Pharmacist interacting with a younger female regular patient with new medication

Scenario 3 outlines when the pharmacist is required to work with a new patient to the pharmacy and is displayed in *Figure 46*. In such scenarios the pharmacist was unable to rely on previous patient knowledge accrued from past experiences or use the information system to check for the patient's history as seen in *Figure 44* and *Figure 45*. This scenario occurred when the pharmacist was required to deal with a young male patient who was new to the pharmacy.

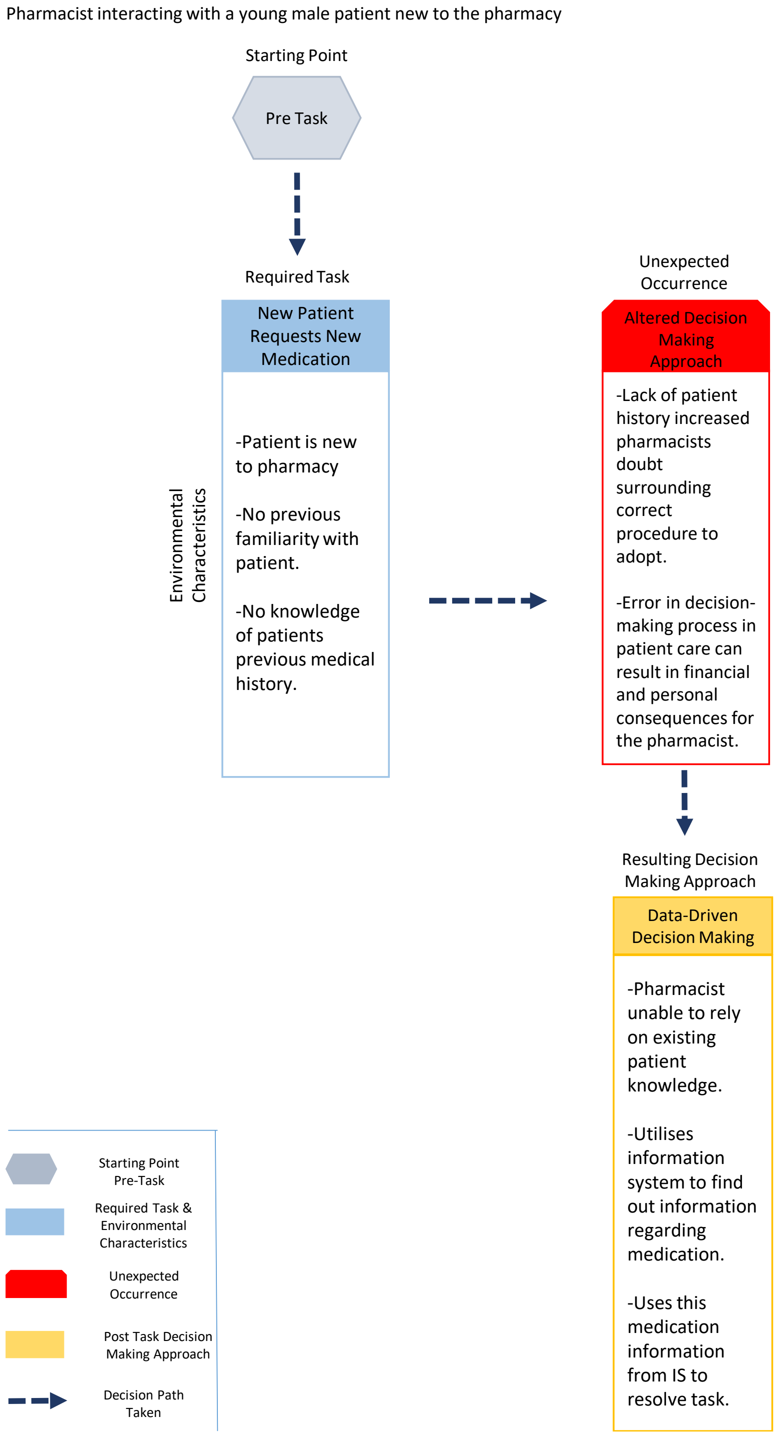

Figure 46 - Pharmacist interacting with a young male patient new to the pharmacy

When the pharmacist had no background knowledge of the patient, they would entirely use the information system as a decision-making tool. This is shown in *Figure 46* with the red text box indicating this was an unexpected occurrence. The pharmacist later noted that this was of critical importance as prescribing the incorrect drug could have fatal consequences for a patient and have severe implications for the pharmacists operating license. This would indicate that the pharmacist was concerned that any negative treatment or negligence on their part may have serious consequences for both the patient and the pharmacist. The pharmacist commented that they could potentially be sued by the patient and also brought before a fitness to practise committee.

This section has reviewed the pharmacist's decision-making process whilst working with a variety of patients. It was found that the pharmacist would oscillate between differing decision-making processes depending on the type of patient encountered which would alter the pharmacist's decision-making environment. It was found and shown in *Figure 44* that when the pharmacist had a high level of familiarity with both the patient and the medication that was requested, the pharmacist was able to utilise an intuitive decision-making approach to rapidly recall the patient's medical history. The pharmacist would then cross check this with any potential complications with the new medication from memory. The pharmacist was also shown to be able to recall past errors the patient may have made when using the medication and warned them not to repeat these specific errors.

This contrasted with the pharmacist's decision-making process shown in *Figure 45*. In this scenario the pharmacist had experience of working with a young female patient extensively in the past but the patient was requesting a new type of medication. The pharmacist needed to use the information system to gain information about the medications correct dosage amount and any potential side effects. The pharmacist would then use this information in conjunction with the intuitive in depth knowledge of the patient's medical history to advise the patient on when to take the medication, the correct dosage to take, and if there were any side effects they needed to be made aware of. The lack of knowledge regarding the new medication the patient requested altered the pharmacist's operating environment and would subsequently adopt a system aided judgement approach. The altering of the decision-making environment for the pharmacist was also seen to have an effect on their decision-making approach in *Figure 46*. In this scenario the pharmacist had no previous knowledge of the young male patient who was new to the pharmacy. This resulted in the pharmacist being unable to utilise an intuitive approach due to having no previous exposure to the patient's medical history. The pharmacist was required to utilise a data driven decision-making approach to seek further information regarding the requested medication from the patient. This was to ensure that the medication was safely and correctly prescribed to the patient. It was seen that when the pharmacist was unsure of a solution or required more information they would revert away from an intuitive decision-making approach and shift towards an information system based decision-making approach of system-aided judgement or data-driven decision making. The pharmacist later revealed that this was due to the potential catastrophic consequences of giving a patient the incorrect medication, dosage amount, or not being made aware of the side effects. Based on what was seen and revealed by the pharmacist it was found that the pharmacist altered their decision-making approach due to potential negative outcomes occurring from an error on their part. This is an important factor which was not found in existing literature and requires further exploration.

5.2.2 Information Challenges

In addition to the operating environment and patient interactions as outlined in the previous sections, information fluctuations were also found to be a factor in altering the decision-making approach of the pharmacist. Information flow for the pharmacist was found to be continuous but of a slow pace whilst interacting with patients, co-workers, and the information system. Whilst working with a regular patient with a child, information was primarily provided to the pharmacist via a medication prescription. It was seen that information fluctuations regarding the information available to the pharmacist would alter their approach to utilising the information system or not.

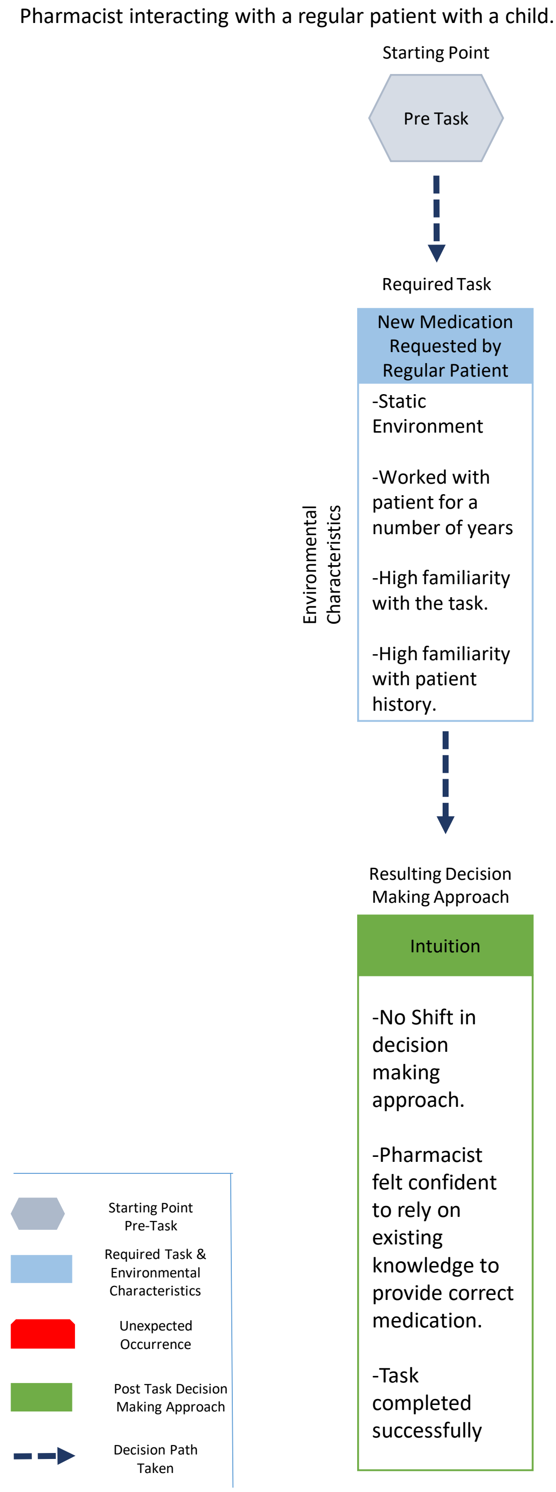

Figure 47 - Pharmacist interacting with a regular patient with a child.

Scenario 4 is an example of the pharmacist interacting with a regular patient and is displayed in *Figure 47*. As the patient with a child was a regular customer, data relating to the patient was available on the information system for the pharmacist to utilise; the pharmacist choose to forego the option of using these data sets and use their own knowledge of the individual patient. The intuitive knowledge the pharmacist had accrued over time allowed the information flow between the pharmacist and patient to be rapid. The pharmacist felt confident in the information that they were able to recall, and using that utilising the information system would have slowed down their progress in completing the task. The rapid information flow was also seen to benefit the pharmacist and their co-workers.

Once the pharmacist had verified the prescription was correct and that the medication was compatibility with the patient's medical history; the pharmacist would rapidly provide specific details on the medication to their co-worker who would then proceed to complete this task. This information was passed to the co-worker rapidly and allowed the patient to receive their medication without delay. As shown in *Figure 47* the pharmacist was successfully able to complete the task without the aid of the information system. It was seen that when information flow between the patient and the pharmacist was high the information system would have slowed down the decision-making process.

This section has reviewed information fluctuations between the pharmacist and the patient, the next section will review time pressure.

5.2.3 Time Pressure

The findings presented in the previous sections have shown that the pharmacist operated in a mostly static environment which would occasionally become dynamic. Unstructured tasks were introduced to the environment in the form of unfamiliar patients to the pharmacist or new medications requested which the pharmacist had not previously worked with. These unfamiliar tasks were shown to alter the decision-making approach of the pharmacist. The literature review concluded that time pressure may also alter the decision-making approach of individuals. Time pressure has been shown to reduce the quality of decisions made, reduce propensity to take risks, and increase the stress that an individual is under all contributing factors which may alter an individual's decision-making approach. The previous sections have shown that the pharmacist is required to operate with different parties such as regular patients, new patients, and co-workers. The pharmacist is required to operate, monitor, and interpret the health-care information system; whilst also being responsible for the safe prescription of the correct medication and correct dosage of medication to a patient. It was shown in previous sections that the pharmacist will shift between differing decision-making approaches to successfully complete a task. Factors such as patient history, medication history, and information fluctuations were all found to influence the decision-making approach adopted.

Although the literature review revealed that time pressure will influence a decision-makers decision-making approach, the pharmacist was found to operate in an environment with negligible time pressure. Negligible time pressure was seen right across the pharmacist’s task and decision-making spectrum. This included whilst the pharmacist was interacting and making decisions whilst working with regular patients, new patients, regular medications, new medications, and their co-workers. This operating environment can be viewed as advantageous for the pharmacist as existing literature indicates time pressure can be problematic for a decision maker. The literature review in chapter 2 showed that decision makers under stress may:

- Inadvertently alter their decision-making strategy to a simpler strategy
- Increase feelings of stress
- Avoid a propensity to rely on negative information
- Filter or omit certain information due to time pressure

The negligible time pressure exerted on the pharmacist resulted in the pharmacist being unaffected by these characterises. Time pressure was found to not alter or impact the pharmacist’s decision-making process in any circumstances. This can be seen in *Figure 48* which is a modified version of *Figure 44* to show the scenario from a time pressure perspective.

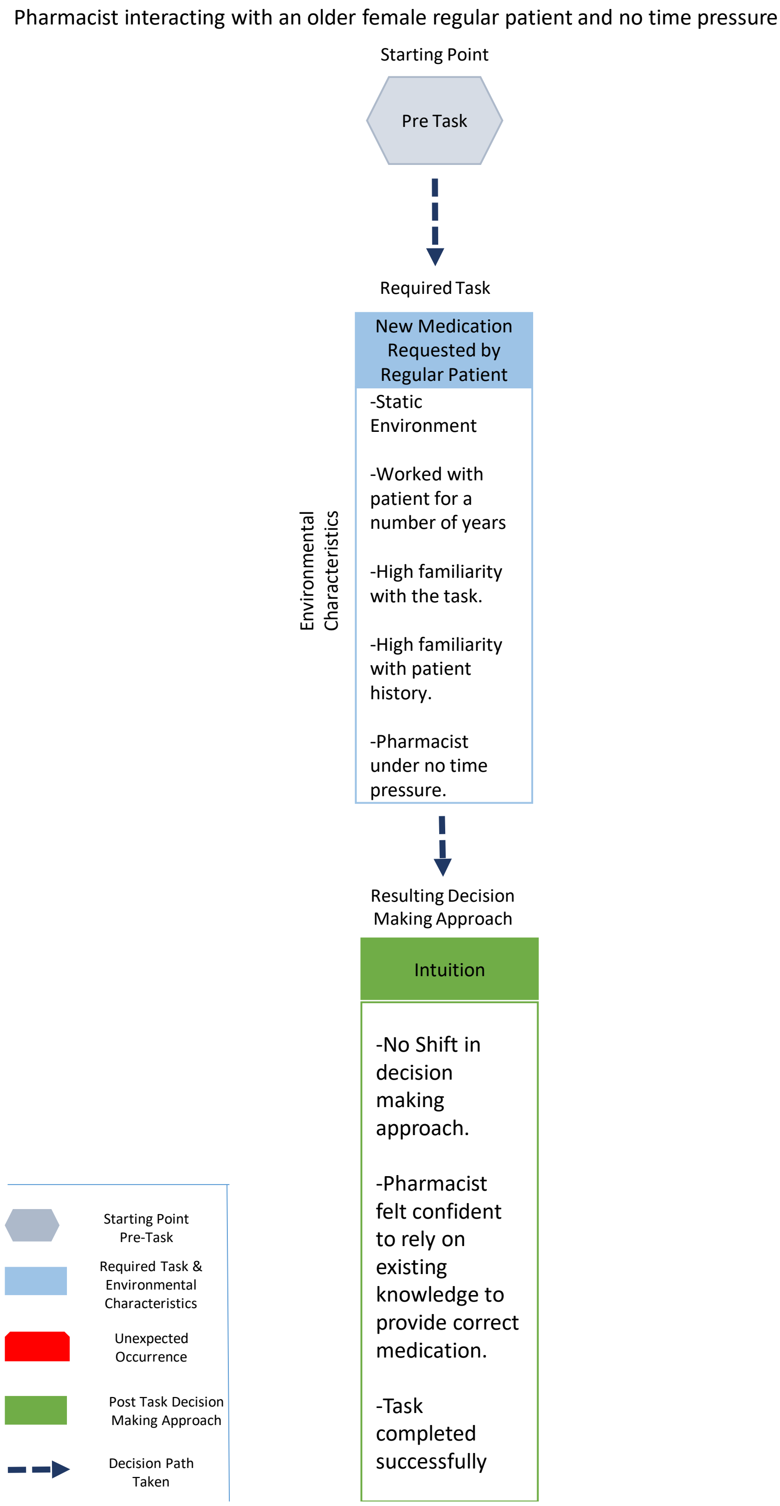

Figure 48 - Pharmacist interacting with an older female regular patient and no time pressure.

Scenario 5 which is displayed via Figure 48 shows the pharmacist interacting with an older female patient who was a regular visitor to the pharmacy. Despite their being a queue of two further patients whilst interacting with this patient, this did not increase or alter the time pressure the pharmacist was placed under. The negligible time pressure was evident from the pharmacist who displayed no characteristics of time pressure as outlined in the literature review and remained calm and jovial throughout the process. It was found that when the pharmacist was interacting with a patient whom they had a high familiarity with their personal medical background, past medication use, and current medication usage; the environment was static overall and no time pressure was evident for the pharmacist to complete the task. These results were replicated even when the pharmacist was interacting with a patient who was new to the pharmacy or required new medication the pharmacist was unfamiliar with. It can therefore be stated that time pressure was not a factor which influenced or altered the pharmacists decision-making approach across all scenarios.

This section has reviewed the effects of time pressure on the pharmacist's decision-making approach. It was found that time pressure was negligible and did not interfere or alter the pharmacist's decision-making approach in any observed scenario. This was found to be advantageous for the pharmacist as the literature review showed that time pressure can negatively affect a decision-makers decision-making approach. This would potentially have serious ramifications for the pharmacist as adopting the incorrect decision-making approach will result in severe professional ramifications for the pharmacist who prescribed the incorrect medication or incorrect dosage to a patient.

5.3 Task Familiarity

The previous section has identified that the pharmacist operated in a moderate to low dynamic environment. It was found that in such an operating environment, information fluctuations, time pressure, and stress were all found to be moderate and did not significantly alter the pharmacist's decision-making approach. The low level of dynamism in the environment allowed the pharmacist to be confident in their decision-making approach. The environment was also found to be static which allowed the pharmacist to analyse specific scenarios at ease. The literature review concluded that when the decision-making system utilised is aligned with the task characteristics of the scenario, decision-making performance can be improved. The following sections will present the findings from data collected in relation to task non routineness and task interdependency.

5.3.1 Task Non-Routineness

It was identified in chapter 2 that task non-routineness is constructed of task variety and task difficulty. Task variety is the frequency of unexpected and novel events that occur when preforming a task. Task difficulty refers to the way individuals respond to problems that arise, and refers to the degree to which a decision maker lacks a formal, well – defined search procedure to solve a given problem. This section will review observations surrounding the pharmacists decision-making approach from a task non-routineness perspective. The previous sections have outlined that the pharmacist operated in an undynamic environment with low time pressure and information fluctuations. This undynamic environment was characterised as having minimal fluctuations in the operating environment with the pharmacists having experienced the various scenarios numerous times in the past.

Task variety can be considered low or high for a decision maker. The literature review identified that when low task variety is present decision makers will have less uncertainty about the task in hand or in future activities. In contrast to low task variety, a high task variety scenario infers that a decision maker will find it increasingly difficult to predict problems and future activities arising. When task variety is low the decision maker will find it easier to predict problems and future activities before they arise. The previous section identified that the pharmacist operates in an un-dynamic environment and as a consequence, task variety is lowered. Low task variety was observed in scenarios which were in the pharmacists control which were easier to predict and react to. Scenario 1 is an example of this occurring in the pharmacy and is displayed via *Figure 49*.

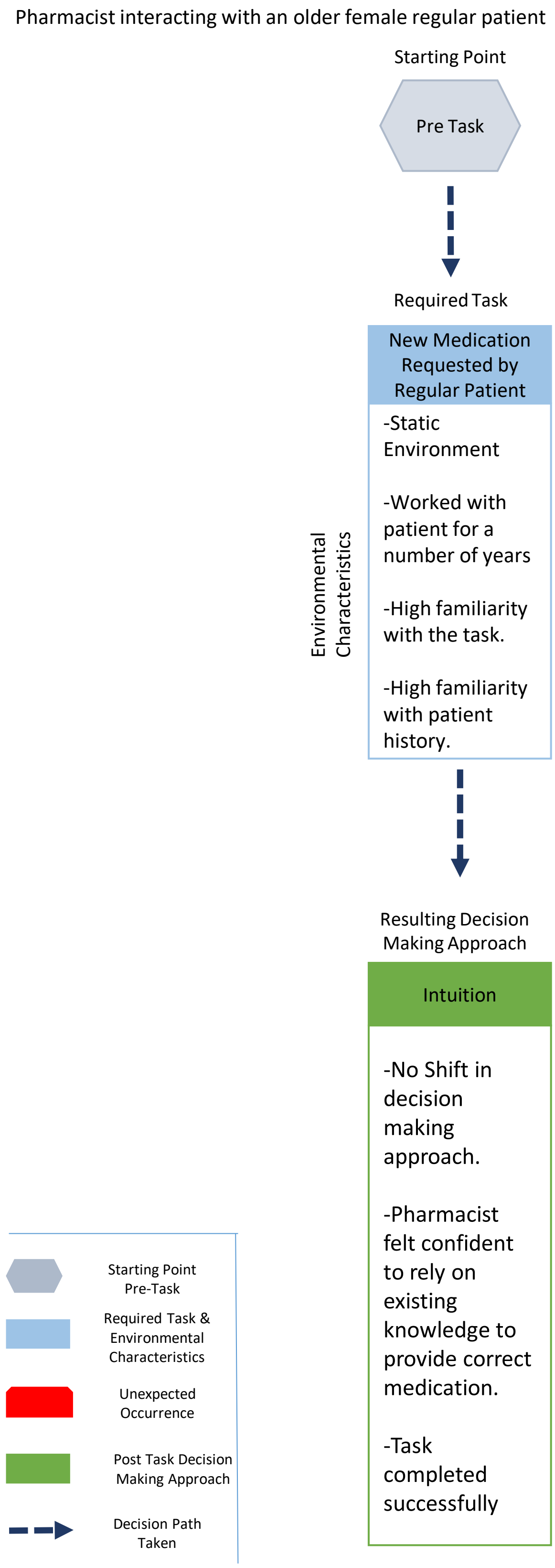

Figure 49 - Pharmacist interacting with an older female regular patient

During scenario 6, the task variety facing the pharmacist was low with a low degree of uncertainty and low difficulty surrounding the task. The pharmacist had encountered this issue numerous times in the past and was comfortable adopting an intuitive decision-making approach to resolve the issue. This is detailed in *Figure 49* when the prescription was handed to the pharmacist by the older female regular patient, the pharmacist was able to recall information about the patient's medical history from adopting an intuitive approach rather than search for the information by using the information system. The pharmacist would later comment that they felt the information system would slow them down when working with a patient who had been visiting the pharmacy regularly. Due to this reason, the pharmacist decided to forego the use of the work-flow manager application. The pharmacist did not need to utilise the information system to search for specific patient details and their medical history. It was seen that the pharmacists high level of medical knowledge, high individual patient experience, in conjunction with a low task variety allowed the pharmacist to remain calm and use an intuitive decision-making approach. These factors allowed the pharmacist to maintain an intuitive decision-making approach and not oscillate towards a data driven approach to decision making. In this instance the pharmacist adopted the correct decision-making approach and was able to resolve the patients issue successfully.

This decision-making approach would alter as the environment the pharmacist was operating in began to alter and become more dynamic. Scenario 6 is an example of this and is displayed via Figure 50. Once the prescription was found to be valid, the pharmacist then began to utilise the information system to search for the new medication. The pharmacist would utilise the work-flow manager application as seen in Figure 41 to search for the new medication. This decision-making approach contrasts with the pervious scenario were the pharmacist adopted an intuitive approach to decision making.

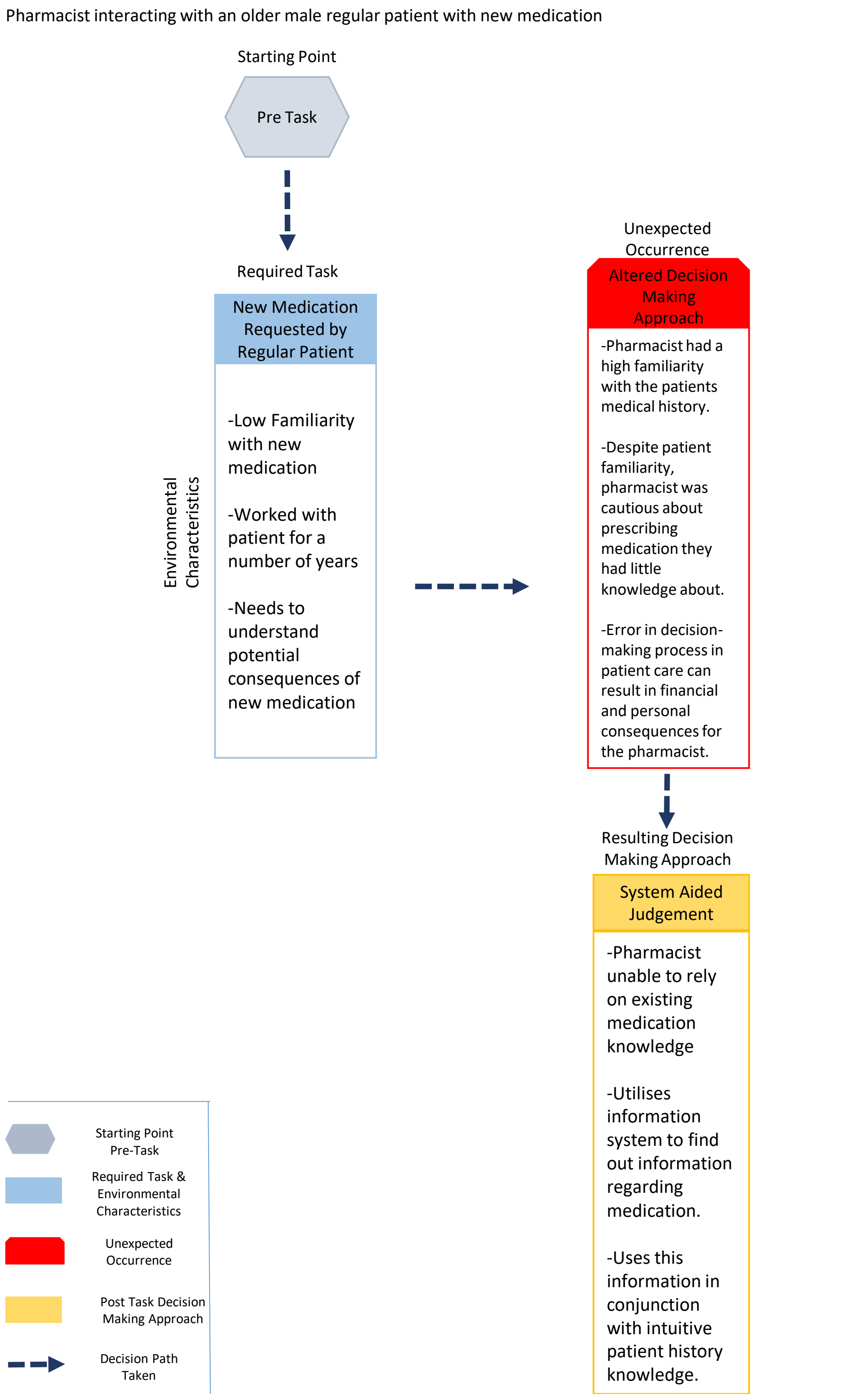

Figure 50 - Pharmacist interacting with an older male regular patient with new medication

It was seen that when the pharmacist had no previous knowledge of a medication that there was an altering in the task difficulty and task variety. The pharmacist in this instance utilised the work-flow manager application to search for information relating to dosage amount and allergies to a specific medication. The pharmacist would use a search function via inputting the name of medication into a text box in the work-flow manager application; once the pharmacist hit search, detailed information on the specific type of medication would be displayed to the pharmacist. Information regarding the correct dosage amount and any potential complications was shown. The pharmacist then had the option of comparing this information vs a pervious medication administered to a patient side by side on the information system. Once this information was obtained from the information system the pharmacist would use it in conjunction with the intuitive knowledge of the individual patient they had gained over the years.

This section has reviewed observations from a task variety and task difficulty perspective. It was found that the pharmacist operated mostly in a low task variety and low task difficulty environment, however, when task variety and task difficulty were increased the pharmacist would alter their decision-making approach towards a data-driven decision-making approach. It is vital for the pharmacist to adopt the correct decision-making approach even when task variety and task difficulty are increased to ensure the safety of all patients. The next section will review the observations from a task interdependence perspective.

5.3.2 Task Interdependence

The literature review showed that as environmental uncertainty increases, interdependent tasks become more important due to the increased need for coordination to resolve ambiguity. Interdependence is required between the pharmacist and their co-workers to ensure the safe administering of medication to patients. Task interdependence was seen in scenarios where a patient would request a specific medication from the pharmacist. Such a scenario was seen when the pharmacist was interacting with a regular patient to the pharmacy with a child. This patient would visit the pharmacy on a weekly basis.

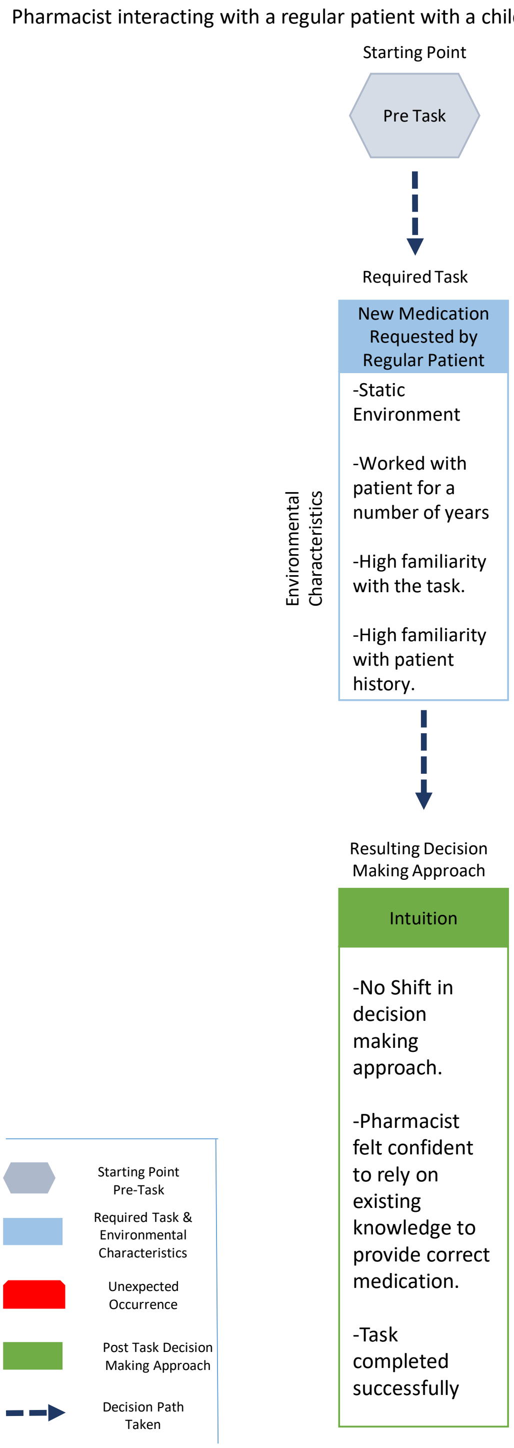

Figure 51 - Pharmacist interacting with a regular patient with a child.

The pharmacist had a high familiarity with the scenario, individual patient, and the task which needed to be completed. The pharmacist had been working with their co-workers for 10 years and described their co-workers as “family’. The high task familiarity of the task coupled with the high familiarity between sub units or independency of units allowed the pharmacist to complete the task with ease. Scenario 4 and shown in *Figure 51* is an example of the task interdependence facing the pharmacist. As the patient was a regular customer, data relating to the patient was available on the information system for the pharmacist to utilise; the pharmacist choose to ignore these data sets and use their own knowledge of the individual patient as seen in *Figure 51*. The pharmacist would later comment that they felt they had sufficient knowledge for the scenario, without relying on the information system. It was seen that task interdependence between the pharmacist and their co-worker was vital to ensure the safe dispensation of medication to the patient. It was seen that the pharmacist’s high level of medical knowledge, high individual patient experience and strong working relationship with their co-worker allowed the pharmacist to remain calm and utilise an intuitive decision-making approach.

This section has reviewed data regarding the pharmacist from a task interdependency perspective. The next section will review data from an intuitive perspective.

5.4 Intuition

The literature review in chapter 2 concluded that intuition is an associative and rapid decision-making system utilised by domain experts. It was shown that in domains of high stress and high time pressure that intuitive decision-making can be an effective decision-making tool. The use of an intuitive decision-making approach allows the decision maker to cut through vast quantities of information to arrive at a decision rapidly. Literature has also shown that as environmental uncertainty increases there is a shift away from structured standard operating procedures to a more intuitive decision-making approach. In these scenarios, time pressure can be extremely high which requires a decision maker to arrive at a decision rapidly. The use of an intuitive decision-making approach is seen in scenarios 1, 4, and 5 represented by *Figure 44*, *Figure 47*, and *Figure 48*. In all three of these scenarios, the pharmacist opted to forego the use of the work-flow manager application on the information system and instead opted to utilise an intuitive decision-making approach. The pharmacist was able to recall previous health conditions, previous medications, and previous medical complications caused by incompatible medication the patient had without the aid of the information system. The pharmacist felt comfortable recalling this information from memory instantaneously utilising their intuition. These scenarios all displayed commonality in that the patient was well-known to the pharmacist; with the pharmacist and the patient having years of interaction with one another. This allowed the pharmacist to build up a personal profile of the patient which could be intuitively recalled for specific scenarios. The pharmacist later revealed they felt recalling past interactions with the patient was a faster and more efficient method than using the information system. This was an interesting disclosure by the pharmacist as one of the primary goals of the information system in the pharmacy is to expedite and improve decision-making.

This section has reviewed data collected regarding the pharmacist from an intuitive decision-making approach. It was found that the pharmacist felt comfortable adopting an intuitive decision-making approach when they had prior experience of working with a patient and were thus comfortably able to predict what the outcome would be. This allowed the pharmacist to instantaneously work through vast swathes of data to provide the optimum medication for the patient. The next section will review data collected from a system aided judgment perspective.

5.5 System Aided Judgement

The literature review in chapter 2 explored how the increasing introduction of information systems to aide employee's decision making has grown dramatically over the past decade. The medical industry and in particular pharmacists, are no exception to this and have seen the widespread introduction of information systems to assist with clinical care. Pharmacists are specifically trained to utilise these systems to improve decision making related to patient care. Incorrect decision making by a pharmacist can result in life threatening scenarios for patients and affect the pharmacist's future career. In addition to the introduction of information systems to the pharmacy domain, the previous section has outlined how pharmacists are required to utilise their own decision-making approach for specific scenarios.

The previous section outlined that as the environment remained static with the pharmacist interacting with a regular patient, the pharmacist would adopt an intuitive decision-making approach which would allow the pharmacist to rapidly complete tasks. This decision-making approach would begin to alter as the environment in which the pharmacist was operating in began to alter. A system-aided judgement decision-making approach was seen to be adopted by the pharmacist when they had an understanding of a scenario but required further clarification on specific points. This was seen when the pharmacist interacted with a regular patient who required a new type of medication the pharmacist was not familiar with. It was seen that the pharmacist was able to intuitively recall information regarding the patient's medical history and discuss this with the patient. In addition, the pharmacist also use the work-flow manager application of the information system to find out specific details about the medication that was to be prescribed. The pharmacist would then use the intuitive knowledge they had stored in conjunction with data from the information system to advise the patient on what course of action to adopt; this is referred to as a system-aided judgement approach.

It is of vital importance for both the patient and the pharmacist that the correct decision-making approach is adopted and the patient receives the correct medication for their illness. A breakdown in decision-making approach may result in the patient receiving the incorrect medication and aggravating their illness. If this were to occur, it would result in the pharmacist potentially being sued and suffering a large financial penalty. The pharmacist would also be called in front of a fitness to practise committee, where there is the potential for the pharmacist to lose their license. This highlights that an incorrect decision-making approach can have negative consequences for both the patient and the pharmacist. The personal ramifications of prescribing the incorrect medication dosage or if it adversely affected the patient the pharmacist altered the pharmacists decision-making approach towards a system aided judgement approach. It was seen that the pharmacist was more likely to utilise the information system when there was ambiguity surround a specific medication that would lead to negative consequences for both the pharmacist and patient.

5.6 Data Driven Decision Making

The literature review in chapter 2 showed how organisations in differing domains are moving towards a data-driven approach to decision making. It was shown that data-driven decision making is now seen as a key differentiator in organisations and employees are specifically being recruited for their expertise in utilising analytical systems. Analytical information systems have also been introduced to the medical domain and in particular pharmacies. Pharmacists are now expected and required to interact with data sets regarding patient medical history, medication information, and data regarding the best course of action for a pharmacist to adopt. The pharmacist is also expected to interpret, compute, and relay this information between the patient, their co-workers, and the information system. A breakdown in this information chain can have catastrophic consequences leading to possible life threatening scenarios for the patient.

It is vital that the pharmacist adopts the correct decision-making approach as it can have negative ramifications for both the patient and the pharmacist. If a breakdown in the decision-making process results in a patient receiving the incorrect medication, the pharmacist may receive financial and professional penalties. It was evident that the pharmacist would take great care in dispensing the correct medication and dosage to a patient. This was seen when the pharmacist was required to interact with a new patient who had no previous record of receiving medication at this pharmacy.

When a new patient to the pharmacy sought specific medication the static environment the pharmacist had been operating in would alter and the pharmacist would need to seek information for the patient through alternative means. The pharmacist would take the prescription from the patient and search the work-flow manage application for the requested medication. Once the medication was found in the information system, the pharmacist would study the system for information regarding correct selection, dosage amount of the medication, and any potential side effects the medication may cause. Using a data-driven approach to decision making, the pharmacist would use the information to look up the correct dosage and any potential side effects of taking this medication. The pharmacist would use the work-flow manager tool on the information system to enter the name of the medication and click search. This would return detailed information about the medication such as dosage amounts and if it would cause an allergy. The pharmacist would then advise the patient on this specific feedback received from the information system. It was seen that when there was a possibility of prescribing a patient the incorrect medication; the pharmacist would adopt a data-driven approach to decision making. This allowed the pharmacist to provide the patient with detailed information regarding the medication to the patient. This detailed information was unavailable to the pharmacist as they had no prior working knowledge of the patient. This is of critical importance as any incorrect medications or dosage prescribed to the patient would have negative consequences for the patient and negative personal consequences for the pharmacist.

This section has reviewed data collected surrounding a data-driven approach for the pharmacist. It was found that the pharmacist will shift their decision-making approach towards a data-driven approach to decision making as more novel and uncertain tasks occur. It was found that in scenarios with novel, unexpected environmental changes, with high task variety and task difficulty the pharmacist will alter their decision-making approach and adopted a data-driven approach. The pharmacist felt this approach was necessary as any incorrect medication distribution would result in potential fatal consequences for the patient.

5.7 Pharmacist Summary

This section has reviewed data collected from a series of observations of a senior pharmacist working in a pharmacy. The data collected looked at the pharmacist through the lens of cognitive continuum theory which consisted of the environment, task characteristics, and the decision-making approach adopted by the pharmacist. As pharmacists are dispensing high dosage medication to patients, it is vital that the correct drug and dosage is administered to the patient. If the pharmacist makes an error in relation to their decision-making approach, it can lead to life threatening scenarios for the patient. It can also lead to professional ramifications for the pharmacist which would be of high personal cost. Ramifications would include being sued by the patient and being called before a fitness to practise committee. It was found overall that the pharmacist operated in a static environment which allowed the pharmacist to routinely adopt an intuitive approach to decision making. It was found that during scenarios of uncertainty the pharmacist would shift their decision-making approach to a data driven decision-making approach. This was seen when the pharmacist was required to work with a new patient or an existing patient who required a new type medication the pharmacist wasn't familiar with. During such scenarios the pharmacist would utilise the information system to further understand any ramifications a specific type of medication would have on a patient. In contrast to the data-driven approach, it was found that when the pharmacist was working under less pressure, less stress, and had past experience with a patient or medication the pharmacist would adopt an intuitive decision-making approach. It was found in such scenarios, that the pharmacist was comfortably to rely on their own decision-making approach without the use of the information system.

In conclusion, this section has found that the pharmacist is normally required to operate in an environment of low pressure, low stress, and with a low level of uncertainty. Despite this the dynamism of the environment can alter these factors and subsequently alter the pharmacists' decision-making approach.

5.8 National Grid Controller Introduction

This chapter reviews data collected in relation to a case study involving the manager of the control room of a national grid power station. As discussed in chapter 2, using the correct decision-making approach given the task characteristics of the task being performed can improve decision making effectiveness. In highly dynamic environments the contextual familiarity of a task can alter rapidly. This may affect decision making performance if the decision-making approach is not amended to reflect the changes in the environment. This chapter will look at the national grid managers decision-making approach through the lens of environmental dynamism, contextual task familiarity, and the decision-making approach utilised by the decision maker for specific tasks.

Having detailed the importance of utilising the correct decision-making approach in the literature review, this chapter will discuss in further detail the emergent themes from the conceptual model which has been inferred from the data.

This case study took place at a national grid control room which is responsible for the safe distribution of power for one half of the country. The other half of the country is managed at a separate location to the control room which was observed. The manager of this facility is expected to interact with information systems which show data relating to power usage, distribution of power, power types such as electricity, hydro-electricity, and wind power. Managers in the control centre of the national grid are also required to interact with on the ground technicians and maintenance teams in real time. The control room of the national grid has a responsibility to these ground crews to direct them to issue resolution and protect them from potential unsafe scenarios. The manager also interacts with two other co-workers in the control room. The manager was viewed as ideal candidate for this study as they operate in dynamic environments often under situations of time pressure and uncertainty. The manager of the national grid is the unit of analysis for this case study.

Observation for this case study took place in a live national grid control room which was operated by three senior control room managers. Each manager interacted with four graphical user interfaces displaying data from a SCADA information system. The manager of the national grid control room is required to be comfortable operating a range of information systems. The SCADA information system utilised by the manager will be discussed in the next section.

5.8.1 Information System

The national grid manager was required to interact with an information-system to monitor, control, and operate the flow of power throughout their region for homes, businesses, and public buildings. The information system utilised was a supervisory control and data acquisition information system known as SCADA. SCADA is a control system architecture that uses networked computers, controllers, sensors of power lines, substations, power plants. SCADA also monitors generators for electricity, hydro-power, and wind turbines. SCADA is an industry standard information system and is used world-wide in production plants, control centres, manufacturing plants, mass transit authorities, governments, and military operations. The manager has a graphical user interface to monitor performance of the various systems and sensors. The system is also able to issue process commands such as decreasing or increasing power production from a specific power source. SCADA allows the manager to control and monitor the flow of energy throughout specific zones in a country from a secure and remote location.

SCADA information system allows the manager to direct control over numerous subsystems as shown in *Figure 52*. Due to the sensitive nature of the control room the manager worked in, it was not possible to take a photo of the live SCADA system; however *Figure 52* outlines the general SCADA setup that is operational at the control centre. SCADA is generally comprised of 5 different functional levels of differing information systems, sensors, and controllers. Level 0 is typically comprised of devices or sensors in the field. This would be sensors and control valves at power plants, hydro plants, wind plants, power lines, and sub stations. These sensors are continuously taking it data surrounding performance levels and if there are any issues.

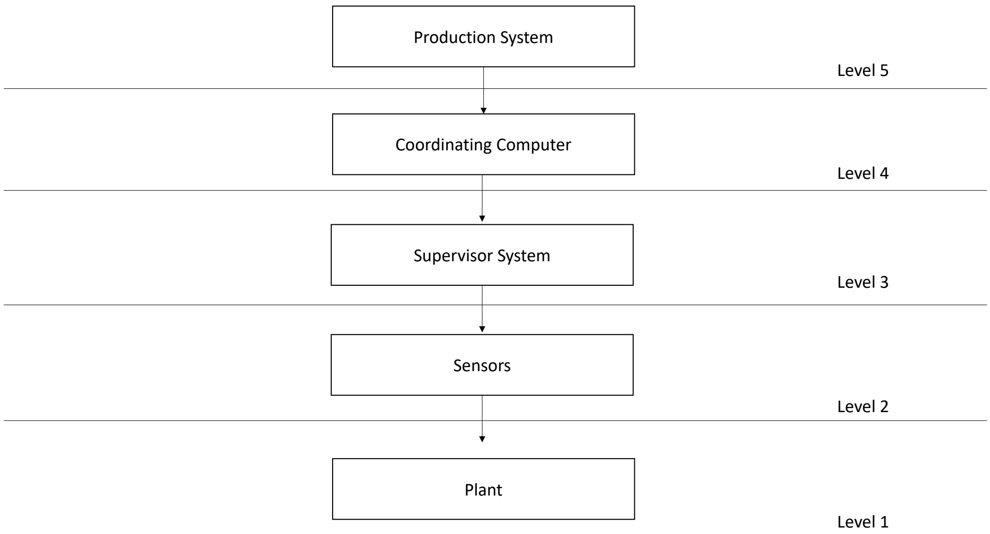

Figure 52 - Overview of SCADA Functional Levels.

Level 1 is the direct control level which contains the input/ouput (I/O) functionality of the information systems, the input/output functionality allows the manager to interact, control and change specific settings on the devices. An example of this functionality would be if the national grid manager was required to turn off or lower the amount of power being generated at a specific location. Level 2 are the plant supervisory computers which collect and collate data from the different nodes on the SCADA system. This data is then presented to the manager visually on the graphically user interface. Level 3 is the production control level which monitors the behaviour of specific nodes and will alert the manager if specific targets are being missed. This is important functionality as it will alert the manager if there is a potential error at a specific location. The final level is 4 which looks after production scheduling of specific tasks that the manager can set.

The manager will use the SCADA system to monitor, control, and interact with various different nodes on the network. The SCADA system also has alarm functionality which will alert the manager if a specific scenario occurs on the network. An example of this would be, an novel loss of power at a specific location will alert the manager to this fault via a message prompt on the SCADA graphically user interface. A text message and email alert will also be sent to the relative personnel to inform them of this error. Once the error is acknowledged the manager will then decide how to proceed and safely resolve the issue. The SCADA information system will not provide the manager with specific details on how to resolve the task. The manager will need to consult and discuss the issue with an engineer who's in the field from the control centre to attempt to resolve the issue. The manager will use the SCADA information system to provide an engineer in the field with the necessary data they require to resolve the issue.

This section has given an overview of the SCADA information system utilised by the manager at the control centre of the national grid. It was found that the information system offers the manager a range of functionality with the overall aim of improving efficiency, quality in decision-making, and overall control of the state's power supply. The next section will review the differing scenarios the national grid manager had to undertake on a daily basis.

5.8.2 National Grid Controller Scenarios

The following section will outline and describe a series of scenarios the national grid manager was involved with. These scenarios encompassed the entirety of the managers daily duties and ranged from mundane tasks to more in-depth problem solving. It was found that the national grid manager was required to complete three distinct scenario tasks. These scenarios will now be discussed in further detail.

<u>Scenario 1 – Monitor Information System for Any Faults or Outage.</u>

A primary responsibility of the national grid manager is monitoring the SCADA information system to ensure the safe and correct flow of energy across their designated zone. The manager has various differing data points to monitor such as data on various substations, specific power line, power generators, hydro power performance, wind power performance, and the overall status of the network as a whole. If these data points are performing as expected they would be displayed in green, amber indicated that there may be a potential issue, and red indicated a serious issue or data point had gone offline. The data points were displayed via four differing graphical user interfaces that the manager could interact with. The manager could click on a specific data point to reveal more information regarding the data point and also check if a differing manager had left a note regarding a specific issue.

Scenario 2 - Manager Contacts Maintenance Team.

In addition to monitoring the SCADA information system for any changes or imbalances in the system, the manager would also be required to contact and liaise with a maintenance team if a serious error was detected. The SCADA information system would automatically detect and display the error to the manager. Once this occurred the manager would be notified by a red flashing icon for the specific data point. The manager would use the SCADA information system to gain more information surrounding the individual faulty beacon. Information from the beacon included how much power was being transmitted on the specific power lines, what the maximum capacity of the lines were, which regions were affected, was it an isolated issue, and if there was a knockout effect to other zones. The manager also utilised the SCADA information system to review power lines and nearby stations which would need to be shut down if repairs needed to take place. The manager would then take this information from the information system to formulate a plan with maintenance teams to resolve the issue in a timely and efficient manner.

Scenario 3 - Change in amount of wind power being produced.

The environment the manager was working in was dynamic and weather conditions in remote locations away from the manager can impact their job performance. The manager is required to monitor the information system closely for any potential changes in power creation on the national grid. Failure for the optimum amount of power being created could create power outages in the localities the manager is responsible for. The manager has responsibility for ensuring public services, businesses, and homes remain being actively supplied by electricity. This highlights the importance and pressure on the manager to make the correct decisions. It was seen that the manager began to notice data from the information system that the amount of power being generated by wind turbines was decreasing due to weather altering. This can produce a knock-on effect whereby power being supplied to services, businesses, and homes is affected due to less power being produced by wind turbines. If the manager was made aware of a potential issue by the SCADA information system or the manager realised that an issue may occur, the manager would contact the relevant station operator to alter the configuration and output on their end. This amended system setup would then be displayed on the national grid managers SCADA information system.

This section has provided an overview of the main scenarios the manager of the national grid will encounter on a daily basis. The subsequent sections will now review these scenarios through the following lens:

- Operating Environment
- Task Operations
- Information Fluctuations
- Time Pressure
- Task Familiarity
- Task Non-Routineness
- Task Interdependence
- Intuition
- System Aided Judgement
- Data Driven Decision Making

These lenses will explore and attempt to explain if and how the manager will oscillate between differing decision-making approaches when working through the three differing scenarios.

5.9 Operating Environment

5.9.1 Introduction

The manager of the control room of the national grid is required to perform tasks in environments of high time pressure, high levels of personal stress, and with varying external environmental conditions which can impact their datasets. National grid managers face numerous challenges such as interacting with a number of different information systems, interacting with ground crews who will seek guidance to resolve issues, and interacting with their colleagues. Due to the varying operating environment national grid controllers are expected to perform to a high standard; failure to do so can result in consequences for electricity supplies to cities, towns, villages, business, and homes. The national grid controllers are required to continuously scan the information system, take on board information, and if necessary, relay this to the ground crew. The subsequent sections will show how the operating environment for the national grid controller is mostly static but can be unexpected and novel.

5.9.2 Task Operations

Scenario 1 outlines the manager performing basic task operations and is displayed in *Figure 53*. The national grid control manager was required to monitor various information system displays to ensure everything was running as expected. The manager would use a system aided judgement approach to scan the four information system monitors for any potential faults or unexpected outages which may have occurred. The information system would display data on various substations, power lines, and power generators and their current status. The substations, power lines, and power generators would be displayed in green, if all was running as expected, amber, if there were any potential issues, or red if the systems were offline. When viewing the monitors, the manager appeared in a relaxed and calm state. The manager was often making conversation with his co-workers on topics external to the job such as sports. The manager was highly experienced in his role with over 20 years' experience of monitoring these information systems for any potential issues and trusted their ability to read a situation correctly. This was evident from the managers confident and relaxed demeanour whilst working with the information systems and interacting with their co-workers. The high level of experience the manager had accrued over time coupled with their confidence surrounding the use of the information systems revealed that the manager had a high familiarity with required tasks.

This was seen when the information system began to display an error message with a power line. As shown in *Figure 53*, the manager had been adopting a system-aided judgement approach whilst monitoring the information system for issues. As the environment the manager was working in was live and dynamic, the manager was required to stay alert at all times to ensure that the system was running as normal. As the environment began to alter, it was seen that the managers decision-making approach would shift. This was seen when a fault occurred with a power line which resulted in a power outage occurring for one particular area. As shown in *Figure 53*, once the environment began to alter the manager's decision-making approach would also shift towards a data driven decision-making approach to attempt to resolve the issue.

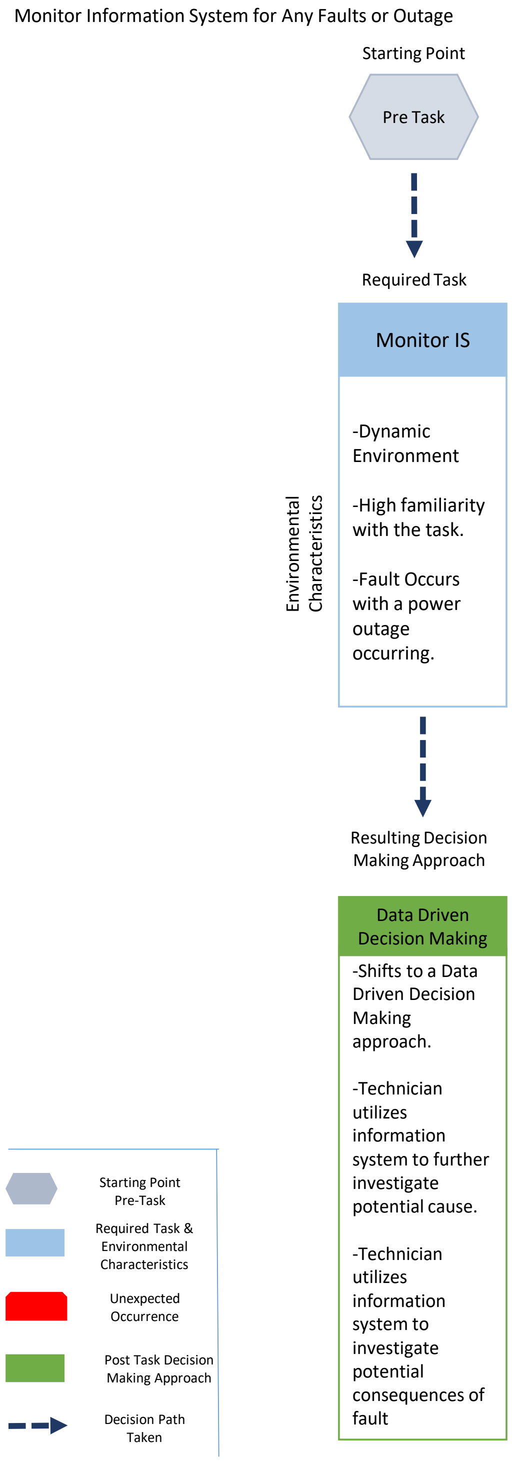

Figure 53 - Monitor Information System for Any Faults or Outage

In this instance the manager immediately paid closer attention to the SCADA information system as a warning signal from one particular power line indicated there was a fault with the line. It was seen that the manager had now altered their decision-making approach to further investigate this issue through the use of the information system. The manager was able to click on the line which was indicating a fault to gather more data surrounding the individual line. Information such as how much power was being transmitted on the power lines and what the maximum capacity of the lines were was displayed. The manager would also use the information system to attempt to discover how the fault occurred, if the outage was due to a system error, a human error, or if the natural environment had caused the outage. Once the manager had gathered data surrounding the root cause of the outage, it was then relayed to service teams who were on the ground.

This section has reviewed the manager of the national grids operating environment. It was found that the operating environment was dynamic and changes can occur rapidly at any moment. It is vital for the manager to remain alert and use the information systems data points to ensure that operations are running as expected. Despite the abundance of data being produced by the information system, it was seen that the manager would also use their intuition or a hybrid decision-making approach referred to as system-aided judgement. This allowed the manager to use a combination of the data being produced by the information system in additional with latent knowledge built over time for specific tasks by the manager. The next section will review these scenarios from the perspective of information fluctuations.

5.9.3 Information Challenges

Information fluctuations were also found to be a factor in altering the decision-making approach of the manager. Information flow for the manager was found to be continuous via real-time data from the SCADA information system. Real-time data was provided to the manager at all times, for all eventualities, and the manager was required to continuously monitor the information system for any potential issues to ensure the safe and correct flow of power throughout their area of responsibility on the national grid.

Figure 53 in the 5.9.2 Task Operations section outlined the managers approach when monitoring the SCADA information system for any changes or potential faults in the network of power throughout their zone of responsibility. This example refers to scenario 1 and from an information fluctuation perspective. This is a very important task as the environment has been shown to be dynamic with changes environment either through human error, system error, or natural faults potentially occurring at any time.

The SCADA information system will provide the manager with real-time data from 1000s of different sensors across the manager's zone relating to performance of power lines, generators, substations, and renewable energy locations. The manager is required to deal with such a range of differing data points and provide solutions for any potential issues that arise. As discussed in the 5.9.2 Task Operations section, the manager monitored the system closely and the system alerted the manager to an error in a specific fault line. This scenario highlights the rapid fluctuations in information available to the manager and overall dynamism of the environment. The manager was expected to utilise the SCADA information system to further understand the issue surrounding this faulty power line before liaising with a maintenance team on the best approach to take for resolving the issue. Information available to the manager in the event of an error was a specific error message, time stamp of the error, specific lines affected, and specific areas that had downtime. In addition to this information, the manager was also required to have a detailed procedural knowledge of best manager practise for specific scenarios on how to long errors, how to action errors, and how to support and direct maintenance teams. This scenario further highlights that there could be variances in information being produce on the ground and by the information system that the manager needed to take on board. These information fluctuations may on the surface appear minor but will affect the managers output when under time pressure to resolve an issue.

This section has reviewed information fluctuations in the managers working environment. The next section will review the manager's decision-making approach from a time pressure perspective.

5.9.4 Time Pressure

The findings presented in the previous sections have shown that the manager operated in a dynamic environment which presented challenges for the decision maker. It was seen that the operating environment would affect the manager's decision-making whilst monitoring the information system, interacting with co-workers, and interacting with various information systems. The dynamism and shifting of the environment may also affect the time pressure that the manager was placed under.The manager has a responsibility, even under time pressure, to ensure the safe production of electricity.

It was seen that time pressure was raised in scenarios were there was an error occurring the network which needed to be resolved. Any error in the network can create electricity downtime or safety hazards for public services, businesses, and homes. It is vital for the manager to manage the increased time pressure correctly and adopt the correct decision-making approach to resolve the issue. Such a scenario was observed when the manager was notified by the information system that there was an outage with a specific power line by the information system. The manager is made aware of an outage by the information system displaying data about the issue and is responsible for finding a solution and putting a plan in place to resolve the fault. It was seen that despite the increase in time pressure to resolve the issue, the manager would remain calm, confident, and relaxed throughout the process. This indicated that the manager had a high familiarity with the task at hand and felt comfortable resolving any issue. As shown in *Figure 54* the manager is required to notify and instruct maintenance crews on how to proceed and resolve issues relating to power outages. During such an outage it was seen that the manager would utilise information system to gather data surrounding the issue.

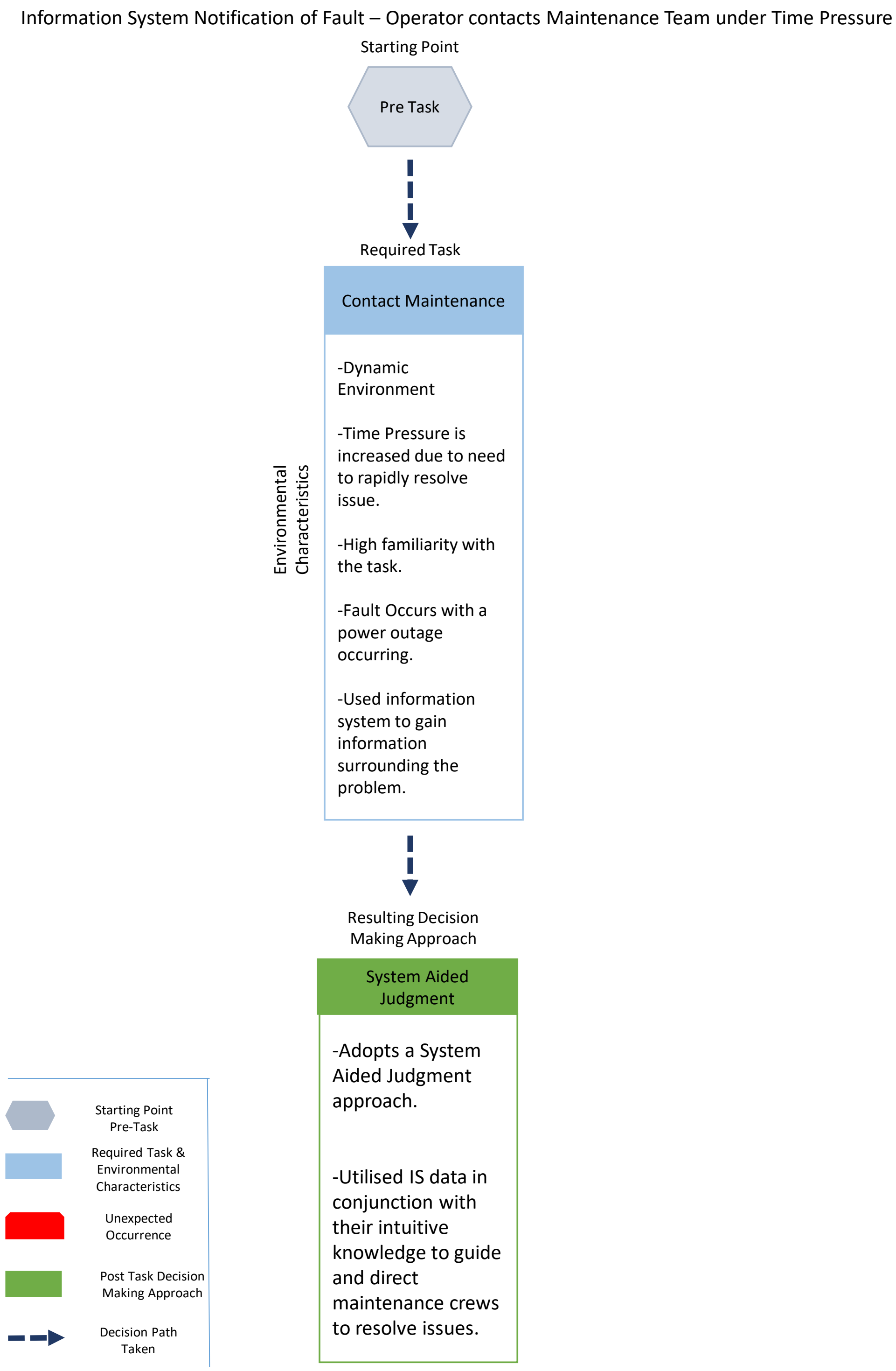

Figure 54 - Information System Notification of Fault – Manager contacts Maintenance Team

The manager would also use their own decision-making process to instruct the maintenance ground team on how to proceed. As time pressure was high, there was an emphasis on resolving this issue as rapidly as possible. It was seen that once the manager had reviewed data surrounding the fault, the manager was rapidly able to use their own intuition to formulate a plan that would assist the ground maintenance team. This is shown in *Figure 54* where the decision maker adopts a system-aided judgement approach as time pressure increases.

The adoption of a system-aided judgement approach allowed the decision maker to gain specific insights about the problem via the information system; crucially the manager was also able to rely on intuitive knowledge about problem resolution built over time. This allowed the manager to rapidly form a plan of action that the ground maintenance team could utilise. The manager took information from the information system such as data surrounding the individual faulty line such as how much power was being transmitted on the power lines and what the maximum capacity of the lines were. The manager also used the information system to review power lines and nearby stations which would need to be shut down whilst the repairs were taking place. Once this data was obtained from the information system the manager would relay this information and direct the maintenance teams surrounding the task at hand. The manager requested specific power lines and generators to be turned offline to accommodate repairs and directed the maintenance crew on the best approach to adopt. It was seen that the manager was able to successfully complete this task despite the increase of time pressure due to adopting a system-aided judgement approach. This approach allowed the manager to gain insights from new data being produced by the information system but also rely on previous known working strategies for specific scenarios.

This section has reviewed the effects of time pressure on the controller’s decision-making approach. Time pressure was viewed as an external factor outside of the controllers control, however it was found that the controller was able rectify issues rapidly even under time pressure. The controller would alter their decision-making approach to resolve issues whilst under time pressure. This was found to be an important skill for the controller to possess as any deterioration in decision-making performance can result in public services, businesses, and homes being without power for a number of hours or days.

5.10 Task Familiarity

The previous section has identified that the national grid manager worked in a low to moderate dynamic environment. It was found that in such an environment that information fluctuations, time pressure, and the operating environment were all found to have a low of dynamism which did not significantly alter the manager's decision-making approach. It was seen that the low of dynamism in the environment allowed the manager to be calm and confident in their decision-making approach. The literature review concluded that when the decision-making approach utilised is aligned with the task characteristics of the scenario the decision-making outcome will be positive. The following sections will present the findings from data collected in relation to task non routineness and task interdependency

5.10.1 Task Non-Routineness

It was identified in Chapter 2 that task non-routineness is constructed of task variety and task difficulty. Task variety is the frequency of unexpected and novel events that occur when performing a task. Task difficulty refers to how individuals respond to problems that arise and refers to the degree to which a decision maker lacks a formal, well-defined search procedure to solve a specific problem. This section will review observations regarding the national grid managers decision-making process from a task non-routineness perspective. The previous sections have shown that the controller operated in an undynamic environment. This was characterised by the controller operating in an environment of low time pressure with familiar tasks to perform and low information fluctuations. It was seen that the controller had experienced the scenarios multiple times in the past.

Task variety can be considered low or high for a decision maker. The literature review identified that when low task variety is present that decision makers will have less uncertainty about the task in hand or in future activities. High task variety scenarios infer that a decision maker will find it increasingly difficult to predict problems and future activities arising. When task variety is low the decision maker will find it easier to predict problems and future activities before they arise. The previous sections have identified that the national grid manager works in an undynamic environment which results in task variety being lowered. The low task variety allowed the manager to remain relaxed, in control of the situation, and arrive at the correct solution for an issue.

Scenario 2 outlines when the manager is required to contact the maintenance team which is an example of low task non-routineness. The manager was now required to process data that had been obtained from the information system. The manager was also required to relay information, direct a maintenance team, and provide support once the team was active in order to resolve the issue. It was seen that the manager was utilising data from the information-system but also their knowledge of the current situation; a system-aided judgement approach was seen to be adopted by the manager. This is visualised in *Figure 55* where its shown that the manager uses a combination of their own knowledge and the latest data that is being provided by the information system about the current issue. It was seen that the task non-routineness facing the manager was low.

The low level of task non-routineness was seen in how comfortable the manager was able to use the information system in reviewing key pieces of information that would assist in resolving the issue. It was again found that the national grid manager worked in a low task non-routineness environment. The manager took data from SCADA information system such as data surrounding the individual faulty line such as how much power was being transmitted on the power lines and what the maximum capacity of the line was. The manager also used the SCADA system to review power lines and nearby stations which would need to be shut down whilst the repairs were taking place.

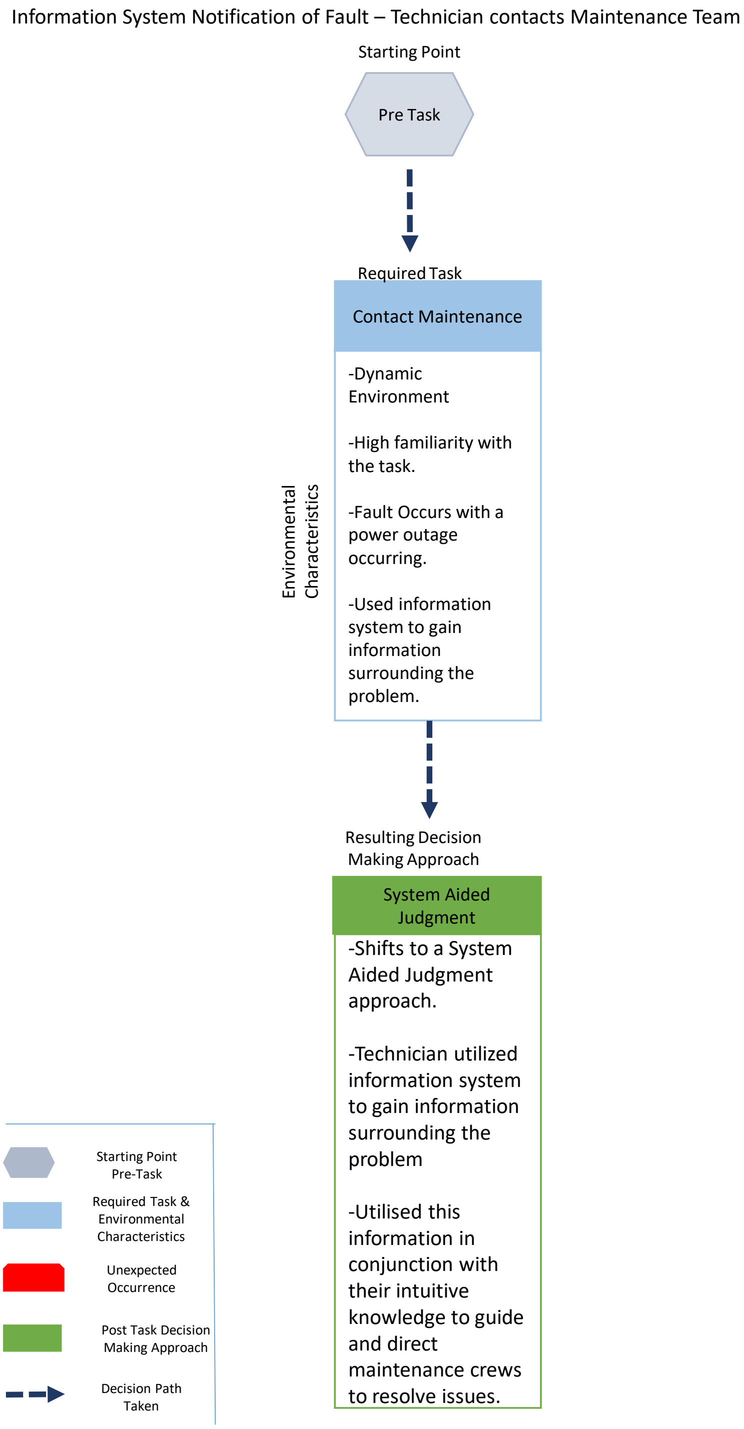

Figure 55 - Information System Notification – Manager Contacts Maintenance Team.

It was also seen that the task non-routineness was low for the manager as they were at ease providing the relevant pieces of information to the maintenance team and using their own knowledge to assist the maintenance team; advising the maintenance team on the best approach to adopt in order to minimise downtime. It was seen that the low task-non routineness allowed the manager to utilise a system-aided judgement decision-making approach which resulted in the task being completed successfully.

This section has reviewed the national grid manager's decision-making approach from a task non-routineness perspective. It was found that the manager worked in a low task non-routineness environment which allowed them to remain calm, comfortable, and in control of their task. It was found that the manager would adopt a data-driven or system-aided judgement approach to decision making depending on what the scenario required. The next section will review scenarios the manager faced from a task interdependence perspective.

5.10.2 Task Interdependence

The literature review showed that as environmental uncertainty increases, interdependent tasks become more important due to the increased need for coordination to resolve equivocality. This section will review data collected from a task interdependence perspective.

Interdependence is required between the manager and their co-workers to ensure the safe and correct flow of energy to a correct location. Task interdependence was observed when the manager was required to lower or increase the output of power being created by a particular power source. The manager may be required to alter the power being generated by a particular location depending on demand or if there is an issue producing the appropriate amount of energy at a particular location. Although the environment was mostly static a scenario such as this can increase the dynamism of the environment. The manager is required to remain alert to the potential of such scenarios occurring at all times.

Scenario 3 is an example of the manager showing the task interdependence required when operating the national grid. The manager would monitor the four graphical user interfaces of the SCADA information system to ensure that powering was flowing correctly.

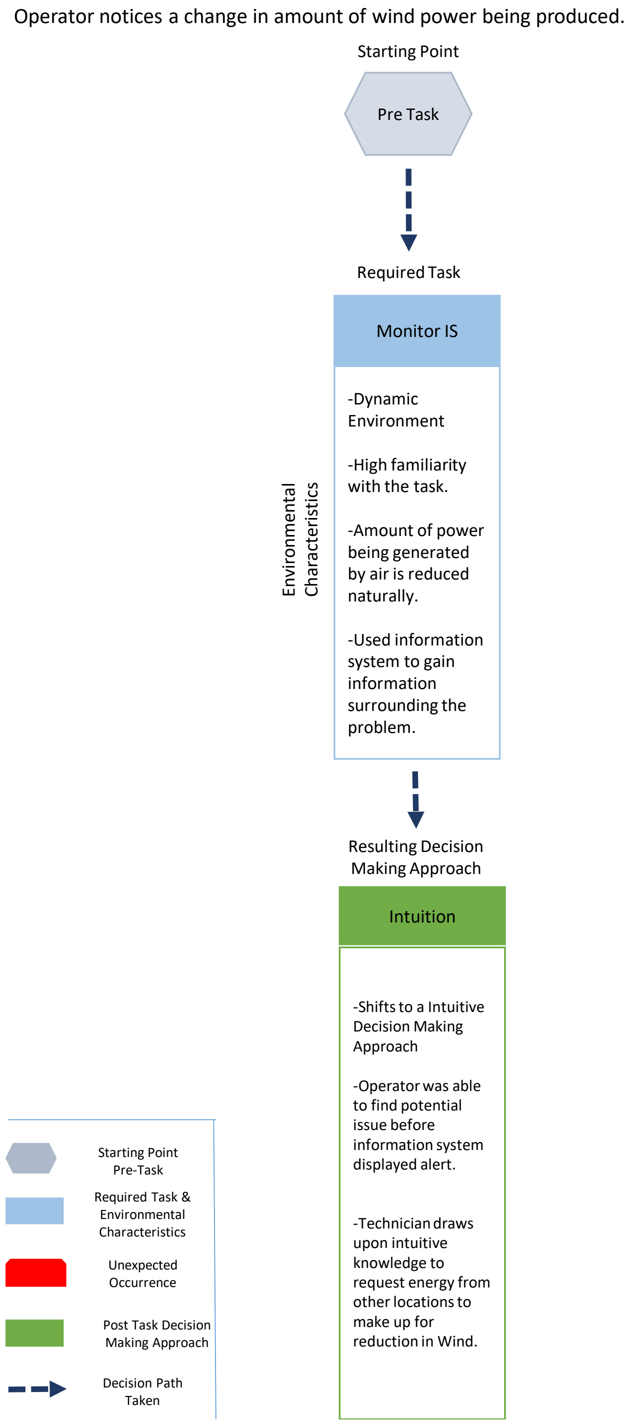

Figure 56 - Manager notices a change in amount of wind power being produced.

It was seen that the manager was made aware by the information system that power being generated by wind turbines was decreasing due to changing weather conditions. Varying weather conditions increase the dynamism of the environment and thus the task interdependence required. As the weather conditions changed, the manager was required to increase power production at an alternative source to counteract the decreasing power being generated by the wind turbine. It was seen that despite the system not actively warning the manager that wind turbines were not generating a sufficient amount of power, the manager was able to recognise this issue occurring before it became critical.

The manager contacted the station manager of an alternative power supply and requested the increase in production of power, as the wind turbines would be lowered over the coming hours. This highlights the increase in task interdependence between the manager and other members of staff as the environment became more dynamic. When the environment is static the manager remains controlled and monitors the information system; however, as the environment became more dynamic it was necessary for the manager to increase their dependency on other members of staff and combine tasks. It was seen that the manager adopted an intuitive decision-making approach for this task which allowed them to infer from the SCADA system an issue before it became critical.

This section has reviewed data regarding the national grid manager's decision-making approach from a task interdependency perspective. It was found that as the environment became more dynamic, the manager became more reliant on other members of staff to ensure that systems were running as expected. The next section will review data from an intuitive decision-making perspective.

5.11 Intuition

The literature review in chapter 2 concluded that intuition is an associative and rapid decision-making approach used by domain exerts. It was shown that in domains of high stress and high time pressure that intuitive decision-making can be an effective decision-making tool. Despite intuition being used in dynamic environment's intuitive decision-making was found to be used by the national grid manager whilst the environment was undynamic. In such an environment, the time pressure facing the manager was low, there were no errors displaying on the SCADA information system, and no unexpected occurrences had occurred throughout the day. On this day a large amount of power was being supplied to the national grid via wind power. This power source can vary in what is produced due to natural conditions of wind which are outside of the manager's control; if the required wind drops below a specific level, an alert will notify the manager that they need to take action urgently. In this instance, it was seen that the manager was able to notice a potential drop in wind performance before the SCADA information system alerted them.

The manager was monitoring the system closely and noticed the drop in performance and began to notify different power stations that there would need to be a switch away from wind power for the remainder of the day. It was seen that the manager felt comfortable utilising their own intuition to resolve a potential issue before it became larger rather than solely rely on the SCADA system to alter them when an issue is occurring. The manager's use of their intuition to allow other facilities to put the necessary plans in place to move away from wind power for the remainder of the day. This pre-emptive intuitive move by the manager lowered the potential time pressure, potential uncertainty, and any potential downtime for power. It was seen that the manager's use of their intuition, despite the abundance of information systems data available to them was an invaluable tool and was respected by their peers.

This section has reviewed the manager's use of an intuitive decision-making approach. It was found that the manager's use of intuition was of great advantage to them in pre-emptively resolving issues before they became larger. The next section will review the manager's decision-making approach from a system-aided judgement perspective.

5.12 System Aided Judgment

The literature review in chapter 2 explored how the increasing introduction of information systems to aide employee's decision making has grown dramatically over the past decade. Control rooms such as the national grid are no exception to this. This was seen in this case study with the SCADA information system the manager utilised drawing data in from 1000s of sensors and displaying this on four graphically user interfaces. The manager had received specific training in order to utilise the SCADA information system to its maximum efficiency and also had over 20 years' experience of using such an information system. The training and expertise the manager had was shown with the ease and comfort the manager displayed in interacting with the information system. The SCADA information system goal is to allow the manager to make the best possible decision by processing 1000s of data points immediately from various locations across the country.

It was seen that the manager would adopt a system-aided judgement approach to decision making when they had an understanding of a specific scenario but required further clarification and could utilise the information system to gain more insight into a problem.

This was seen when the manager was required to interact with a maintenance team when a fault occurred resulting in a power outage. It was seen in such a scenario that the manager displayed expertise on the issue. The manager was able to recall correct procedures and organisational best practise for such a scenario. It was seen that the manager knew which steps to adopt such as shutting down specific lines or facilities close by, how to contact the maintenance team, which data to provide the team, the direction they should adopt, and how to log the issue in the system correctly. In addition to the high familiarity displayed with procedural actions, the manager also felt comfortable using this in conjunction with the SCADA information system to gain real time, up-to date, and location specific data to assist in the problem resolution. Using a system-aided judgement approach allowed the manager to safely and rapidly direct the maintenance team on how best to respond to the issue using procedural knowledge combined with real-time live data from the SCADA information system. This was seen when the manager shut down specific power lines and generators to accommodate repairs almost instantaneously. The manager directed the ground maintenance crew to conduct repairs and the best approach to adopt.

This section has outlined how the manager would utilise a system-aided judgement decision-making approach when the task required them to do so.

It was shown that the manager would use in-depth procedural knowledge of the scenario, combined with real-time data in order to adopt best practise when directing a maintenance team. The next section will review the manager's decision-making approach from a data-driven decision-making perspective.

5.13 Data Driven Decision Making

The literature review conducted in chapter 2 showed how organisations in differing domains are moving towards a data-driven approach to decision making. It was shown that data-driven decision making is now seen as a key differentiator in organisations worldwide. Employees are being specifically recruited for their expertise in utilising information systems. The national grid where this case study occurred was no different to these organisations. The manager is required to have an expertise in utilising the information system rapidly. The manager is required to interact with multiple real-time data sets from 1000s of location points and displayed on four graphical user interfaces via the SCADA information system. The manager is also expected to interpret, compute, and relay this information to other parties such as maintenance teams and/or co-workers if required to do so. A breakdown or misinterpretation of the real-time data being provided could have serious implications for private residences, business, and public sector managers in the region.

The pervious section outlined that the manager would utilise an intuitive decision-making approach or system-aided judgement approach depending on the task scenario and operating environment the control manager was working in. A third decision-making approach referred to as data-driven decision-making was seen and recorded when the manager was utilising the information system to monitor the national grid for any suspected faults or potential errors. It was seen that the manager was alerted of a specific error with a power line in one location. This further emphasised the dynamic and live environment the manager was working in. The manager needed to stay alert and monitor the system at all times. The managers decision-making approach was found to alter when the SCADA information system altered the manager for a particular error. As this error was occurring at a remote location, the manager was required to alter their decision-making approach in order to attempt to gain more insight from the information system in order to best formulate a plan to resolve the issue.

The manager used all four of their graphical user interfaces to display information on the error such as how much power was being transmitted on the power lines, what the maximum capacity of the lines were, and previous error and/or information logs that had been submitted against this power line. The manager would also use the information system to attempt to discover how the fault occurred, if the outage was due to a system error, a human error, or if their natural environment had caused the outage. This information would then be complied and used at a later date when working with a maintenance team or other co-workers to formulate a plan to attempt to resolve the issue as promptly as possible.

This section has reviewed data collected surrounding a data-driven approach for the national grid manager. It was found that the manager will adopt a data-driven approach to decision-making when they are required to solely monitor for potential errors at remote locations. Such a scenario can be described as a novel, with unexpected environmental changes, and including a great deal of task variety. It is important for the manager to monitor the SCADA information system at all times to ensure the safe and correct performance of the national grid in their jurisdiction.

5.14 National Grid Control Manager Summary

This section has reviewed data collected from a series of observations of a manager at the national grid control room of Ireland. This section has given further understanding to how a manager will make decisions during different real-time scenarios the manager faced. This was achieved by focusing on and discussing different aspects of the manager's decision-making approach; including the information system, the operating environment, the task characteristics, information fluctuations, time pressure, and task familiarity. Specific scenarios were then discussed from an intuitive, system-aided judgement, or data-driven decision-making approach. It was seen that the manager is required to remain alter at all times and have the ability to compute large quantities of data that the SCADA information system is producing and displayed on four graphical user interfaces. The large amount of real-time data being produced places further importance on the decision maker to adopt the correct decision-making approach.

The manager was found to primarily adopt a data-driven decision-making approach to resoling tasks. This was due to the nature of the role which predominately required the manager to monitor the graphical user interface of the SCADA information system to ensure the safe and correct flow of energy throughout the network. This indicated that when the overall operating environment facing the manager was static in nature the manager was comfortable and correctly used the information system in a monitoring capacity. In contrast, it was found that as the environment became more dynamic and novel occurrences such as faulty power lines or unexpected downtime would occur, the manager would use a combination of the information system and their own judgement in conjunction.

This system-aided judgement approach allowed the manager to use real-time live data that the SCADA system was producing, this was used in conjunction with procedural knowledge the manager had of specific scenarios. A system-aided judgement approach was a powerful tool for the manager when dealing with maintenance crews as it allowed the teams to get clear, concise, and best practise directions from the manager in conjunction with real-time data from the manager. This allowed plans for plans to resolve errors occurring in the network to be formulated rapidly. It was also seen that the manager would utilise an intuitive decision-making approach. This occurred when the manager had been monitoring the SCADA information system to ensure that the network was preforming as expected. It was seen that the manager was able to use their intuitive knowledge of the both the information system and the overall network to detect an issue with the generation of wind energy before the SCADA system alerted the user. This was highly advantageous for the manager as it allowed them to be proactive in their configuration of the network rather than reactive if an error or alert from the system was displayed.

It was seen that the manager had an excellent command of the information system, procedural knowledge of what to do, and the overall network configuration which allowed them to rapidly transition between the three differing decision-making approaches outlined.

This section has reviewed a manager of the national grids decision-making approach during different real-life scenarios. The next section will now compare and contrast the decision-making of the aircraft pilot, the air-traffic controller, the pharmacist, and the national grid manager.

5.15 Chapter Conclusion

This chapter has discussed two case studies which were viewed as being in a undynamic environment. An undynamic environment was classified as having increased lower time pressure and reduced information challenges. This more stable environment (compared to Chapter 4) creates a higher task familiarity for the decision maker. The first case study involved pharmacist at a pharmacy. The second case study involved a national grid control manager of the national grid. The unit of analysis in each case study was the key decision maker or manager. Across both case studies, it was found that the key decision maker would oscillate between differing decision-making approaches. Unexpectedly it was also found that the pharmacist would oscillate their decision-making approach to a data-driven approach when under examination. This was a novel occurrence as they had previously completed the task successfully when not under examination. In addition, it was also found that the national grid manager would be required to oscillate their decision making due to organisational processes. Further analysis of these emerging concepts will be conducted in a cross-case analysis in Chapter 6.

Chapter 6: Cross Comparison of Case Studies

This chapter will compare and contrast the findings of the four case studies. It will build upon the conceptual model created in Chapter 2. Arising from this analysis, a new conceptual model, refined based on the analysis of the cases, is presented. The proceeding section will present and discuss the format used to categorise the comparisons and contrasts of the four individual case studies. This research study was identified in Chapter 3 as being a critical realist study. As such, this chapter will be structured to investigate if an oscillation in decision making is reliant on events such as a task which is reliant on mechanisms in a given context (dynamic or undynamic environment). Chapters 4 and 5 discussed oscillations in modes of cognition for each individual case study. The individual oscillations were displayed in a visual format shown in Figure 12 to Figure *56*. This chapter will now compare and contrast the individual case study oscillations in a tabular format which are shown in Figures 58 to 63. Displaying the individual oscillations in decision making approach in a tabular format allows the researcher to conduct pattern-matching across the case studies. This will facilitate the identification of mechanisms which were found in more than one case study. Comparing and contrasting the individual case oscillations in this way will provide an extra layer of validation to the results (Tellis, 1997). This is an important step as understanding the mechanisms which create events in a given context will allow the researcher to answer the research questions.

The chapter begins by comparing and contrasting four case studies at an overall environmental level and at an individual task level. Tasks performed by a decision maker are then mapped to individual decision-making oscillations using the theoretical lens of Cognitive Continuum Theory. The chapter concludes by introducing two new mechanisms which have the potential to cause a decision maker to oscillate their decision-making approach. The next section will discuss the environmental and individual task characteristics.

6.1 Environment Characteristics

The four case studies presented in the Chapters 4 and 5 outlined the environments in which the key decision-maker operated. The pilot and air traffic controller were found to operate in a dynamic environment. The pharmacist and national grid controller operated in an undynamic environment. Part of the literature review conducted in chapter 2 found that the environment (context) a decision maker works in can affect the task a decision maker is working on. The model shown in Figure 57 summarises this by displaying how the various environmental characteristics can affect the individual's task.

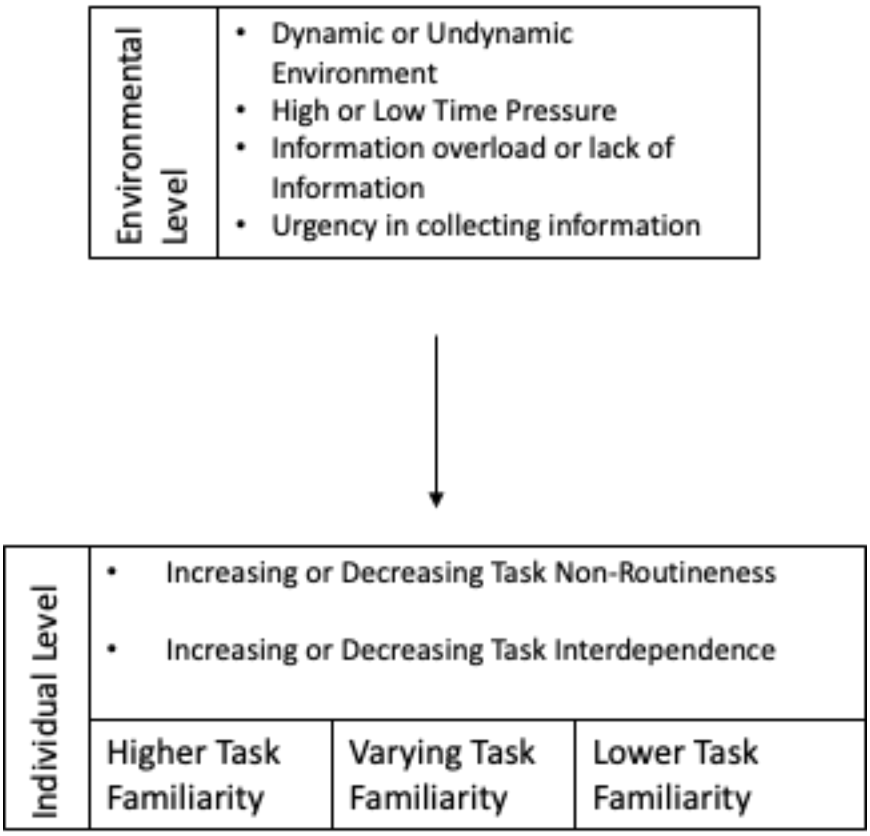

Figure 57 - Environmental & Individual Considerations

The following sections now use part of the theoretical model derived in Chapter 2 and displayed in Figure 57 to compare and contrast the four case studies. This will allow the researcher to further explore the research objective.

6.2 Time Pressure

Time pressure varied across the four case studies but can be categorised into two distinct levels: high time pressure and low time pressure. Both the pilots and the air traffic controllers were subjected to higher time pressure, whereas the pharmacist and national grid controller operated under low time pressure. High time pressure was exhibited in scenario 7(See section 4.1.2 Pilot Scenarios) for the pilot and in scenario 4(See section 4.8.2 Air Traffic Control Scenarios) for the air traffic controller (ATC). Scenario 7(See section 4.1.2 Pilot Scenarios) saw the pilot under high levels of time pressure when landing the aircraft. The pilot was required to setup the various information systems to begin the descent, while also remaining in communication with the air traffic controller. Time constraints are increased for a pilot when landing due to:

(i) The need to interact with air traffic controllers
(ii) Setup information systems correctly to facilitate a safe landing.
(iii) Errors relating to fuel when airborne for longer than scheduled in the simulator.

These factors increased time pressure for the pilot and acted as a mechanism in oscillating their decision-making approach towards a data-driven approach.

The pilot became overly focused on adjusting the information system to ensure the aircraft would land safely and missed vital information being provided by air traffic control (ATC). As the pilot was being graded by an instructor for their commercial license, the pilot was personally nervous about failing. The need to interact with air traffic control, amended the setup of the information systems in the cockpit, and the nervousness of the pilot resulted in the pilot experiencing more time pressure to make the correct call in the allotted time. The increased nervousness when attempting to land the aircraft resulted in the pilot taking too long with information system setup. The pilot was overly focused on their altitude system and keeping the aircraft level due to their nervousness about veering off course in front of the instructor while under examination. The pilot was under a specific time window to complete the landing task while under examination. The increased amount of time the pilot spent focusing on the information system inadvertently caused the pilot to increase the time pressure they were placed under to complete all necessary steps in time. Information system setup is one part of successfully landing an aircraft, but the pilot is also required to liaise with air traffic control. Overly focusing on the information systems due to nervousness, increased the time pressure on the pilot who then missed vital information being provided to them by the air traffic controller such as angle of landing and crosswind information. This is ordinarily a routine task for a pilot who should have ample time to complete the task. Due to being examined, the context the pilot was performing a landing scenario had altered. As a result, the pilot became overly focused on their information system and self-created a time pressure scenario.

A comparable time pressure scenario was observed in the air traffic controller case study in scenario 7(See section 4.8.2 Air Traffic Control Scenarios). This occurred when the air traffic controller was resolving a warning signal for a near collision of aircraft. Whilst the air traffic controllers were monitoring their workstations, an alarm began to sound from the approach desk. This changed the context the air traffic controller was working in. When this occurred the other members of staff looked to the air traffic controller manager to resolve the issue. The air traffic controller manager had a limited time window the resolve the issue or catastrophic consequences would arise. When the approach desk alarm sounded the air traffic controller would oscillate their decision-making approach towards a data-driven approach. Adopting a data-driven approach is vital for the air traffic controller as they need to use the information systems to gauge the distance between airborne aircraft. Once the air traffic controller has interpreted the data from the information system, they are required to relay this information to the aircrafts immediately to avoid mid-air collisions. When the alarm sounded the other members of the control tower would ignore the alarm and wait for the manager to take responsibility for the situation. Other members of staff ignoring an emergency scenario was identified as a mechanism in the air traffic controller oscillating their decision-making approach. Although both decision makers had oscillated their decision-making approaches, the underlying mechanisms for both differed. The pilot had oscillated their decision-making approach due to their increasing nervousness of landing the aircraft creating a time pressure scenario. The pilot's nervousness resulted in them becoming solely focused on the information and not having time to take on board information being relayed to them by air traffic control. The reason which caused the pilot to oscillate their decision making was the increase in time pressure caused by their nervousness. This nervousness resulted in the pilot being overly focused on the information system phase of the task. In contrast, the time pressure scenario faced by the air traffic controller was time pressure created outside of their control by an emergency scenario. In such a scenario, the air traffic controller was required to use the information system. This process required the air traffic controller to oscillate to a data-driven approach. The time pressure in such a scenario was extremely high due to the urgency of relaying the correct information to the airborne pilot to resolve the issue.

The behaviour in the cockpit and the air traffic control tower under time pressure contrasted with the low time pressure environment the pharmacist and the national grid operator faced. The pharmacist was seen to encounter low occurrences of time pressure in Scenario 5(See section 5.1.1 Pharmacist Scenarios). Despite the pharmacy having a queue of patients, the pharmacist displayed no characteristics of time pressure and remained calm throughout the process. When the pharmacist was interacting with a patient with whom they had a high familiarity, the environment was undynamic overall and no time pressure was evident for the pharmacist to complete the task. There was no change in context for the pharmacist when working with a regular patient. High familiarity with a patient involved the pharmacist knowing the personal medical background, past medication use, and current medication usage of the patient. No decision-making oscillations were observed in this scenario. Scenario 2(See section 5.8.2 National Grid Controller Scenarios) is an example of the national grid operator operating in a scenario of apparent time pressure. This scenario involved a fault occurring in the power grid and the operator being required to investigate and contact maintenance teams. During an electoral outage, the operator would use the information system to gather data surrounding the issue but also utilise their own decision-making process to instruct the maintenance ground team on how to proceed. The operator was then able to formulate a plan using a system-aided judgement approach and discuss this plan with maintenance crews. The operator had a well-learned response to this issue and did not alter their decision-making approach. The other members of staff would wait for the operator to take charge of the situation and to investigate. This is comparable to Scenario 4 of the air traffic controllers who also waited for the ATC manager to take charge of the situation.

Although this may be perceived as being a scenario of high time pressure it was not. The context of the national grid controller differed from the pilot and the air traffic controller due to:

1) The national grid controller was not under time pressure for an immediate resolution. This differed from the air traffic controller who was required to make a rapid decision to avert an emergency scenario. The national grid controller was required to investigate the issue and formulate a plan at a later date.

2) The national grid controller was calm and had a well learned response to the issue. The national grid controller was under no immediate time pressure to resolve this issue; their task was to investigate why it had occurred. This differed from the pilot who became extremely nervous when conducting their task. This nervousness resulted in the pilot spending too much time on specific phases of the task and running out of time to complete all necessary steps. The pilot had a window of time to land the aircraft.

The national grid controller and the pharmacist differed from the pilot and air traffic controller as they were under no external pressure (crisis scenario) or a self-imposed (nervousness) time pressure to resolve the issue.

Increased time pressure was found to occur in the dynamic environment with the pilot and air traffic controller and low time pressure was found in the undynamic environment with the pharmacist and national grid controller. Although time pressure was found to be a contributing factor in a decision maker oscillating their approach, further analysis has found that the pilot oscillated their decision-making approach due to increasing nervousness about failing the task when time pressure increased. When the pilot was personally sensitivity to a negative outcome, it was found that the pilot would forget learned and correct procedures. This resulted in the pilot becoming overly reliant on the information system which was incorrect procedure when attempting to land the aircraft. In contrast analysis from the air traffic controller case study found that being personally sensitivity to a negative outcome was not a concern. This was due to the air traffic controller remaining calm throughout their task due to not being responsible for errors between airborne aircraft. This contrasted with the pilot who became increasingly nervous while attempting to land the aircraft. The increased nervousness of the pilot resulted in them spending too long focusing on information system setup. This had a knock-on effect of increasing time pressure for subsequent steps when landing the aircraft and missing vital information being provided by the air traffic controller.

A second mechanism was also found in the air traffic controller and national grid controller case studies despite contrasting time pressures. In both case studies, it was found that other members of staff would not attempt to resolve tasks, instead leaving them to the manager of both facilities to resolve. Although this mechanism was found across both case studies, the decision-making outcome differed. The high time pressure environment the air traffic controller operated in, required them to adopt a data-driven approach to decision making to immediately resolve the issue. In contrast, the low time pressure environment the national grid controller operated in, allowed them to use a system-aided judgement approach and to formularise a plan of action over time. This mechanism was found to not occur with the aircraft pilot. Neither of the two mechanisms were found to be activated with the pharmacist from a time pressure perspective.

This section has identified two mechanisms that will oscillate a decision makers decision-making approach. The first of these is if a decision maker has increased nervousness when attempting to complete a task. This resulted in the decision maker spending too long on certain phases of the task and running out of time to complete the task in full. This was found to be a self-created time pressure. The second mechanism was found to be if team members ignore a task until the key decision maker will attempt to resolve it. This was found to be an external mechanism for the key decision maker which would oscillate their decision-making approach. An important question to understand is if this mechanism can only be activated in dynamic, high time pressure environments? This will be explored in section 4 of this chapter. Both mechanisms were unaccounted for in existing literature and will be discussed in further detail in subsequent sections. This section has provided further analysis on the four case studies from a time pressure perspective. The next section will now look at these case studies from an information perspective.

6.3 Information Challenges

Information challenges which can affect the decision maker in obtaining the correct information for a task were summarised in Chapter 2 as:

1. Potential for information scarcity or information overload when making a decision.
2. Varying time pressure in collecting information for making a decision.
3. The reliability of information collected due to factors 1 and 2.

Any one or combination of the three challenges outlined above can result in difficulties for the decision maker making the correct decision. Information scarcity was found to occur with both the national grid controller and air traffic controller. Scenario 1 of the national grid controller showed how information availability could alter rapidly throughout the day whilst the controller was on duty depending on the context. A primary task of the national grid controller is to monitor their information system for any faults in the network. A fault in the network can result in homes and businesses being without power for a period of time. It was seen that when a fault occurred in the network, the controller would be notified by the information system. When this occurred, the national grid controller would oscillate their decision-making approach towards a data-driven decision-making approach. The controller would use the information system to further investigate the issue because they would have no information on the issue affecting the network without the multiple diagnostic reports provided to them by the information system. As the national grid controller works at a remote location, it was not possible for the controller to understand how the issue occurred without the diagnostic report being provided to them by the information system. The national grid controller was working under constraints of information scarcity without the use of the information system.

A similar scenario occurred in scenario 4 of the air traffic controller when an emergency notification sounded from the approach desk. The air traffic controller was now required to work solely with the information system and will immediately oscillate towards a data-driven approach to decision making. As the context had altered, the air traffic controller was now operating under conditions of severe time pressure and requiring detailed information on the airborne aircraft. Similar to the national grid controller the air traffic controller would be working under conditions of information scarcity without the use of the information system. Information from the system was needed to ensure the safety of all passengers and crew on board. In this scenario, the approach desk warning signal began to sound and flash indicating that two aircraft were too close to one another. Using data from the information system, the air traffic control manager would then contact the aircraft pilot to amend the flight trajectory. The air traffic controller was obligated to adopt a data driven decision-making approach as it was not possible to view the aircraft which were travelling a great distance away from the air traffic control. This scenario compares with the national grid controller who also required detailed and reliable data to be provided when a potential crisis occurred. The remote location of the air traffic controller away from the source of the error would cause the controller to work under conditions of information scarcity unless they oscillated their decision-making approach towards a data-driven approach. The air traffic controller required the use of the information system to view up-to-date and live information regarding current airborne aircraft. The mechanism which caused the air traffic controller to oscillate to a data-driven approach compares with the national grid controller. Errors or potential crisis changed the context both controllers worked in and caused information scarcity. To obtain more information both controllers were required to use the information system to resolve any issue. In both cases, information scarcity about errors the decision maker had to resolve was identified as a mechanism. This mechanism was found to oscillate both decision makers to a data-driven approach. By using a data-driven approach, both decision makers were able to compile the necessary information required to resolve errors in their domain. This would not have been possible without the mechanism that oscillated their decision-making approach occurring. It was also noted that the other members of the air traffic control tower and national grid control room would wait for the manager to take action even though there was an alarm sounding. This section has identified information scarcity as a mechanism which will oscillate a decision-making approach. This mechanism was identified as occurring with both the air traffic controller and the national grid controller. Although the environments contrasted, both key decision makers would oscillate their decision-making approach to a data-driven approach when requiring further information to resolve a task.

6.4 Task Familiarity

Chapter 2 concluded that when the decision-making approach used is aligned with the task characteristics of the scenario, the decision-making outcome will be more likely to be correct. Task characteristics can be viewed and deconstructed to task non-routineness and task interdependency (Karimi, Somers et al. 2004). In addition, task variety can be considered low or high for a decision maker.

6.4.1 Task Non- Routineness

Task non- routineness was found to be very high for the pilot when performing scenario 3. In this scenario, the pilot was forced to react when the plane had engine failure. An engine failure scenario is not a routine task for the pilot to encounter, even in a training simulation. As such, the task non-routineness facing the pilot was substantially increased. As the pilot was under examination for their pilot's license, the context the pilot was conducting this scenario in was different to normal. During such an engine failure scenario, the pilot is placed under increasing time pressure due to the need to stabilise the aircraft to prevent it from crashing. The increased time pressure and high task non-routineness makes this a challenging scenario for the pilot. During an engine failure scenario, the cockpit becomes increasingly uncomfortable for the pilot to work in due to various warning signals sounding. The pilot also became increasingly nervous when attempting an engine failure scenario. It was important for the pilot to complete this scenario successfully as they were under examination for their commercial pilot's license, so the context was different to normal. The nervousness facing the pilot was evident in their voice (voice was breaking and pitch higher) when speaking to the co-pilot or air traffic control tower and the pilot was sweating. When performing the task, the pilot focused on the altitude system and flight stabiliser and ignored any information being relayed to them by air traffic control. The pilot had oscillated their decision-making approach towards a data-driven approach, moving away from a system-aided judgement approach. The increased task non-routineness which heightened the pilot's nervousness about failing the exam, was identified as a mechanism that caused the pilot to oscillate their decision-making approach. This was found when the pilot was required to complete the task in the context of an examination.

Despite the contrast in operating environments, this behaviour was mimicked by the pharmacist in Scenario 6. The pharmacist was required to interact with a regular patient who required new medication of which the pharmacist was unfamiliar. The pharmacist was unable to rely on pre-existing knowledge of the scenario as they had no prior knowledge of the medication. When interacting with a known medication, the pharmacist is able to intuitively recall the potential complications associated with the medication. A new medication that the pharmacist is unaware of increases the task non-routineness facing the pharmacist and changes the context of working with a regular patient. The pharmacist is required to ensure that the correct medication is issued to a patient as any error could result in fatal consequences for a patient. The pharmacist would also face severe personal consequences such as facing a fine and/or having their license revoked. In this scenario, the pharmacist oscillated their decision-making away from an intuitive approach and adopted a system-aided judgement approach. The pharmacist used the information system in conjunction with knowledge they had accrued overtime with the patient. The pharmacist's apprehension about making an error is a mechanism which caused the pharmacist to oscillate their decision-making approach. This occurred due to the changing of the context when working with a regular patient as the pharmacist had no prior knowledge about a new type of medication. This resulted in the pharmacist using a system-aided judgement approach.

The pilot and the pharmacist were both categorised as operating in contrasting environments. Despite operating in contrasting environments, a similarity was found when attempting to conduct a task with higher non-routineness. Both decision makers were found to oscillate their decision-making approach to become more information-systems driven when task non- routineness was increased. When confronted with a task that was non-routine, it was found that both decision makers were apprehensive and did not trust themselves fully to be able to resolve the issue. This was found when the context for both decision makers differed from normal and there was a potential personal impact on the decision maker. If the pilot failed their exam, they would lose the opportunity to become a professional commercial pilot. If the pharmacist incorrectly administered the wrong medication they risked losing their license to practise. The pilot oscillated their decision making to a data-driven approach to become fully reliant on the information system. The pharmacist oscillated their decision making to a system-aided judgement approach to reassure themselves about the course of action they would take for the task.

Across both case studies the mechanism identified was that when task non-routineness was increased the key decision maker would have doubt in their ability to complete the task without the aid of the information system. The key decision maker across both case studies would use the information system to reassure themselves about the correct course of action. The pilot was nervous about failing their examination and used the information system when confronted with a high non-routine task. Similarly, the pharmacist when confronted with a non-routine task relied on the information system to assist their decision-making process. This finding indicates that if a decision maker is personally affected by the outcome of a decision, they are more likely to use a data-driven approach to decision making. This is a mechanism which is not accounted for in existing literature and will be analysed in further detail in section 6.10 Personal Sensitivity to a Negative Outcome Mechanism

This finding across both case studies shows that if a decision maker is nervous or requires further assurance the decision makers decision-making approach to become more information systems based. This was not accounted for in existing literature.

The next section will review the effects of task interdependence on decision-making.

6.4.2 Task Interdependence

As environmental uncertainty (context) increases, interdependent tasks become more important due to the increased need for coordination to resolve ambiguity. Chapter 2 found that task interdependence can be defined as an exchange of output that takes place between segments within a sub-unit and/or with other organizational units. Chapter 2 also found that higher levels of dynamism within an environment will increase the interdependence of tasks.

Task interdependence was observed to varying degrees across the four case studies. Scenario 4 of the air traffic controller is an example of task interdependence. This scenario involved a warning signal sounding to notify the control tower that a potential mid-air collision may occur. The sounding of this warning signal changed the context for the air traffic controller. To resolve this task, a high degree of interdependence was required between the air traffic controller and the airborne pilot. This was due to the air traffic controller being required to notify the airborne pilot of any potential emergency scenarios. An airborne pilot is dependent on the air traffic controller to ensure a safe flight via the information shared between both parties. The sharing of information gives a high degree of task interdependence between both the air traffic controller and the airborne pilot. When an emergency scenario occurs the other members of the control tower would wait for the manager to act. The air traffic controller manager would then rush towards the dedicated information system and attempt to resolve the issue. The manager would oscillate their decision-making approach towards a data-driven approach becoming solely reliant on the information system. The air traffic control manager was analysing data being provided to them by the information system, such as aircraft orientation and travelling speed. The air traffic control manager would analyse the data for a moment and rapidly contact the aircraft to recommend the correct course of action for the pilot to take. The pilot then confirmed the course of action and amended the aircrafts flight trajectory. This scenario highlights the high degree of task interdependence between an air traffic controller and a pilot when resolving potential emergency scenarios.

This heightened level of task interdependence in a crisis scenario was observed in scenario 5 of the pilot case study. This scenario involved increased turbulence being introduced to the simulation for the pilot. The pilot was being examined for their commercial pilot’s license and this altered the context of the scenario. The changing of the context resulted in the pilot becoming visibly nervous. Increased nervousness was observed in the pilot’s body language, speech, and interactions. The pilot was required to keep the flight stable and interact with air traffic control as the flight was approaching its landing. It was seen that the pilot found it difficult to maintain the interdependence between themselves and the air traffic controller and began to focus solely on the information system. There is a high level of task interdependence between an airborne pilot and an air traffic controller when approaching a landing. To complete a landing safely and correctly, the pilot is reliant on information being passed to them from the air traffic controller. The increase in nervousness for the pilot, due to the change in context, resulted in the pilot ignoring the air traffic controller. The pilot had now oscillated their decision-making approach towards a data-driven decision-making approach. The oscillation in the pilot's decision-making approach to focus solely on the information system caused the pilot to miss vital pieces of information regarding landing coordinates from air traffic control. There was a breakdown in communication task interdependence. The pilot took an incorrect flight path, did not receive landing confirmation from air traffic control, and was unable to land the aircraft. The correct approach for the pilot to adopt would have been to adopt a system-aided judgement approach.

In contrast to these scenarios, in Scenario 4 for the pharmacist, when the environment remained undynamic the key decision-maker was comfortable adopting an intuitive approach to decision-making. Whilst interacting with a regular patient who required medication, the pharmacist was able to recall on pervious interactions with the patient and with specific medications. In such a scenario, the pharmacist is very familiar and comfortable with the context of the task. This allowed the pharmacist to rapidly assist the patient and did not require the use of the information system. It was noted that in such a routine scenario for the pharmacist that task interdependence is very low. There was no need for the pharmacist to further interact with the patient or the information system to complete this task. The pharmacist was able to take the prescription and intuitively take the best course of action. This compares similarly to the national grid controller, who in Scenario 3 was required to monitor the information system for changes. The controller was able to use their vast experience of the information system to quickly realise a change in approach was required; the controller then altered the amount of wind power being produced before the information system alerted them of the issue. The controller did not oscillate their decision-making approach and remained using an intuitive decision-making approach. This was a routine scenario for the national grid controller and the context of the task was routine. In this scenario, it was again noted that task interdependence was considered low. The controller had all the required information available to them on the screen and could amend setup accordingly. The national grid controller did not need to interact with other parties, units, departments, or obtain further information to successfully complete the task.

The findings presented in this section corroborates existing research which found that task interdependence increases in more dynamic environments. This was shown in scenarios involving the pilot and the air traffic controller. In both case studies, as the environment became increasingly unpredictable and dynamic the key decision maker, became more reliant on interdependency and support of other tasks to resolve their immediate issue. This finding contrasted with the pharmacist and national grid controller. In both of these case studies, it was found that the undynamic nature of the environment resulted in much lower task interdependency. This section has compared and contrasted the task interdependence perspective of the differing case studies. The next section will discuss decision-making oscillations across all four case studies. The next section will build upon the findings presented in this section by discussing if specific environmental or task characteristics induced a specific decision-making approach. This will allow the research to further explore the research objective of this study

6.5 Decision-Making Oscillations

Chapter 3 identified that this research objective and research questions are most aligned with a critical realist study. The previous section analysed data across all four case studies from the perspective of the actual (task) and the context (dynamic or undynamic environment). This section will now build upon this analysis by discussing analysis of decision making. This analysis will show if decision-making oscillations occurred. The section will begin by looking at intuitive decision-making. This will be followed by analysis of both system-aided judgement and data-driven decision making. The section will conclude with a summary of the cross-case analysis from a critical realist perspective.

6.6 Intuition

This section will review findings from all four case studies from an intuitive decision-making perspective. Cognitive continuum theory in Chapter 2 described how decision makers will oscillate between differing decision-making approaches. The findings presented in this section will support this by showing that decision-making oscillations were observed. The next two sections will compare and contrast findings from an intuitive decision-making perspective.

6.6.1 System-Aided Judgement to Intuition

The matrix presented in Figure 58 displays instances when the key-decision maker moved from a system-aided judgement approach to an intuitive decision-making approach. It is noticeable that this decision-making oscillation was primarily used by both the air traffic controller and the pharmacist. This was unexpected as the context (environment) that each decision maker operated in differed. The pharmacist's context was an undynamic environment and the air traffic controller was a dynamic environment.

Pilot		Air Traffic Controller		Pharmacist		National Grid Controller	
Scn No.	SAJ to Int	Scn No.	SAJ to Int	Scn No.	SAJ to Int	Scn No.	SAJ to Int
P1	-	ATC1	√	Phrm1	√	NG1	-
P2	-	ATC2	-	Phrm2	-	NG2	-
P3	-	ATC3	√	Phrm3	-	NG3	√
P4	-	ATC4	-	Phrm4	√		
P5	-	ATC5	-	Phrm5	√		
P6	-	ATC6	√	Phrm6	-		
P7	-	ATC7	-	Phrm7	-		

Key	Acroynm
Scenario Number	Scn No.
Pilot	P
Air Traffic Control	ATC
Pharmacist	Phrm
National Grid	NG

Figure 58 - System-Aided Judgement to Intuition.

Intuitive decision making was used by the air- traffic controller in Scenario 1,Scenario 3,and Scenario 6 (see section 4.8.2 Air Traffic Control Scenarios) Intuitive decision making was used by the pharmacist in Scenario 1,Scenario 4, and Scenario 5 (see section 5.1.1 Pharmacist Scenarios). In Scenarios 1,4, and 5 for the pharmacist, it was found that the pharmacist felt comfortable and relaxed adopting an intuitive approach. These scenarios all had commonalities such as the patient being regular, requesting medication the pharmacist was familiar with, and the pharmacist was under no time pressure. It was observed that the pharmacist will oscillate their decision-making approach to an intuitive decision-making approach when familiar with a patient and the medication. The pharmacist would oscillate away from a system-aided judgement approach and trusted their own intuition to resolve the task. The pharmacist felt at ease in such scenarios adopting an intuitive approach to decision making and did not rely on the information system to assist in helping patients.

A comparable phenomenon occurred with the air traffic controller in Scenarios 1 and 3(see section 4.8.2 Air Traffic Control Scenarios). In both of these scenarios, the air traffic controller felt confident, relaxed, and in control of the task at hand. The ATC was able to relay information and precise data points to an aircraft requesting take-off clearance in Scenario 1(see section 4.8.2 Air Traffic Control Scenarios), and to a VFR aircraft (see chapter 5) requesting landing in clearance in scenario 3. In such scenarios, the air traffic controller did not require the use or part use of the information system to make decisions. It was observed that the air traffic controller had oscillated to an intuitive decision-making approach.

Although the air traffic controller operated in a dynamic environment and the pharmacist in an undynamic environment, both decision-makers were comfortable adopting an intuitive decision-making when they felt confident and comfortable to do so. This was a novel finding as the context (environment) that both decision makers operated in differed. This finding would indicate that decision-making oscillation from a system-aided judgment approach to an intuitive approach is not determined by environment. As this would indicate that mechanisms are more important driver in creating decision-making oscillations. This is an important consideration as existing research has primarily focused on how the environment (context) is a primary driver in facilitating oscillations in decision making. The next section will review how decision makers oscillated to an intuitive approach away from a data-driven approach.

6.6.2 Data-Driven Decision Making to Intuition

Figure 59 shows a matrix of all four case studies were instances of the key decision-maker oscillating from a data-driven approach to an intuitive approach were identified. There was consistency across all four case studies in that this was a rare decision-making oscillation.

Pilot		Air Traffic Controller		Pharmacist		National Grid Controller	
Scn No.	DD to Int	Scn No.	DD to Int	Scn No.	DD to Int	Scn No.	DD to Int
P1	-	ATC1	-	Phrm1	-	NG1	-
P2	-	ATC2	-	Phrm2	-	NG2	-
P3	-	ATC3	-	Phrm3	-	NG3	-
P4	-	ATC4	-	Phrm4	-		
P5	-	ATC5	-	Phrm5	-		
P6	-	ATC6	-	Phrm6	-		
P7	-	ATC7	√	Phrm7	-		

Key	Acroynm
Scenario Number	Scn No.
Pilot	P
Air Traffic Control	ATC
Pharmacist	Phrm
National Grid	NG

Figure 59 - Data-Driven Decision Making to Intuition.

One instance of an oscillation from data-driven decision making to intuitive decision-making was recorded for the air traffic controller (see section 4.8.2 Air Traffic Control Scenarios). There were no other observations of this oscillation occurring with the air traffic controller or in any other of the case studies. Scenario 7(See section 4.8.2 Air Traffic Control Scenarios) for the air traffic controller showed that the key-decision maker would oscillate from data-driven decision making to an intuitive approach. The air traffic controller received a request from an aircraft to take off whilst working with an airborne aircraft. This was a time critical task with the ATC being required to provide both the airborne and taxiing aircraft with specific key points of information in a specific time window. The air traffic controller used the information system to briefly check for the airborne aircrafts distance from the airport, but relied on their intuition to review their physical, external environment to direct the aircraft to land at a specific runway. The air traffic controller is expected to factor in the speed the aircraft is travelling at, the distance to the airport, current aircraft on specific runways, aircraft that are due to land, and which runway is available for airborne aircraft. The air traffic controller's high level of intuition allowed them to cut through vast swathes of information to reach the correct conclusion for the airborne aircraft.

This scenario highlights the air traffic controllers vast experience when conducting this task. As the context the air traffic controller was working was routine. The air traffic controller had conducted a VFR landing request from aircraft thousands of times over the course of their career. As such, the context the air traffic controller was working was quite routine and did not exhibit any increase in dynamism. The air traffic controllers vast experience when conducting the task is identified as the activated mechanism which allowed them to complete this task with ease. Their experience allowed the air traffic controller to visibly take on board information such as weather conditions, wind speed, and runway occupancy. This information is not readily available to the air traffic controller using an information system. The air traffic controller had completed this task thousands of times in the past and, as such, had a very high task familiarity. The air traffic controller had oscillated their decision-making approach to a data-driven approach. This was an expected outcome and the air traffic controller successfully completed the task.

Although the air traffic controller was vastly experienced, the pharmacist, national grid controller, and pilots were all similarly experienced. All four decision makers across each study were the key decision makers for their role. This would indicate that experience is not the sole reason for oscillating from a data-driven approach to an intuitive approach. The difference with the air traffic controller was they were required to take on board information from their external environment such as weather conditions. This was not found with any other key decision maker other than the air traffic controller.

This section has compared and contrasted oscillations to an intuitive decision-making approach from either a system-aided judgement approach or a data-driven approach. Oscillations from a system-aided judgement approach to an intuitive approach were common for both the air traffic controller and the pharmacist. This indicated that the environment did not have an impact on this decision-making oscillation. This section also reviewed findings from a data-driven to intuitive decision-making approach. This oscillation was rare and only occurred in one scenario involving the air traffic controller. The next section will review decision-making across all four case studies for a system-aided judgement approach.

6.7 System Aided Judgement

This section will review findings from a system-aided judgement perspective, Cognitive continuum theory in Chapter 2 discussed how decision makers will oscillate between differing decision-making approaches. The findings presented in this section will support this by showing that decision-making oscillations were observed. The next two sections will compare and contrast findings from a system-aided judgement perspective

6.7.1 Intuition to System-Aided Judgement

Figure 60 below displays instances when visible observations of the key-decision maker oscillating from an intuitive decision-making approach to a system-aided judgement approach occurred. Figure 60 shows that an oscillation from intuitive decision-making to system-aided judgement occurred.

Pilot		Air Traffic Controller		Pharmacist		National Grid Controller	
Scn No.	**Int to SAJ**	Scn No.	**Int to SAJ**	Scn No.	**Int to SAJ**	Scn No.	**Int to SAJ**
P1	-	ATC1	-	Phrm1	-	NG1	-
P2	-	ATC2	√	Phrm2	√	NG2	
P3	√	ATC3	-	Phrm3	-	NG3	-
P4	-	ATC4	-	Phrm4	-		
P5	-	ATC5	-	Phrm5	-		
P6	-	ATC6	-	Phrm6	√		
P7	-	ATC7	-	Phrm7	-		

Key	**Acroynm**
Scenario Number	Scn No.
Pilot	P
Air Traffic Control	ATC
Pharmacist	Phrm
National Grid	NG

Figure 60 - Intuition to System-Aided Judgement.

Figure 60 show that, at the empirical layer, it was observed that oscillations from an intuitive to a system-aided judgement approach occurred in both contexts (dynamic and undynamic environment). An intuitive to system-aided judgement oscillation was visible for the pilot in Scenario 3 (see section 4.1.2 Pilot Scenarios) and for the air traffic controller in Scenario 2 (see section 4.8.2 Air Traffic Control Scenarios). It was also visible for the pharmacist in Scenario 2 and Scenario 6(see 5.1.1 Pharmacist Scenarios).

Scenario 3(see section 4.1.2 Pilot Scenarios) with the aircraft pilot involved a mechanical error, which was shown to oscillate the pilot's decision-making approach. In this scenario, the pilot oscillated to a system-aided judgement approach from an intuitive approach using specific data from the information system such as the altitude. This data was used in-conjunction with a well-learned crisis response on how to react when a mechanical failure occurs. When this well-learnt response was used with live data from the information system the pilot was able to successfully resolve the task. This behaviour compares with the air traffic controller who also oscillated to a system-aided judgement approach when they had a well-learned response. In Scenario 2(see section 4.8.2 Air Traffic Control Scenarios), the air traffic controller oscillated towards a system-aided judgement approach. The air traffic controller was required to assist an airborne aircraft with landing. The air traffic controller was required to use local environment information obtained in conjunction with live data from the information system. Data from the information system includes the aircraft call sign, the actual speed across ground, the altitude the aircraft is flying at, the flight route, the distance from the air traffic control tower, and the true air speed. The air traffic controller used this information to provide the airborne aircraft with the necessary information and to give clearance for the aircraft to land. Despite both the air traffic controller and pilot operating in a dynamic environment, their decision-making oscillation was observed with the pharmacist who was working in an undynamic environment. Scenario 2(see 5.1.1 Pharmacist Scenarios) involved the pharmacist working with a regular patient who required new medication of which the pharmacist was unfamiliar. When a regular patient requested this new type of medication the pharmacist was visibly surprised. The pharmacist then queried the prescription and began to use the information system to gather information on the medication. The pharmacist had altered their decision making from an intuitive approach to a system-aided judgement approach. The pharmacist was now using existing knowledge they had accrued over time on the individual patient, in conjunction with information from the information system on the new medication. It was noted that, when the pharmacist was unsure of a particular medication, they would use the information system to reassure themselves. This would indicate that when the pharmacist was nervous about potentially failing a task a personal sensitivity to a negative outcome mechanism would activate. The personal sensitivity to a negative outcome mechanism would have the pharmacist use the information system, thus oscillating to a system-aided judgement approach. This is understandable as the pharmacist would be called before a fitness to practise council for distributing the incorrect medication for a patient. This contrasts with the pilot and the air traffic controller who had no option and were required to use the information system to resolve their task.

This section has reviewed decision-making oscillations from an intuitive approach to a system-aided judgement approach. This decision-making oscillation occurred in both a dynamic and undynamic environment. It was also shown that this approach was adopted when the key decision-maker had a well-learned response, utilising local environmental data in combination with data from the information system. It was also observed that the pharmacist would oscillate their decision-making approach when nervous about completing a task. The next section will review oscillations from a data-driven decision-making approach to a system-aided judgement approach.

6.7.2 Data-Driven Decision Making to System-Aided Judgement

Figure 61 shows the cross-case matrix where instances of the key decision-maker oscillating from data-driven decision making to a system-aided judgement approach were observed. There was a commonality across the case studies in that this was a rare occurrence. Only one instance of a key decision-maker oscillating from a data-driven approach to a system-aided judgement approach was seen.

Pilot		Air Traffic Controller		Pharmacist		National Grid Controller	
Scn No.	DD to SAJ	Scn No.	DD to SAJ	Scn No.	DD to SAJ	Scn No.	DD to SAJ
P1	-	ATC1	-	Phrm1	-	NG1	-
P2	-	ATC2	-	Phrm2	-	NG2	√
P3	-	ATC3	-	Phrm3	-	NG3	-
P4	-	ATC4	-	Phrm4	-		
P5	-	ATC5	-	Phrm5	-		
P6	-	ATC6	-	Phrm6	-		
P7	-	ATC7	-	Phrm7	-		

Key	Acroynm
Scenario Number	Scn No.
Pilot	P
Air Traffic Control	ATC
Pharmacist	Phrm
National Grid	NG

Figure 61 - Data-Driven Decision Making to System-Aided Judgement.

The one instance of this oscillation occurring was in Scenario 2 of the national grid controller(see section 5.8.2 National Grid Controller Scenarios).This scenario involved a fault occurring in the power grid and the operator being required to investigate and contact maintenance teams. Although this may be perceived as being a scenario of high time pressure, the operator was relaxed throughout the process. During such an outage, the operator would use the information system to gather data surrounding the issue but also, use their own knowledge of the task to instruct the maintenance ground team on how to proceed. The operator was then able to formulate a plan using a system-aided judgement approach and discuss this plan with maintenance crews. Other members of staff would wait for the control manager to take charge of the situation and to investigate.

This scenario highlights the national grid controller's role as the key decision maker. It was evident that the controller was highly experience when required to formulate a plan to resolve grid downtime. Although this was perceived as an unusual scenario, the controllers vast experience alleviated this issue and in fact, it was routine for the controller. The controllers experience with conducting this task countless times in the past allowed them to complete the task. The familiarity of the task oscillated the controller's decision-making approach. The oscillation in decision-making approach allowed the controller to use information from the information system in conjunction with their well-learned response for such a scenario. This was an expected outcome and the controller successfully resolved the task.

Although the observed oscillations differ between this section and section 3.2.1. The underlying mechanism of both key decision-makers vast experience and ability to draw upon a well-learned response are similar. This shows that if a decision maker is comfortable and has successfully completed a task numerous times in the past it will alter the context of a task. This finding has shown that mechanisms generated can inform the context. This finding would contradict some existing research discussed in Chapter 2 which states that the environment a decision maker operates in will inform their decision-making approach (Goll and Rasheed, 1997, Elbanna, 2015).

This section has reviewed oscillations occurring from a data-driven to system-aided judgement perspective. The next section will review decision-making across all four case studies from a data-driven decision-making approach.

6.8 Data Driven Decision Making

The next two sections will compare and contrast the findings to further understand when the key decision maker oscillated to a data-driven decision-making approach from either an intuitive approach or system-aided judgement decision making approach.

6.8.1 Intuition to Data-Driven Decision Making

An intuitive oscillation to a data-driven decision-making approach was found to be a rare occurrence with only one recorded instance of this oscillation. The only recorded instance of this oscillation occurred in Scenario 5(See section 4.8.2 Air Traffic Control Scenarios) of the air traffic controller, with no recorded instances for the pilot, pharmacist, or national grid controller.

Pilot		Air Traffic Controller		Pharmacist		National Grid Controller	
Scn No.	Int to DD	Scn No.	Int to DD	Scn No.	Int to DD	Scn No.	Int to DD
P1	-	ATC1	-	Phrm1	-	NG1	-
P2	-	ATC2	-	Phrm2	-	NG2	-
P3	-	ATC3	-	Phrm3	-	NG3	-
P4	-	ATC4	-	Phrm4	-		
P5	-	ATC5	√	Phrm5	-		
P6	-	ATC6	-	Phrm6	-		
P7	-	ATC7	-	Phrm7	-		

Key	Acroynm
Scenario Number	Scn No.
Pilot	P
Air Traffic Control	ATC
Pharmacist	Phrm
National Grid	NG

Figure 62 Intuition to Data-Driven Decision Making.

Scenario 5(See section 4.8.2 Air Traffic Control Scenarios) for the air traffic controller involved the ATC working with dynamic weather conditions. Scenario 5(See section 4.8.2 Air Traffic Control Scenarios) demonstrated how the air traffic controller's decision making would observably oscillate. This occurred when the ATC was required to give a long-range forecast to an aircraft. In such a scenario, the task the air traffic controller was required to work with had changed; because they were required to obtain long range weather the air traffic controller was required to use the information system. This air traffic controller could no longer rely on their own intuition and had to oscillate towards a data-driven approach. This was observed as the air traffic controller began to interact and study the information system. The oscillation in decision-making approach allowed the ATC to successfully complete the task by relaying weather data to the airborne aircraft. In this scenario, the air traffic controller conducting a task when they are fully reliant on the information system was identified as the reason for oscillating their decision-making approach. This was an expected outcome based on existing literature. It was also seen that when the request from an airborne aircraft came into the ATC, it would be ignored by the other members of the team until the ATC manager responded to the request as internal processes dictated. The next section will review oscillations from a system-aided judgement to data-driven decision-making perspective.

6.8.2 System-Aided Judgement to Data-Driven Decision Making

A system-aided judgement to data-driven decision-making oscillation was found to be a common oscillation. The recorded instances of an oscillation from system-aided judgement to a data-driven approach can be seen in Figure 63.

Pilot		Air Traffic Controller		Pharmacist		National Grid Controller	
Scn No.	SAJ to DD	Scn No.	SAJ to DD	Scn No.	SAJ to DD	Scn No.	SAJ to DD
P1	√	ATC1	-	Phrm1	-	NG1	√
P2	√	ATC2	-	Phrm2	-	NG2	-
P3	-	ATC3	-	Phrm3	√	NG3	-
P4	√	ATC4	√	Phrm4	-		
P5	√	ATC5	-	Phrm5	-		
P6	√	ATC6	-	Phrm6	-		
P7	√	ATC7	-	Phrm7	√		

Key	Acroynm
Scenario Number	Scn No.
Pilot	P
Air Traffic Control	ATC
Pharmacist	Phrm
National Grid	NG

Figure 63 - System-Aided Judgement to Data-Driven Decision Making.

It is noticeable that this decision-making oscillation was evident across all four case studies. In a dynamic environment, this oscillation was found in Scenario 1,A pilot performing this task is required to use the on-board information system and use the information provided by air traffic control to adjust the (i) speed of the aircraft, (ii) altitude of the aircraft, and (iii) angle of decent the aircraft is taking. Pilot errors that occur at this point could result in a failed landing attempt or a catastrophic crash of the aircraft. The pilot is expected to use a combination of their own judgement and the data provided by the information system and air traffic control.

Scenario 2,Scenario 4,Scenario 5,Scenario 6, and Scenario 7 for the pilot (see 4.1.2 Pilot Scenarios). It was also found in Scenario 4 of the air traffic controller (see section 4.8.2 Air Traffic Control Scenarios). In the undynamic environment, this oscillation was found in Scenario 3 and Scenario 7 for the pharmacist(see section 5.1.1 Pharmacist Scenarios) and Scenario 1 of the national grid controller (see section 5.8.2 National Grid Controller Scenarios)

This was unexpected as the environment that each decision maker operated in differed.

A system-aided judgement oscillation to a data-driven approach was found to be extremely common for the aircraft pilot. This oscillation was recorded six times and occurred in all scenarios with the exception of Scenario 3(see 4.1.2 Pilot Scenarios). Pilots are required to contend with issues relating to dynamic weather in their context. Dynamic weather is an external factor outside of the individual's control, but the profession requires the key decision maker to have well learned responses to safely navigate these conditions. When weather conditions deteriorated for the pilot in Scenarios 2 and 6(see 4.1.2 Pilot Scenarios), the pilot was expected to use a system-aided judgement approach. It was observed that the pilots oscillated their decision-making approach to data-driven decision making. The pilot would become solely focused on readings that their information system was displaying to them. The use of a data-driven approach by the pilots was a novel occurrence as the pilots had performed the task successfully and adopted the correct decision-making approach numerous times in the past. As such, dynamic weather was not found to result in an oscillation. However, in these scenarios the pilots were being examined as part of their commercial license exam. Failure in this examination would mean the pilot not receiving a commercial aircraft license after having invested upwards of 100,000 euro into this course. This put enormous responsibility on the pilot for passing and receiving a successful grade to obtain their pilots license. This personal sensitivity of failing the exam was identified as the mechanism which oscillated the pilot to a data-driven approach.

This decision-making oscillation was also observed in Scenarios 1 and 7(See section 4.1.2 Pilot Scenarios) when the pilot was performing routine tasks that they had completed countless times in the past. This gives further validity to pervious assumptions in this chapter (6.7.2 Data-Driven Decision Making to System-Aided Judgement) that it is not the environment alone that resulted in a decision-making oscillation. It was the context in which the task was being conducted, in this case being under examination. In both Scenarios 1 and

7(See section 4.1.2 Pilot Scenarios), the pilot would become visibly nervous, quivering voice and sweating, when undertaking their tasks under examination. The optimum performance of this task was of great importance to the pilot as it was part of a series of examinations determining if they would obtain their commercial pilot license. This indicated that the pilots had a higher personal sensitivity to a negative outcome due to the professional risk of failing and the financial burden. It was observed in both scenarios that when the pilot was under examination, they would oscillate their decision-making approach to a data-driven decision-making approach. In scenario 1,2,6, and 7(See section 4.1.2 Pilot Scenarios), the pilot became overly focused on the information-system and missed important information from the environment and air traffic control; this resulted in the pilots failing specific tasks. This was found to be an novel occurrence as the pilots had performed the task correctly in the past. When under examination however, it was observed that the pilot would oscillate to a data-driven approach. This finding indicates that the pilots fear of a negative outcome in their examination is the mechanism which caused the oscillation.

This oscillation was not limited to the pilot. Despite the contrasting environment (context), two similar instances were recorded in Scenario 3 and Scenario 7(See section 5.1.1 Pharmacist Scenarios) of the pharmacist. In Scenario 3(See section 5.1.1 Pharmacist Scenarios) the pharmacist was required to work with a new patient to the pharmacy. As the patient was new, the pharmacist had no knowledge of the patients medical or medication history. The pharmacist having no prior knowledge of a patient changed the context for the pharmacist. It was observed that the pharmacist would oscillate their decision-making approach toward a data-driven decision-making approach. The pharmacist would use the information system to provide the new patient information about the medication they were requesting. The use of the information system was of personal importance to the pharmacist; a pharmacist who incorrectly prescribes medication can risk facing prosecution and have their license to operate revoked. Similar, to the pilot, this increased the personal sensitivity on the pharmacist for successful outcome of the task. This resulted in the pharmacist using a data-driven approach to decision making. In scenario 7(See section 5.1.1 Pharmacist Scenarios), the pharmacist had to work with a patient who was new to the pharmacy and also requested a medication the pharmacist was unfamiliar with. Although this scenario was rare it was important for the pharmacist to correctly administer the medication as there could be negative consequences for both the patient and the pharmacist. In such an instance, the pharmacist would rely solely on the information system for their decision-making. It was observed that pharmacist would oscillate to a data-driven approach when they had no knowledge of the patient. In Scenario 3 and 7(See section 5.1.1 Pharmacist Scenarios), the personal negative consequences for the pharmacist would be very high if an error in decision-making occurred. In both scenarios, it was observed that the pharmacist would oscillate their decision-making approach to a data-driven approach. The commonality across both these scenarios was that the pharmacist had increased ambiguity about how to dispense medication they were unfamiliar with or to a patient they were unfamiliar with. Such a scenario increases the probability of a personal negative outcome affecting the pharmacist. An error in dispensing the incorrect medication or dosage amount will result in financial and personal consequences for the pharmacist (such as losing license to practise.) It was identified that the activated mechanism which caused the oscillation was personal sensitivity of a negative outcome. Personal sensitivity to a negative outcome mechanism was also found to be activated with the pilot despite the contrasting environments. This finding indicates that the personal sensitivity to a negative outcome mechanism can be activated regardless of the environment.

Scenario 4(4.8.2 Air Traffic Control Scenarios) for the air traffic controller also showed the key decision-maker oscillate from a system-aided judgement approach to a data-driven approach. Scenario 4(4.8.2 Air Traffic Control Scenarios) involved an emergency signal sounding from the approach desk. The approach desk is a surveillance display which assists the ground movement position with the use of a secondary radar. When the air traffic controllers were monitoring their workstations, an alarm began to sound from the approach desk. When this occurred, the other members of staff looked to the air traffic controller manager to resolve the issue. This was due to internal organisational processes within the air traffic control tower which stated that in an emergency scenario the ATC manager was the individual who was required to take ownership of this issue. The air traffic controller manager has a limited time window the resolve the issue or catastrophic consequences will arise. When the approach desk alarm sounded the air traffic controller would oscillate their decision-making approach towards a data-driven approach. In such a scenario, it is not possible for the air traffic controller to resolve the issue without the aid of the information system. The air traffic controller would take information from the system and relay it to the airborne pilot. In this scenario, it was noted that the process loafing mechanism for the air traffic controller oscillating their decision making was the necessity to use the information system due to internal processes. This was an expected occurrence and the air traffic controller successfully resolved the task.

This decision-making oscillation was similar to the national grid controller when errors were detected. In scenario 1(See section 5.8.2 National Grid Controller Scenarios), the national grid controller is required to monitor the information system for any faults. It was seen that when a fault occurred in the system the controller would oscillate their decision-making approach towards a data-driven decision-making approach. Similarly, to the air traffic controller, the national grid controller required the use of the information system to resolve the task. It was not possible for the controller to understand how the issue occurred from their remote-control centre without the use of data being provided by the information system. It was noted that the national grid controller oscillated to a data-driven approach due to the requirement to use the information system to complete the task as the internal process stated. This was an expected occurrence and was similar to the air traffic controller. This oscillation was observed as normal behaviour for the national grid controller and they successfully completed the task.

This section has provided further analysis on observations across all four case studies. The context differed across all four case studies. The pilot and air traffic controller were classified as dynamic and the national grid controller and pharmacist as undynamic. Despite the context contrasting, similarities were found in the activated mechanisms which caused observably oscillations to a data-driven approach. The personal sensitivity to a negative outcome mechanism was found with both the pilot and the pharmacist. In both of these cases, when the repercussions of failing a task would personally affect the key decision maker a mechanism would activate. The personal sensitivity to a negative outcome mechanism would oscillate their decision-making approach to a data-driven approach. Both key decision makers felt more confident using the information system to complete a task rather than their own intuition. The personal sensitivity to a negative outcome mechanism activated even in contrasting contexts (dynamic and undynamic environment). This finding indicates that when the personal sensitivity to a negative outcome mechanism is activated it will supersede the context a decision maker works in. This will in turn oscillate their decision making to a data-driven approach. This is an important finding and is not accounted for in existing literature. This finding will be discussed in greater detail in section 6.10 Personal Sensitivity to a Negative Outcome Mechanism

Internal organisational processes were also found to alter the decision-making approach of the unit of analysis. This was found with both the national grid controller and air traffic controller. In both of these case studies, it was found that employees were content to ignore potential errors or emergency scenarios due to workplace processes which stated the manager needed to take charge of such situations. This resulted in the manager being required to stop the task they were currently working on and attempt to resolve the error Business processes would result in the manager observably oscillating their decision-making approach.

This section has discussed instances recorded when the key decision-makers oscillated from a system-aided judgement approach to a data-driven approach. The next section will provide a summary of the cross-case analysis.

6.9 Summary of Cross-Case

The previous sections have discussed decision making oscillations from an intuitive, system-aided judgement, and data-driven perspective. These three decision-making approaches were analysed from a critical realist perspective. In summary, the cross case found the following:

- It was observed that for the key decision-maker would oscillate between differing decision-making approaches at the empirical layer.
- The key-decision maker would oscillate between differing decision-making approaches regardless of their operating environment (context).
- These findings are displayed in Figure 64.

In addition to the above, the following was also found

- As the key decision-maker would become more personally sensitive to a negative outcome the personal sensitivity to a negative outcome mechanism would activate.
- The personal sensitivity to a negative outcome mechanism would oscillate the decision maker to a data-driven approach.
- The personal sensitivity to a negative outcome mechanism was observed regardless of the context.
- Employees were found to ignore potential errors or emergency scenarios due to organisational processes which stated the manger was required to take responsibility.
- The process loafing mechanism would oscillate the decision makers decision-making approach.

Both the personal sensitivity to a negative outcome and managerial following of process findings were not found in existing literature and will be explored in more detail in subsequent sections.

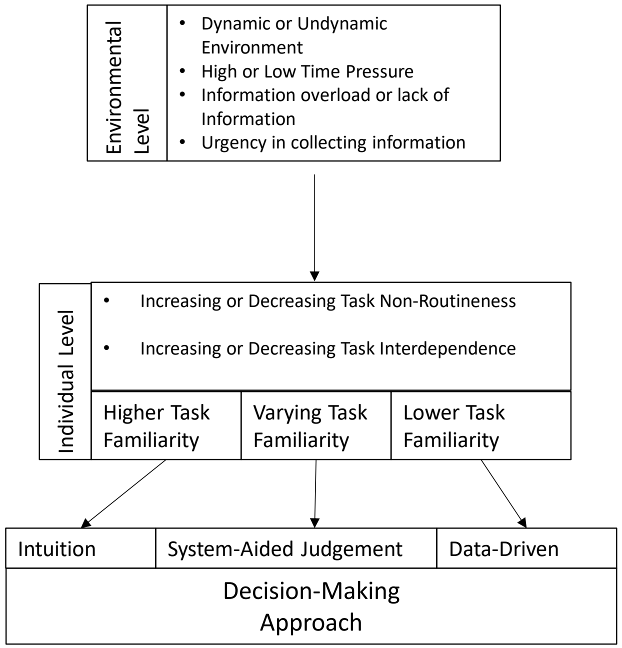

Figure 64 –Environmental, Individual, and Decision-Making Oscillations

6.10 Personal Sensitivity to a Negative Outcome Mechanism

The cross-case analysis showed that the key-decision makers oscillate between differing decision-making approaches. It was seen that factors such as time pressure, information challenges, task non-routineness, and task familiarity were all mechanisms which could oscillate decision-making approaches. Two other mechanisms were also identified. The key decision-maker's personal sensitivity to a negative outcome and process loafing with the decision-maker. The scenarios in which the mechanism, personally sensitive to a negative outcome was activated are shown in Figure 65 under the heading Finding 1. This section will now discuss the personal sensitivity to a negative outcome mechanism in more detail.

	Decision Making Approach			Finding 1
Themes	**Data Driven**	**System Aided**	**Intuition**	**Personal Sensitivty**
Pilot Error	P1,P7			P1,P7
Mechanical Error	P3			
Dynamic Weather	P2,P6, ATC5		ATC6	P2,P6
Aircraft Communication		ATC2	ATC1,ATC3	
Patient Interactions			Phrm1,Phrm2,Phrm 3	Phrm2,Phrm 3
Task Operations	NG1			
Information Fluctuations	NG1		ATC3,Phrm 4	
Time Pressure	P7, ATC4	P3,NG2	ATC7,Phrm5	P7
Task Non-Routineness		P3,P5,NG2, Phrm 6	ATC3,ATC6, Phrm 1	P3,P5,Phrm 6
Task Interdependence	ATC4	P5	NG3,Phrm 4	P5

Key	**Acroynm**
Pilot	P
Air Traffic Control	ATC
Pharmacist	Phrm
National Grid	NG

Figure 65 – Finding 1 – Personal Sensitivity to a Negative Outcome

In professional environments, events can occur which will increase the risk of negative personal outcomes for an individual's professional career if an incorrect decision is made. The increase in risk of a negative personal outcome will create a response in an individual where they will become increasingly sensitive to making an incorrect decision. The individual may be personal sensitive about making the incorrect decision and losing money or workplace prestige with colleagues. In such an instance, the decision maker is personally sensitive to a negative outcome due to context of a task which may increase the likelihood of the task outcome negatively impacting the individual's professional career. The mechanism of personal sensitivity to a negative outcome was found to be activated in Scenarios 1,2,3,5,6, and 7 for the pilot and in Scenarios 2,3, and 6 for the pharmacist. The following sections will explore and discuss the mechanism known as personal sensitivity to a negative outcome.

Personal sensitivity to a negative outcome mechanism was found to be activated in Scenarios 1,2,3,5,6, and 7 for the pilot. The personal sensitivity to a negative outcome mechanism resulted in the pilot altering their decision-making approach. In all the scenarios listed, the pilots were being observed, graded, and reviewed by a highly qualified flight instructor as part of a series of exams. These exams would determine if the pilot would successfully obtain a commercial pilots license. This was an extremely important examination for the pilots. The exam would determine the future course of their career depending on whether they obtained their license or not. The pilots also had potential contracts with reputable commercial airline careers worldwide, which would become void if they failed their examinations. In addition to the pressure of the exam, the pilots also had invested upward of 100,000 euro in order to undertake the course. This is a large sum of money for an individual to invest. The pilots having invested a combination of their savings, financial support from family members, and/or securing loans from a financial institution in order to undertake the course. The combination of these factors made the examination an extremely personally sensitive event in the pilots' lives, which was vital for their professional career. With these factors considered, the consequences of a negative outcome for the pilot's examinations would jeopardise their professional career, financial resources, and social standing with work colleagues. These factors made the event of the commercial license examination of extreme personal importance to the pilot. In these scenarios, the pilot's personal sensitivity was raised to the potential outcome of a negative outcome, failing their exam.

As the students were walking into the cockpit they were extremely nervous. It was seen that the pilots were sweating and had a shaking voice when responding to basic questions. This nervousness was repeated in Scenario 5 and 6 were the pilots were visibly sweating when attempting to perform the task indicating their personal sensitivity to a negative outcome was heightened. In Scenario 1, the pilot was audibly nervous as their voice was shaking when describing actions to the flight instructor such as “lowering landing gear” or “lowering throttle”. In Scenario 7, the pilot was asked by air traffic control on the angle they would be taking on approach, the pilot who was not expecting this question became visibly nervous and was unable to respond to the question in the allotted time. In scenario 3 it was observed that there was a nervousness in the voice of the pilot when attempting to perform the task and that they found it difficult to concentrate on the information being presented to them. This was similar to when the pilot was attempting to perform scenario 1, landing the aircraft in moderate conditions. This was a routine task for the pilot but under conditions of examination, it was seen that the pilot would become extremely nervous and found it increasingly to focus on anything but the information system.

In all of these scenarios, the pilot’s personal sensitivity to a negative outcome would raise when under examination. This manifested itself in the pilots being visibly nervousness, sweating, and having an audible shaking voice. Increased personal sensitivity to a negative outcome mechanism would oscillate their decision-making to a data-driven approach. In all the scenarios, the pilots would ignore information external to the information system. This included data from the environment, the air traffic controller, and/or their co-pilot. The pilots also found it difficult to answer routine questions from air traffic control such as the degree angel they were adopting when attempting to land the aircraft. This was due to oscillating their decision-making approach to a data-driven approach. This decision-making behaviour contrasted with pilot’s behaviour when they were under non-examination conditions. When not under examination, the pilots were able to successfully complete all scenarios. This shows the examination increased the pilot’s personal sensitivity to a negative outcome. This would activate the personal sensitivity to a negative outcome mechanism. The personal sensitivity to a negative outcome mechanism oscillated their decision-making approach to a data-driven approach despite this being the incorrect approach for the task. This evidence shows that when personal sensitivity to a negative outcome was raised, the pilots would trust and have a favourable view of the information system to mitigate against the probability of a personal negative outcome occurring. The oscillation to a data-driven decision-making approach by the pilots resulted in an inability to perform routine tasks. This resulted in the failing of Scenarios 1,2,3,5,6, and 7 due to the mechanism of personal sensitivity to a negative outcome becoming activated over the examination.

The personal sensitivity to a negative outcome mechanism was also found to be activated for the pharmacist manager although they were not under examination conditions. A pharmacist manager is a highly qualified individual who has undertaken rigorous third level training, examinations, and has thousands of hours of experience of working with patients. A pharmacist must adhere to a strict code of conduct and ethics whilst they are working in their profession as they have a responsibility to their patients. Failure for a pharmacist to adhere to this code of conduct can have serious negative professional ramifications for the pharmacist. If a pharmacist is found to have incorrectly administered the wrong medication or dosage to a patient, the pharmacist will be called to appear to a fitness to practise council. This governing body may decide to suspend or revoke the pharmacists license to operate and also administer fines to the pharmacist for failing to adhere to specific standards. This will have serious personal ramifications for a pharmacist were they will suffer negatively in their career, financially, and their standing amongst their peers will also be affected. This shows that despite the pharmacist not being under examination like the pilots, there will be a context when pharmacist's personal sensitivity to a negative outcome will be activated.

An increase in personal sensitivity to a negative outcome was observed with the pharmacist in Scenarios 2,3, and 6(See section 5.1.1 Pharmacist Scenarios). In all three of these scenarios, the pharmacist would oscillate their decision making to a data-driven approach. This was found to be unusual behaviour for the pharmacist as it was rare for them to use the information system. The only instances of them using the information system was when their personal sensitivity to a negative outcome was raised. Although the oscillation to a data-driven approach when personal sensitivity compared with the pilots, their physical behaviour contrasted, as they displayed no physical signs of an increase to personal sensitivity. There were no recorded instances of sweating or being audibly nervous when performing tasks. In scenario 2 and scenario 6(See section 5.1.1 Pharmacist Scenarios), the pharmacist was working with regular patients who required new medication the pharmacist was not familiar with and in scenario 3 the pharmacist was required to work with a new patient to the pharmacy. In all three of these scenarios, there was a heightened risk to the pharmacist in that they were unfamiliar with either the patient or the medication. As a result, the pharmacist was unable to rely on their past experience with a patient or medication.

The added complication for the pharmacist was that if an incorrect medication or instructions are administered to a patient it will have serious ramifications for the patient and personally for the pharmacist's professional future. For the patient, an individual who takes the incorrect medication can have life-impacting risks associated with this. A patient or medication that the pharmacist had no prior knowledge about activated the mechanism of personal sensitivity to a negative outcome. When the personal sensitivity to a negative outcome mechanism was activated, it was observed that the pharmacist would oscillate to a data-driven approach. The pharmacist would attempt to lower the risk of a personal negative outcome to them by oscillating their decision-making approach to a data-driven approach. This decision-making behaviour is similar to the pilots. The key decision maker in both trusted the information system to lower the risk of a personal negative outcome.

The air traffic control manager and the national grid manager contrasted with the pilot and the pharmacist in that personal sensitivity to a negative outcome was not observed in either of these cases. The context across all four case studies differed. The pilot and air traffic controller were classified as being in a dynamic environment, while the national grid controller and pharmacist were in an undynamic environment. This finding indicates that personal sensitivity to a negative outcome can be activated in any context regardless of the environment. Existing research discussed in Chapter 2 has highlighted that the environment (context) a decision maker operates in will have implications for their decision making. This finding reveals that when the personally sensitivity to a negative outcome mechanism is activated it will do so regardless of the context. It also reveals that the personal sensitivity mechanism may not activate due to a context. The pilot and air traffic control manager were classified as being in a dynamic environment but only the pilot was found to have the personal sensitivity to a negative outcome mechanism activated. The pharmacist and national grid manager were classified as being in an undynamic environment but only the pharmacist was found to have the personal sensitivity to a negative outcome mechanism activated. This finding has been used to inform the theoretical model displayed in Figure 66.

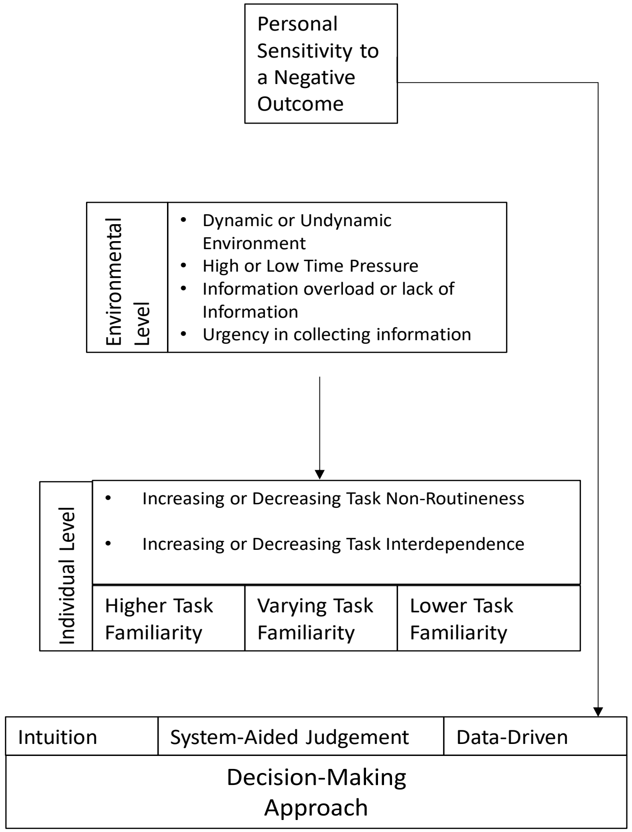

Figure 66 - Personal Sensitivity to a Negative Outcome Mechanism

This section has discussed a new finding that has been referred to as a decision-maker's personal sensitivity to a negative outcome. This was observed with the pilot and the pharmacist despite both decision-makers operating in different environments (context). Despite the difference in environments, the key decision-makers were found to oscillate their decision-making approach when the mechanism of personal sensitivity to a negative outcome was activated. It was found that an event would occur such as the pilot's examination or an unknown patient entering the pharmacy, which would increase in the personal sensitivity to a negative outcome for the decision-maker and activate the mechanism. The pilots were found to be personal sensitivity about failing their examination and losing their commercial pilots license as well as having severe financial consequences. The pharmacist was also personally sensitive to making an error that would lead them to potentially having their license revoked or facing financial penalties due to administering the incorrect medication. Once the key decision-maker's personal sensitivity was increased they would oscillate their decision-making to a data-driven approach. This showed that the key decision-maker used the information system to mitigate against a personal negative outcome. This behaviour was found to work successfully for the pharmacist; however, the pilot adopted the incorrect decision-making approach for the task. This caused the pilot to fail a task they had previously successfully completed under non-examination conditions.

This finding will have implications for the design and use of information systems in situations where an individual's personal sensitivity to a negative outcome is raised. The next section will discuss a second finding referred to as process loafing.

6.11 Process Loafing Mechanism

Process loafing occurs when an individual is not required to take responsibility or action due to organisational procedures (McAvoy and Butler, 2009). Process loafing differs from phenomena such as social loafing as other members of a team will maintain the same workload and effort but will choose to ignore undertaking a new task. Social loafing occurs when an individual lower their work effort and "coasts" due to another member of staff increasing their workload to compensate. Process loafing also differs from diffusion of responsibility. Diffusion of responsibility occurs when other members of staff maintain the same standard of work but chose to ignore scenarios outside their remit. The scenarios in which the process loafing mechanism were found to be activated are shown in Figure 67.

	Decision Making Approach			Finding 2
Themes	Data Driven	System Aided	Intuition	Process Loafing
Pilot Error	P1,P7			
Mechanical Error	P3			
Dynamic Weather	P2,P6, ATC5		ATC6	ATC5,ATC6
Aircraft Communication		ATC2	ATC1,ATC3	
Patient Interactions			Phrm1,Phrm2,Phrm 3	
Task Operations	NG1			
Information Fluctuations	NG1		ATC3,Phrm 4	
Time Pressure	P7, ATC4	P3,NG2	ATC7,Phrm5	ATC4
Task Non-Routineness		P3,P5,NG2, Phrm 6	ATC3,ATC6, Phrm 1	NG2
Task Interdependence	ATC4	P5	NG3,Phrm 4	ACT4

Figure 67 - Finding 2 –Process Loafing

Process loafing was found to occur with the air traffic control manager and the national grid manager as they could not hand over an issue to a colleague. In contrast process loafing was not found to be a factor in either the pilot or the pharmacist. Process loafing was found in Scenarios 4,5, and 6 with the air traffic control manager and in Scenario 2 of the national grid controller. These individual instances are displayed in Figure 67. The previous chapters identified that the air traffic control manager operated in a dynamic environment and the pharmacist operated in an undynamic environment. The fact that process loafing was found to occur in both a dynamic and undynamic environment is an important finding. This indicates that process loafing is not reliant on a specific environment for the mechanism to activate.

Process loafing was found in Scenarios 4,5, and 6 of the air traffic controllers. Scenario 4 involved a potential mid-air collision between two aircraft. This is an emergency scenario and can occur at any time of the day or night. The air traffic control manager had been working on a different task when an alarm began to sound and warning light flash from the approach desk. At this point, it was found that the other staff members of the air traffic control tower would ignore the warning signals and that the air traffic control manage had to take responsibility for the emergency situation. This was due to workplace processes being put in place which stated that the manager on duty should resolve an emergency scenario. It was found that other members of staff would ignore the signal due to workplace processes.

This was found to be process loafing by the other staff members and it caused the air traffic control manager to oscillate their decision-making approach. Process loafing was evident in that the other members of staff did not reduce their workload and maintained the same standard of work. The other members of the team would however choose to allow the manager to take responsibility because of the processes in place. If the other members of staff had lowered their work effort or working load it would have indicated social loafing was occurring, the fact the other members of staff did not do this shows process loafing occurred. In addition, it was found that the other members of staff did not ignore warning signals by choice but rather that the internal workplace processes dictated they should. Process loafing by the other team members would result in the air traffic control manager oscillating their decision-making approach. Prior to this emergency scenario occurring, the air traffic control manager had been adopting a system-aided judgement approach. As process loafing occurred in the control tower, the air traffic control manager was required to oscillate their decision-making approach towards a data-driven approach. Using data from the information system, the air traffic control manager would then contact the aircraft pilot to amend the flight trajectory. The aircraft pilot successfully amended the flight trajectory and the approach desk warning signals stopped sounding. The air traffic controller adopted the correct decision-making approach for the task and the situation was resolved successfully. Although this scenario was an emergency, the error that led to the alarm sounding was not from the behaviour of the air traffic control manager. In the unlikely event the two aircraft came close to one another or collided, the responsibility for this would not lay with the air traffic control manager. This removed the heightened risk of negative professional consequences for the air traffic control manager in the event of an error. In addition, it was found that the oscillation in decision-making approach was due to the internal processes of the workplace which activated the mechanism referred to as process loafing.

This occurrence of process loafing was replicated in Scenario 5, where a pilot requested a long-range forecast from the air traffic control tower. When this request is received by the control tower the weather information system will sound, and an individual will be required to input and relay information to the requesting pilot. As with Scenario 4, it was found that the other staff members of the control tower would ignore this request and would not alter the task they were performing expecting the air traffic control manager to take responsibility for the task. It was also noted that social loafing was not occurring as the other members of staff would maintain their effort in their workload to the same level as before the weather IS notification. This behaviour showed that process loafing occurred in the control tower. The other members of staff would continue working with their current task with the same level of effort but would ignore the alarm, confident that the air traffic control manager would take control of the issue. The air traffic control manager resolved the issue by taking control of the task and interacting with the aircraft via the information system. The air traffic control manager was required to oscillate their decision-making approach and undertake a separate task due to the mechanism of process loafing activating. This was due to internal organisational policies in the control room.

Process loafing was seen again in scenario 6, when the unexpected event of agricultural lime began to blow onto the runway. Visibility on the runway being lowered is a serious scenario that can result in dangers to crew and passengers in the aircraft due to take off or land. It was found that when the agricultural lime began to block visibility on the runway, the other members of staff chose to ignore the issue despite it being clearly obvious from the view of the control tower. It was also noted that the other members of staff continued to work to the same standard on their assigned tasks even as visibility was lowered. The other members of the control room choose to ignore this issue as internal processes dictated that the manager should resolve the issue. It was then found that the air traffic control manager would take control of the situation and began to intuitively inform aircraft that were due to land and aircraft that were on the runway of the poor visibility. The air traffic control manager also gave the pilots feedback and advice on the best course of action to take due to the unexpected change in the environments weather conditions. The mechanism which caused the air traffic control manager to oscillate their decision making was process loafing which was caused by internal organisational processes. This scenario compares with Scenarios 4 and 5(See section 4.8.2 Air Traffic Control Scenarios) in the air traffic control tower with the other members of staff continuing to work on their own tasks and assuming the manager would take responsibility for the potential emergency situation due to internal processes.

This behaviour was repeated in the control room of the national grid in Scenario 2. In this scenario, the SCADA information system automatically detected and alerted the control room to an error from specific power lines that were being monitored. When the alarm began to sound, the other staff members of the control room would ignore the alarm and continue working on their tasks. The other members of staff would continue to focus on their tasks, maintained the same level of effort, and expected the manager would intervene to resolve the issue. This indicated that social loafing was not occurring. The manager would use the SCADA information system to gain more information surrounding the individual faulty beacon; information included how much power was being transmitted on the specific power lines, what the maximum capacity of the lines were, which regions were affected, was it an isolated issue, and if there was a knockout effect to other zones. The manager also used the SCADA information system to review power lines and nearby stations which would need to be shut down if repairs needed to take place. The national grid manager would then use the information from the system in conjunction with their own procedural knowledge of the scenario to formulate a plan with the maintenance teams. Despite this occurring in close proximity to other staff members, they would ignore the issue as the manager would intervene and resolve it as the process dictated. It was found that the national grid manager had oscillated their decision-making process from a data-driven approach to a system-aided judgement approach to resolve this task due to the mechanism of process loafing activating. Although this was a task which the national grid manager was required to resolve; the error that led to the system failure was not caused by the national grid manager. As such, there was no risk of a negative outcome to the manager's professional career. Despite this, the manager was still required to complete the task and use the information system in doing so as the process dictated that they do so.

Although this analysis has identified internal organisational processes as activating a mechanism known as process loafing it differs from personal sensitivity to a negative outcome as a mechanism. Process loafing was found to be a mechanism which observably oscillated decision making due to internal workplace processes. Examples of this were found to be processes in relation to error handling and emergency situations. As a result, individual was required to oscillate their decision-making approach for situations which were created outside of their control. As these situations were created outside of their own control, the manager would not be reprimanded or sanctioned for any errors. The individual was required to follow internal policies relating to the error. This contrasted with the identification of personal sensitivity to a negative outcome as a mechanism. With the process loafing mechanism, it was the key decision makers sole responsibility to complete a task successfully. As such the key decision maker was responsible for any errors that were created. This resulted in the process loafing mechanism activating. It was observed that when the process loafing mechanism was activated it oscillate the decision maker to a data-driven approach. In short, personal sensitivity to a negative outcome is a self-created mechanism whereas process loafing is a mechanism created external to the unit of analysis due to the context created by organisational processes. This is shown in Figure 68.

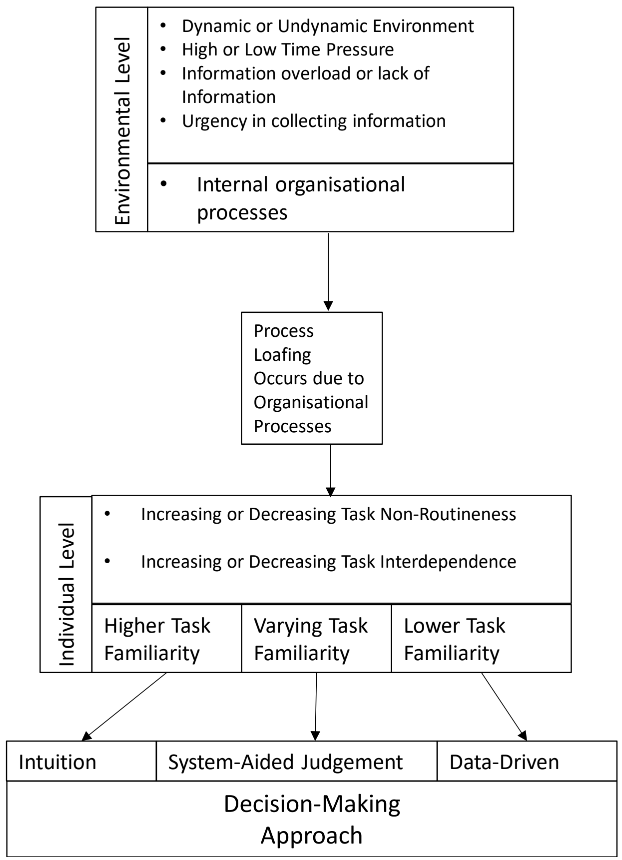

Figure 68 - Organisational Processes activates process loafing mechanism.

This section has discussed the context of organisational processes activating a mechanism of process loafing. The mechanism of process loafing occurred in both the air traffic control tower and the national grid control room. The air traffic control manager and the national grid manager were comparable in that both were required to perform specific tasks when problems or errors arose due to workplace processes dictating they do so. These errors were not as result of the behaviour of the key decision-maker but by other individuals or system errors. These errors would not negatively impact the key decision makers professional career if they were not resolved successfully. However, the key decision maker in both the air traffic control tower and national grid control room had a responsibility to resolve any error that arose due to the internal processes of the organisation. Despite the contrasting operating environments (dynamic vs undynamic) the members of staff in both control rooms would ignore potential emergency situations and warning signals by various information systems assuming the manager would intervene and resolve the issue. This behaviour differed from existing phenomena such as social loafing and diffusion of responsibility because the other members of staff maintained the same standard and effort in their work. The other members of staff chose to ignore the warning signals which resulted in the manager oscillating their decision-making approach to a data-driven approach as they were required to intervene and resolve a new task. The next section will provide an overview of the updated theoretical model displayed based on the findings discussed in the previous two sections.

6.12 Theoretical Model

The findings presented in Chapter 4 and 5, as well as the cross-case analysis conducted in this chapter are used to inform Figure 69. The model in Figure 69 is structured to show if a shift in decision making is reliant on events such as a task which is reliant on mechanisms such as time pressure in a context. This chapter has presented two new mechanisms which inform the theoretical model displayed in Figure 69. These mechanisms are called personal sensitivity to a negative outcome and process loafing.

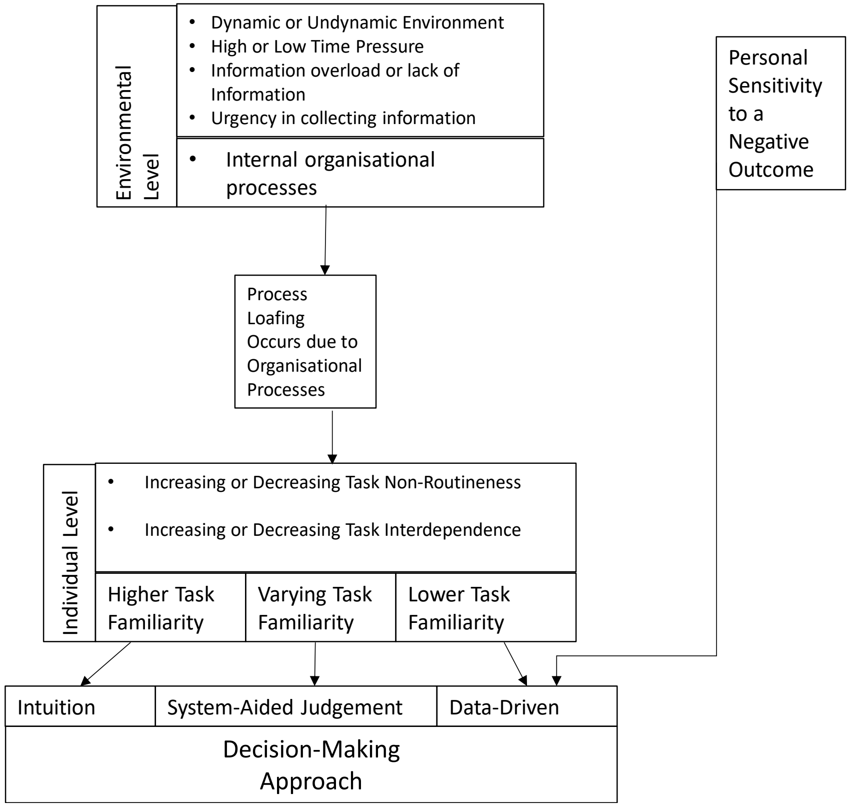

Figure 69 - Personal Sensitivity to a Negative Outcome Mechanism & Process Loafing Mechanism.

The first of these is when a decision maker is personal sensitivity to a negative outcome. The personal sensitivity to a negative outcome mechanism will observably oscillate their decision-making approach to a data-driven approach. Individuals at workplaces may often have a heightened risk of a personal negative outcome and will become sensitive to failure when performing a task. When both the pharmacist and the pilots were faced with events where failure may result in personal negative outcomes for their profession, they would oscillate to a data-driven approach. In these moments, the key decision-makers viewed the information system as an aide which would lower or remove the risk of a personal negative outcome and increase the likelihood of a personal successful outcome. A successful outcome would remove any feeling of personal sensitivity to a negative outcome. When the personal sensitivity to a negative outcome mechanism activated, it would override the environmental characteristics (context). Personal Sensitivity to a negative outcome is included in the theoretical model shown in Figure 69.

The second mechanism discovered was process loafing. Process loafing differs from phenomena such as social loafing in that team members would maintain the same effort and not avoid performing a task. Team members would not perform a task as internal organisational processes dictated that the manager take over error or emergency situations. The internal organisational policies created a context in which team members would ignore error scenarios, even emergency ones, as internal processes state the manager would intervene and resolve the task. It was found that due to these processes, that if an emergency or error occur the process loafing mechanism would activate. The process loafing mechanism would result in the manager oscillating their decision-making approach to resolve the task. This mechanism activated with both the air traffic control manager and the national grid manager. In both workplaces, team members would ignore emergency scenarios as processes stated the manager would take responsibility. This would then lead to the manager being required to oscillate their decision-making approach to the task at hand. There would be no reprimand or sanction against the manager for the error occurring, but they were responsible for investigating why it occurred. In these scenarios, the managers decision-making approach had not oscillated due to personal sensitivity to a negative outcome but rather process loafing. Therefore, process loafing is included as a mechanism in Figure 69.

Although process loafing and personal sensitivity to a negative outcome were both mechanisms which would oscillate the decision makers decision-making approach, the mechanisms differed. Personal sensitivity to a negative outcome can be summarised as:

- Personal sensitivity to a negative outcome was a mechanism activated due to the decision makers own fear of failing or making an error with a task which would have personal consequences for them.
- An activated personal sensitivity to a negative outcome mechanism resulted in the decision maker oscillating to a data driven decision-making approach

In contrast to the above, process loafing can be summarised as:

- Internal organisational processes were found to alter the context in which decisions relating to errors and emergency situations were handled.
- Team members of the key decision maker would choose to ignore errors or emergency scenarios due to the context of organisational processes.
- When an error or emergency situation occurred, it would activate the process loafing mechanism in the key decision maker.

The next section will provide a summary of this chapter.

6.13 Chapter Conclusion

This chapter built upon Chapters 4 and 5 by providing further analysis of the four case studies. A cross-case analysis approach was used to compare and contrast each of the case studies. The cross-case analysis was performed from a critical realist perspective as Chapter 3 found critical realism was most aligned with this research study. The chapter was structured around the research objective from a critical realist perspective. As such, this chapter sought to investigate if a shift in decision making is reliant on events such as a task which is reliant on mechanisms (such as time pressure) in a context (dynamic or undynamic environment).

The chapter began by looking at the relationship between environmental and task characteristics. This section validated existing research (Chapter 2) which found that the environment a decision maker operates in can affect the task characteristics. The next section built upon these findings by analysis of each case study from the perspective of three decision-making approaches. Intuition, system-aided judgement, and data-driven decision making were all reviewed. It was found that decision makers would oscillate between these three differing decision-making approaches.

From the analysis two further findings were also discovered. The first was a mechanism referred to as personal sensitivity to a negative outcome. The personal sensitivity to a negative outcome mechanism was found in both dynamic and undynamic environments. This reveals that the personal sensitivity to a negative outcome mechanism can activate and supersede the context the decision maker was in. This contradicts existing research which states that differing environments are better suited to differing decision-making approaches. When the personal sensitivity to a negative outcome mechanism is activated, it was found that the decision-maker would oscillate their decision-making approach to a data-driven approach. As well as being a new finding, the identification of the personal sensitivity to a negative outcome mechanism further validates that decision makers will oscillate between differing decision-making approaches. The second finding and mechanism was referred to as process loafing. This finding differed from the personal sensitivity as this mechanism was not self-created. This finding was found in both the national grid and air traffic control centres. It was found that team members would ignore scenarios, even in emergencies, as internal organisational processes dictated that the manager would intervene and resolve the issue. This found to be related to the context from a critical realist perspective. This would activate the process loafing mechanism and oscillate their decision-making approach to resolve the issue. Process loafing was found to be outside of the individuals control and a factor they had no direct control over.

The next chapter will provide further discussion on the findings of personal sensitivity to negative outcome and process loafing. The chapter will also discuss the contributions, implications, limitations, and avenues for future research.

Chapter 7: Discussion

This chapter builds upon the foundations developed in previous chapters to (i) discuss the study's findings; (ii) highlight contributions to theory and practise; and (iii) present the overall conclusions of the study. This research study investigated oscillating decision-making approaches for key decision-makers in dynamic and undynamic environments. Following an in-depth literature review, Cognitive Continuum Theory (CCT) was proposed as the theoretical lens in Chapter 2 to investigate the research objective. CCT has previously been applied to the fields of engineering, management, and the medical profession. However, this theory had not yet been explored from an information systems perspective (Dhami and Thomson, 2012). This gap in existing research provided this study the opportunity to explore oscillating decision making through the lens of CCT from an information systems perspective. Chapter 3 provided the design for this study, positioning it within the critical realist paradigm. A qualitative, multi-case study approach was presented as the most suitable method by which to serve the research objective and associated questions. Chapter 6 preformed a cross-case comparison of the four case studies.

This chapter presents the conclusion of this research study. The chapter will present two new findings referred to as the personal sensitivity to a negative outcome mechanism and the process loafing mechanism. The chapter will subsequently discuss the contributions of this study, exploring the implications of this research for both researchers and practitioners. The chapter concludes by discussing the limitations of the study and proposing areas for future research. The next section will discuss the research background, motivation, and research objective of this study.

7.1 Research Background, Motivation and Research Objective

Existing research has shown that managers will oscillate between differing decision-making approaches when performing tasks. Research in domains such as management (Mahan, 1994; Simon, 1987), engineering (Hammond, 1997), and the medical domain (Custers, 2013) have all found decision makers will oscillate between differing decision-making approaches.

However oscillating decision-making approaches has yet to be researched from an information systems perspective despite calls to do so (Dhami and Thomson, 2012). As information systems continue to permeate throughout organisations this represents a gap in existing knowledge. Given the enormous changes to managerial decision making practice over the past few decades, it is of critical importance that this gap in knowledge be addressed. Chapter 2 showed that managerial decision making has undergone transformational changes due to the rise of big data and introduction of data analytics. These changes have given rise to the data-driven manager but it was also found that mangers will use human-centric decision making such as intuition. What is not apparent however is the interplay between the more human-centric intuitive manager and the information-system centric data-driven manager when using information systems.

Chapter 2 also showed that the environment a decision-maker operates in can raise profound challenges for a decision maker. Factors such as time constraints, complexity, risk, and information challenges impact on the decision-making process (Persson, 2018, Maitland and Sammartino, 2015). As data continues to grow, organisations are required to alter existing decision-making processes to incorporate big data into the decision-making process. Information systems will therefore become increasingly essential and vital to human decision making.

To that end, this research study sought to explore the interplay between human (intuition and analysis) decision-making approaches and the current trend of using a data-driven decision-making approach. Chapter 1 presented the research objective of this study which was:

To explore oscillations in decision-making approaches while having access to information systems in dynamic and undynamic environments.

To address the research objective two research questions were formulated:

1. How do decision-making approaches oscillate while having access to information systems?
2. How does the dynamic or undynamic environment impact on the oscillation of decision-making approaches while having access to information systems?

Further discussion for both the research objective and research questions can be found in Chapter 1. The next section will provide a discussion of the research findings.

7.2 Summary and Discussion of Research Findings

This section discusses findings arising from the research questions addressed in this thesis. This section will highlight the key findings from each of the four in-depth case studies (pilot, air-traffic controller, pharmacist, national-grid controller). This will answer both the research questions that were proposed for the study:

Research Question 1:

How do decision-making approaches oscillate while having access to information systems?

Three modes of cognition were validated when conducting this study. An intuitive approach, an information-systems data-driven approach, and a hybrid approach using a combination of both referred to as system-aided judgement. It was found across all four case studies that the key decision maker would oscillate their decision-making approach but the mechanisms as to why differed.

A human-centric intuitive approach was found to be used by the air-traffic control manager(Section 4.8 Air Traffic Controller Introduction), the pharmacist(Section 5.1), and the national grid control manager(Section 5.8 National Grid Controller Introduction) when conducting routine tasks. When conducting such tasks, it was found that the key decision maker would oscillate their decision-making approach away from either a data-driven or system-aided approach towards an intuitive approach. The mechanism for this oscillation was the decision makers experience and familiarity when conducting such tasks. As the key decision makers were all very experienced in their roles, they felt at ease using an intuitive approach when conducing a routine task. It was found that by adopting an intuitive approach to decision making the key decision maker was able to rapidly perform tasks without the use of the information system. This resonates with existing literature which found that using an intuitive decision-making approach allows users to arrive at decisions quickly (Li et al, 2016).

A system-aided judgment approach was found to be used across all four case studies by each of the decision-makers. A system-aided judgement approach was found with the decision-maker using a combination of human knowledge used in conjunction with the information system. The mechanism for the key decision maker in oscillating their decision-making approach to a system-aided judgement approach was when they were unsure or had any ambiguity around completing a task. The decision-maker would have a well-learned response for a task, using knowledge that they had accrued over time, with data from the information system.

A data-driven approach was found to be used across all four case studies by each of the decision-makers. A data-driven approach was found to be used by the decision maker primarily using the information system to complete a task. The decision makers were found to oscillate their decision-making approach towards a data-driven approach when performing novel tasks. Occasionally, these tasks brought enormous personal pressures for the key decision makers. The key decision maker would be personally responsible for any errors occurring. It was found that when novel tasks occurred, the decision-maker would oscillate their decision-making approach towards a data-driven approach.

This study has found that decision makers will oscillate between an intuitive, system-added judgement, and data-driven approach to decision making. The key decision makers were found to oscillate to an intuitive decision-making approach when having experience with a specific task and did not require the use of the information system. An oscillation to a system-aided judgement approach was found when having familiarity with a task but also requiring further information from the information system before making a decision. An oscillation to a data-driven approach was found when the decision maker required the sole use of the information system to make a decision. It was also found that when the decision maker was personally sensitivity to a negative outcome they would oscillate to a data-driven approach. This was an novel finding and not accounted for in Chapter 2.

Research Question 2:

How does the dynamic or undynamic environment impact on the oscillation of decision-making approaches while having access to information systems?

Dynamic and undynamic environments were classified in the literature review in Chapter 2. Across all four case studies the environment the decision maker operated in was found to cause them to oscillate their decision-making approach when using information systems.

Both the pilot (see Section 4.1) and air-traffic controller (see Section 4.8) were found to operate in a dynamic environment, which routinely caused their decision-making approach to oscillate. The dynamic environment was found to alter the time pressure, information availability, and a novelty of task the decision maker encountered. Changes in the operating environment (context) would require the decision maker to oscillate their decision-making approach in order to be able to successfully complete the task. An example of this was found in emergency scenarios for the pilot, and unexpected scenarios, such as agricultural lime lowering visibility for the air-traffic controller. Both of these scenarios highlighted the challenging and dynamic environment both decision makers operated in.

This contrasted with both the pharmacist and national grid manager. Both of these decision makers were found to operate in an undynamic environment which lowered time pressure, decreased the frequency of change in information availability, and tasks were routine rather than novel. These environmental characteristics (context) allowed both decision makers to use a more human decision-making approach. The pharmacist and national grid manager would primarily rely on an intuitive or system-aided judgement approach to resolve tasks they had a high familiarity with. On a rare occasion when environmental volatility (context) would increase, the environment would become more dynamic and the decision maker would oscillate their decision-making approach to a data-driven approach. The mechanisms which caused this event were not found in previous research examined in Chapter 2 and will be explored in the next section.

This study has found that the environment(context) a decision maker works in will oscillate their decision-making approach. This was found to be more common in a dynamic environment (Chapter 4) as the environmental characteristics fluctuate rapidly. This results in the key decision maker being required to oscillate their decision-making approach to realign with the task being conducted. This result contrasted with the key decision makers of the undynamic environment as the environmental characteristics resulted in less frequent decision-making oscillations.

This section has reviewed and discussed findings from the two research questions. The next section will now discuss two further findings, which were not accounted for in existing literature.

7.3 Discussion of New Findings

In addition to answering the two research questions in the previous section, this research study has found two new and novel mechanisms. This section will discuss the two new mechanisms identified from the cross-case analysis, which are:

(i) Personal Sensitivity to a Negative Outcome Mechanism
(ii) Process Loafing Mechanism

The subsequent sections will discuss these novel mechanisms beginning with personal sensitivity to a negative outcome mechanism.

7.3.1 Personal Sensitivity to a Negative Outcome Mechanism

This research study has found that when a decision maker begins to anticipate potentially adverse individual consequences this will activate a mechanism. This mechanism is referred to as the personal sensitivity to a negative outcome mechanism. This mechanism once activated will oscillate the decision maker to use a data-driven approach to decision making. This is an important finding as many and wide-ranging working environments have regular or isolated incidents, in which individuals will begin to anticipate adverse negative consequences occurring. Professionals such as pilots, surgeons, and financial traders often have situations such as this. Examples of personal negative outcomes could include a loss of workplace prestige with co-workers, emergencies to deal with, or life-threating situations. In such situations, an individual may feel increasingly apprehensive about making an error when making a decision.

This research study has focused on case study sites, which have introduced information systems to lower the cognitive load on managers and assist in their decision making. The introduction of information systems has been successful in allowing managers to interact with larger datasets to gain a completer and more accurate picture of specific scenarios in their field. These systems also require human interaction and/or input and this research has verified three distinct decision-making approaches across all four case studies. The key decision makers were found to use a human centric intuitive approach, a hybrid system aided judgement approach, or an information systems centric data-driven approach when making a decision. The information systems used by the pilot, air traffic controller, pharmacist, and national grid controller all had a commonalty. These systems were introduced to augment and support the key decision makers decision making, meaning that human input and decision making is still required. The identification of the personal sensitivity to a negative outcome mechanism is an important finding in this context. This research has found that the activation of the personal sensitivity to a negative outcome mechanism will cause the decision maker to oscillate their decision-making approach to a data-driven approach. This removes the information system acting as a supportive tool in the decision-making approach. Instead, when the personal sensitivity to a negative outcome mechanism is activated the information system became the sole decision-making system used by the key decision makers. This can revert even a highly qualified, experience individual's decision-making behaviour to resemble that of a novice decision maker. This is because the decision maker will filter out all other information other than what the information system is displaying. This decision-making behaviour created decision-making errors across all four case studies.

As the information challenges facing individuals, organisations and society continue to grow, we as decision makers become ever increasingly reliant on the use of information systems to augment our decision making due to the vast quantities of data being generated. This raises a question on how we reconcile a data-driven decision-making approach with our inherent human-centric mechanisms such as personal sensitivity to a negative outcome? This is a challenge for many industries today and particularly in the industries researched as part of this study.

Prior research using cognitive continuum theory has found factors such as familiarity with task and time pressure (Dhami and Thomson, 2012), as reasons why an individual may alter their decision making approach. Existing research in this area has limitations as they have not concentrated on today's modern manager and their required use of information systems to complete even the most mundane tasks. This research study has found that activating of the personal sensitivity to a negative outcome mechanism will oscillate the decision maker to a data-driven approach. Even highly qualified managers with vast domain experience of policies and procedures, as were observed in this study, oscillated their decision-making approach to a data-driven approach due to the personal sensitivity to a negative outcome mechanism.

The pilots and the pharmacist were both considered domain experts with a vast body of experience in their given fields. Both decision makers had access to large scale, sophisticated, information systems which would provide the decision maker with the required information at any given moment. These systems are now deemed indispensable and necessary in these professions due to the ongoing information challenges surrounding the amount of data being collected and propensity of information overload occurring. Information systems are in place in both professions to process, collect, and distribute information to the manager. The activation of the personal sensitivity to a negative outcome mechanism resulted in serious errors in decision making. The personal sensitivity to a negative outcome mechanism was found to activate as the decision maker was attempting to complete a task successfully when they were apprehensive about failing the task.

Inadvertently, the activation of this mechanism can cause an individual's decision-making approach to not align with the task, thus creating the very error in decision making they were attempting to avoid.

At an environmental level, the personal sensitivity to a negative outcome mechanism was found in both a dynamic (the pilot) and undynamic (pharmacist) environment. This finding contradicts existing research which found that it is primarily environmental demands and complexity that will negatively affect decision making (Maitland and Sammartino, 2015). Existing research has focused upon the environment in which a decision maker operates. However, this thesis' has found that the activation of the personal sensitivity to a negative outcome mechanism will supersede the environment. The identification of the personal sensitivity to a negative outcome mechanism shows that even individuals who operate in un-complex, undynamic environments may perform poorly due to feeling apprehensive about conducting a specific task. This in turn would activate the personal sensitivity to a negative outcome mechanism. This is an important finding as it shows that the personal sensitivity to a negative outcome can occur in all working environments not just those that are dynamic. As information systems have become ubiquitous across both dynamic and undynamic environments it is important for practitioners and scholars of information systems to consider this finding when developing, implementing, and using information systems.

7.3.2 Process Loafing Mechanism

To facilitate the vastly increasing data that the data-driven manger requires an increasing amount of business processes are required by organisations. Organisations have been forced to realign or create new business processes in order to facilitate the integration of big data into the decision-making process. What is not always clear is the potential disturbance that the increasing number of business processes have on managerial decision making. This research study has identified that business processes(relating to emergency scenarios) will activate the process loafing mechanism which will oscillate an individual's decision-making approach. The process loafing mechanism was identified as the second mechanism in the key decision-maker oscillating their decision-making approach. The process loafing mechanism was found to be created at the environment or context layer as shown in Figure 69. At this layer it was found that organisations may introduce specific procedures, processes, or policies for emergency or error handling situations. These procedures state that only the manager may resolve specific situations. The procedures or policies introduced at this layer were found to activate the process loafing mechanism. Once the process loafing mechanism was activated, the decision maker would oscillate their decision-making approach in an attempt to resolve the specific error or emergency situation. This was required as other team members would choose to ignore the emergency scenario as organisational procedures state the manger must only resolve it.

The process loafing mechanism was found to differ from existing phenomena such as social loafing and diffusion of responsibility:

1) Social loafing occurs when an individual lowers their work effort and "coasts" due to another member of staff increasing their workload to compensate (Meyer et al., 2016).

2) Diffusion of responsibility changes the behaviour of the individual by making them feel less responsible for the consequences of their actions (Beyer et al., 2017).

The process loafing mechanism differs from both of these phenomena as process loafing occurs when an individual is not required to take responsibility or action due to organisational procedures (McAvoy and Butler, 2009). This is an important distinction as inaction occurs in social loafing and diffusion of responsibility due to the behaviour of the individual. However, when the process loafing mechanism is activated the individual does not take action due to organisational procedures. Although process loafing has been defined in existing literature, this research is the first to identify process loafing as a mechanism in oscillating a decision-making approach.

The researcher believes that the process loafing mechanism will become increasingly prevalent within organisations over coming years. The vast quantities of data being produced both internally and externally to organisations has increased the requirement for managers to use information systems. This has resulted in an increasing competition for mangers attention within organisations (Lee et al., 2016). As managerial attention becomes increasingly fractured due to the ever-increasing amount of data and information systems; organisations have been required to implement an ever-increasing number of business processes (Van Der Aalst, La Rosa et al. 2016).

As this research has identified the process loafing mechanism as oscillating a decision-making approach; organisations should consider how managerial decision-making compliments the procedures they are implementing. Existing research has shown that task outcome may be unsuccessful if the decision-making approach does not align with it (Dhami and Mumpower, 2018). Although no negative outcomes occurred with either the air traffic or national grid controller, Section 6.10 Personal Sensitivity to a Negative Outcome Mechanism of this study showed the potential negative consequences of incorrect decision-making approaches. This should strike a note of caution for organisations, as decision making becomes increasingly automated and augmented by information systems this will require the further introduction of procedures and policies for decision makers to adhere to. Organisations should consider the most compatible decision-making approach for a task before introducing specific policies or procedures. The next section will discuss the contributions, implications, limitations of this study. Future research areas will also be identified.

7.4 Contributions, implications, Limitations, and Future Research

The research objective of this study was to:

To explore oscillations in decision-making approaches while having access to information systems in dynamic and undynamic environments.

In meeting the research objective, this research offers a number of contributions to both the academic and practitioner communities. Section

7.4.1 will discuss the main contributions of this study. This is followed by section 7.4.2 which will discuss the implications of this research for the academic community. Section 7.4.3 will then examine the significance of this research for practitioners. The chapter will then conclude with sections 7.4.4 and 7.4.5. Section 7.4.4 will give an overview of the limitations of this study, whilst section 7.4.5 will consider potential areas of future research that have been identified.

7.4.1 Contributions

Given the dearth of existing research surrounding the research objective from an information systems perspective, this research offers a number of contributions to the literature on decision making when using information systems. First, this research is the first to extend cognitive continuum theory as a theoretical lens to the information systems domain. Second, the personal sensitivity to a negative outcome mechanism, once activated, was found to oscillate the decision maker to a data-driven approach. Current research has focused on the benefits that organisations and individuals obtain by using a data-driven approach to decision making. Despite the pilots and pharmacist all being domain experts, each decision maker would default their decision-making approach to a data-driven decision making when the personal sensitivity to a negative outcome mechanism was activated. This is an important finding as despite the introduction of information systems to organisations to reduce the reliance on human decision making, information systems may increase the number of errors occurring if the decision-maker is apprehensive about potential negative ramifications occurring when making a decision.

Third, this research has identified the process loafing mechanism. Specific organisational policies and procedures which state that the manager must intervene and resolve the task were found to activate the process loafing mechanism. In addition, these specific organisation policies and procedures would enable the inaction of the managers colleagues. When this occurred the process-loafing mechanism would activate. Once the process loafing mechanism was activated, it was found to oscillate the decision-making approach of the manager away from their current decision-making approach. In contrast to the personal sensitivity to a negative outcome mechanism, the process loafing mechanism was found to be activated due to processes, which were outside of the decision maker's control. This contribution is of value to the practitioner community as organisational policies and procedures should be create with the required decision-making approach required to resolve the task in mind.

Fourth, this study has further validated that the environment or context the decision maker operates in is a factor in the decision-making approach used by the decision maker. It was found that decision makers operate in either dynamic or undynamic environments. The characteristics of these environments can cause the decision-maker to oscillate their decision-making approach when conducting a task. This is an important consideration as how information is presented to a decision maker should factor in the environment the individual operates in. However, it was also found that the personal sensitivity to a negative outcome mechanism once activated will override the environment a decision maker is in. This is an important contribution for current and future information system use as the personal sensitivity to a negative outcome can be activated in a dynamic or undynamic environment. Organisations in both dynamic and undynamic environments should consider training individuals to have a well learned response to lower the potential of individual becoming apprehensive about potential negative ramifications. The decision maker having a well-learned response when feeling apprehensive may lower or remove the probability of personal sensitivity to a negative outcome occurring. This would in turn reduce errors in decision making occurring when an individual is apprehensive about negative consequences from making a decision. The process loafing mechanism was also found to activate in both a dynamic and undynamic environment. The activation of the process loafing mechanism was found to be created at organisational level, outside of the environment the decision maker operated in. As such, organisations should be mindful of the policies and procedures that are being introduced and the effect on managerial decision-making.

Finally, this research study validates critical realism as an appropriate research philosophy for investigating decision-making approaches in the information systems domain. The alignment of a critical realism philosophical approach with this research study allowed the researcher to identify activated mechanisms which oscillate a decision-making approach in dynamic and undynamic environments.

7.4.2 Implications for Researchers

The contributions outlined in the previous section have implications for future researchers in the domain of decision making. The primary contribution of this study is the creation and development of a theoretical framework (see Figure 69 - *Personal Sensitivity to a Negative Outcome Mechanism & Process Loafing Mechanism.* This framework gives future researchers in decision making an understanding of how an oscillation in decision making (the empirical) is reliant on events such as a task (the actual) which is reliant on mechanisms such as time pressure (the real) in a context (dynamic or undynamic environment). The empirical and theoretical findings from this study can assist researchers in their understanding the mechanisms of how and why decision makers oscillate between decision-making approaches. This will allow researchers to better understand why a particular decision-making approach is being used by a decision maker when conducting a specific task.

This research has also extended cognitive continuum theory, which had previously been primarily used in management and engineering studies to the field of Information Systems. The extension of this theory allows Information Systems academics to further their understanding of how and why decision-makers oscillate between decision-making approaches. As information systems continue to become ubiquitous throughout society, organisations, and at an individual level it will become increasingly important to understand how and why decision-makers oscillate between decision-making approaches. This is because decision makers are becoming increasingly reliant on information systems to lower cognitive load and augment human decision making. This research has validated that when the decision-making approach used aligns with the required task the outcome will be more successful. The further understanding of this phenomena has implications for information systems design, information systems use, and the visualisation of information. The researcher recommends that information systems design should include further considerations around the information requirements and prospective task of the end user. Considerations may include and are not limited to the amount of information, the presentation of information, the environment of the decision maker, the task being conducted, and current policies or procedures within the organisation. Research into these areas would help to further identify how to best align a decision-making approach with the current task being performed.

The visualisation of information is another very promising avenue of research. Research within this area should focus on if different methods of visualisation and the presentation of information may induce specific decision-making approaches. This may alleviate decision making errors caused by individuals using the incorrect decision-making approach for a given task. Information systems could potentially be designed to present information in a specific way to lower the possibility of mechanisms such as the personal sensitivity to a negative outcome activating. This research would have an enormous impact on domains such as the aviation industry where the majority of crashes today are caused by human errors in decision making.

This research study also provides empirical evidence that the activation of the personal sensitivity to a negative outcome mechanism will cause the decision maker to oscillate their decision-making approach to a data-driven approach. This is a new finding which was previously not accounted for in existing literature. This finding will be of particular benefit to researchers who wish to study decision makers in dynamic environments. Such environments often expose individuals to life threatening, high stakes, or crisis scenarios were the environment increases the probability of individuals anticipating adverse negative consequences occurring when making a decision. This finding will allow for researchers to account for the mechanism as to why a decision-maker may have oscillated to a data-driven approach when it was not recommended to do so in their basic training.

The further validation of critical realism as an applicable research philosophy for decision making studies in the information systems field is also of benefit to researchers. This research can be extended to investigate additional mechanisms which may result in a decision maker oscillating their decision-making approach in a dynamic or undynamic environment. The researcher recommends that future research should focus on how decision makers oscillate between decision making approaches when using information systems in a variety of different professions such as financial trading or healthcare practitioners. As data-driven decision making becomes increasingly ubiquitous across a range of industries, there are opportunities to investigate how decision makers will use these systems. An increased understanding of how and why decision makers oscillate between decision making when using information systems will allow for the information systems academic community to have further contributions on the development and use of IS. The next section will discuss the implications of this research for practise.

7.4.3 Implications for Practice

One of the main contributions of this study is the validation that decision makers will oscillate between differing decision-making approaches. Decision makers were found to oscillate between three differing decision-making approaches: an intuitive approach, a data-driven approach, or a hybrid of both (a system-aided judgement decision-making approach). This is an important finding as current practitioner trends advocate for an increase in organisational and managerial decision making to be data driven. This research shows an alternative viewpoint by highlighting that managers will oscillate between human-centric and information-system centric decision-making approaches. Organisational processes and information systems should cater for the oscillations in decision-making approaches by managers to improve decision-making outcome.

This research also found that as a decision maker becomes increasingly apprehensive about undertaking a task the personal sensitivity to a negative outcome mechanism will activate. This mechanism will cause the decision maker to oscillate their decision-making approach to a data-driven approach. This is an important finding for the practitioner community as managers adopting the incorrect decision-making approach can result in poor performance or negative consequences occurring. This finding is especially relevant to organisations whose managers who operate in high risk and dynamic environments such as the aviation industry, financial industry, and the medical industry. These industries often expose individuals to life threatening, high stakes, or crisis scenarios were the environmental propensity increases the probability of such scenarios occurring. Organisations in such industries should implement measures to lower an individual's personal sensitivity to a negative outcome. Increased decision-making based training for scenarios of high personal sensitivity to negative outcomes will allow individuals to have a well learned response if such a scenario presents itself in a live environment. Ensuring decision makers have well-learned responses or coping mechanisms when their personal sensitivity to a negative outcome is potentially raised may alleviate the personal sensitivity to a negative outcome mechanism from activating.

In addition, this research has also identified the process loafing mechanism. This mechanism, once activated, will cause the decision-maker to oscillate their decision-making approach due to current organisational processes which state a specific decision maker must resolve the task. As data collected by organisations continues to grow and information systems continue to permeate organisations, this finding will become increasingly important. With the growing information challenges facing organisations over coming years, decision making will become increasingly augmented and automated by information systems. If organisational policies and procedures do not accommodate the increasing introduction of these systems by taking into account human decision-making processes, it may inadvertently cause decision making errors by individuals due to the process loafing mechanism activating. In light of these findings, policies and procedures should be created within organisations that take into account decision-making oscillations. Organisations should consider questions as to what decision-making approach is required to resolve this task? Is the individual solely reliant on an information system? What are the data types required for the decision maker to resolve the task? In addition, organisations should place further consideration for understanding the decision-making approach of individuals for existing procedures. This coupled with adequate training at an individual level will ensure that the individual will use the correct decision-making approach for a process.

7.4.4 Limitations

This research study has sought to achieve high levels of accuracy and validity, but the researcher acknowledges that this study has a number of limitations. This study sought to explore oscillations in modes of cognition in dynamic and undynamic environments. To achieve this objective four case studies were iteratively researched over time. The selection of these four case studies are a limitation, as this study only reports what occurred in these four case studies. Additional case study sites such as financial trading experts or investigation of medical personnel such as surgeons is recommended by the researcher.

The unit of analysis across all four case studies was the key decision maker. This is a limitation as this research has not focused upon decision making of team members or external actors in each case study. This research study can be extended to focus upon differing stakeholders other than the key decision maker such as team members, external actors, or group decision making within the organisation.

This research study has not factored in organisational variables such as the size and culture of the organisation, hierarchical structure, and number of team members under the key decision maker. It is recommended by the researcher that future researchers consider these variables when selecting case study locations.

The adaption of cognitive continuum theory to the information systems domain can be seen as a limitation. Cognitive continuum theory has been successfully applied to domains such as management, the medical profession, and engineering but has yet to be applied to information systems (Hamm, 1988, Dhami and Thomson, 2012). Although cognitive continuum theory has yet to be applied to the information systems domain there have been calls to do so (Dhami and Thomson, 2012).The researcher considered alternative theoretical lenses such as dual processing theory however dual processing theory does not account for the environment and task being undertaken by the decision maker (Polanyi, 2015). As information systems are routinely used to complete tasks in both dynamic and undynamic environments, cognitive continuum theory is an applicable theoretical lens for this study.

This study has identified two mechanisms for decision making oscillations when using information systems in dynamic and undynamic environments. This study recommends further investigation of this phenomena by employing a critical realist approach and using the theoretical model (see figure 69) to investigate if additional mechanisms for decision making oscillation may activate and why. This would allow future researchers to have a more complete understanding of how and why decision makers oscillating between differing decision-making approaches.

This study was conducted using a qualitative case study approach to theory building. Case studies, particularly single case studies, have been criticised for not allowing findings to be generalised (Donmoyer, 2000). The researcher acknowledged this limitation and created a multiple case study approach to improve the generalisability of the results. This was conducted by building four case studies across two differing environments. These four case studies facilitated cross-case analysis which provides an extra layer of validation for findings (Mookherji and LaFond, 2013).

The data collection method found to be most suitable for this study was observation. Despite being the most suitable research method for this study, the researcher acknowledges its limitations. When conducting an observation study individuals may alter their behaviour due to being aware that they are being observed, this phenomena is referred to as the Hawthorne effect (McCarney et al., 2007). To alleviate the Hawthorne effect, it is recommended for the researcher to build up a rapport with the unit of analysis over time (Oswald et al., 2014). The researcher participated in team meetings and attended lunch breaks across all four cases. This allowed the participants across all four case studies to be relaxed and comfortable in the researcher's presence.

This section has reviewed the limitations of this research study. The next section will discuss potential areas of future research

7.4.5 Future Research

Despite the limitations outlined in the previous section, decision making has been and continues to be a highly researched area for the information systems academic community. This study lays the groundwork for a number of future research areas. As this study has shown that decision makers will oscillate to a data-driven decision-making approach when the personal sensitivity to a negative outcome mechanism is activated, future research should focus on whether training or coping procedures can prevent this mechanism from activating. This would allow the decision maker to have a more positive decision-making outcome. A second avenue of research should investigate if the presentation of information in different formats can induce a decision maker to oscillate between differing decision-making approaches when using information systems. As data-driven decision making becomes increasingly ubiquitous across a range of organisations, the presentation of information will become increasingly important. Investigating how the presentation of information alters a decision makers approach is a promising avenue of future research. This research was conducted by adopting a multiple case study qualitative approach but can also be extended by using a quantitative approach. The theoretical model in Figure 69 which shows that decision makers will oscillate to one of three differing decision-making approaches can be used as a foundation for future quantitative studies. A quantitative research study may be able to uncover the degree as to which a specific mechanism once activated will oscillate a decision maker to a specific decision-making approach. A quantitate study involving human behaviour tracking tools, such as eye tracking software, would also be a very promising avenue of research to further our understanding of decision making. Finally, this research should also be extended to additional domains to explore if mechanisms, in addition to personal sensitivity to a negative outcome and process loafing, will result in the decision maker oscillating their decision-making approach. This would give the IS academic community further understanding of how and why decision makers make decisions when interacting with information systems. This understanding will become increasingly important as decision making becomes increasingly augmented by information systems. As we as humans become more reliant on information systems to lower our cognitive load, it is imperative we further understand how and why we make decision when doing so.

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