Towards a Decision Support System for Wicked Problems: A Literature Analysis

by

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Declaration

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Abstract

> Some problems are so complex that you have to be highly intelligent and well-informed just to be undecided about them (Conklin, 2001, p. 1)

Wicked problems are complex and challenging to solve. This is partially due to changing requirements in the problem definition, as well as the fact that proposed and implemented solutions are generally significant in effect and irreversible in nature. In contexts where the consequences of a solution to a wicked problem are comprehended as being critical to an organisation's survival, such firms may elect to build or acquire a decision support system (DSS) to assist decision makers with the vital task of resolving such problems. DSSs have been shown to provide some benefit to users by neutralising cognitive biases as well as improving effectiveness and efficiency of decision making. However, it has been argued that traditional variants of these tools are seldom appropriate for addressing wicked problems, and as such, an alternative approach to solving wicked problems is required to that of typical decision making problems.

The conceptualisation of *procedural rationality* as a suitable underlying approach for support of wicked problems has been argued in a number of studies. Such research asserts that the approach focusing on the *process* of decision making as opposed to the *substance* of the decision process. In order to investigate the nature of wicked problems and decision support in these contexts, a primarily qualitative literature study was completed.

Literature was collected systematically by making use of keyword search, backward search, and forward search. Studies were further analysed to ensure that they explicitly addressed the notion of wicked problems and decision support utilising any combination of theoretical or empirical approaches. The final literature sample consisted of 35 peer-reviewed journal articles from a number of subject areas.

The quantitative element of the literature study found that empirical case studies are the most common research design in this research area, followed by applied-concept theoretical studies. It was also discovered that strategic, business, and organisational planning problems, along with environmental and natural resource planning problems, are the most frequently addressed wicked problem in the literature sample. Finally, the quantitative analysis found that procedural approaches to decision support for wicked problems are the most prevalent in the literature, consisting of almost two thirds of all studies included in the sample.

Qualitative analysis of the literature sample uncovered a number of requirements for wicked problems in the context of DSSs. Examples of common characteristics include tools for collaboration, negotiation, flexible exploration of the decision space, and facilitation of organisational memory through storage and retrieval of previous deliberations.

Finally, the outcomes of all of the previous phases of the study were integrated and a model for procedural DSSs was synthesised, comprising perspectives regarding architecture, evolutionary design and development, the decision process for procedural decision making, and the characteristics of inquiring organisations which are argued to be the organisational perspective most suitable for procedural DSSs.

Opsomming

> Some problems are so complex that you have to be highly intelligent and well-informed just to be undecided about them. (Conklin, 2001, p. 1)

Wicked probleme is kompleks en moeilik om op te los. Die voortdurende verandering van probleem-definisie sowel as die beduidende en onomkeerbare impak van oplossings vir *wicked* probleme is twee faktore wat die uitdagingsvlak vererg. Gevalle waar die oorlweing van 'n organisasie afhang van sy vermoë om 'n *wicked* probleem op to los; mag die organisasie kies om 'n Besluit Ondersteuningstelsel (BO) te bou of te benut. Dit is al bewys dat BOs besluitnemers bevoordeel deur kognitiewe vooroordeling te versag, effektiwiteit van besluitneming te verhoog en doeltreffendheid te verbeter. In teenstryding, is dit voorgesit dat tradisionele BOs weinig 'n goeie oplossing of ondersteuningsmiddel vir *wicked* probleme bied. Dus word daar ondersoek vir alternatiewe benaderings tot die ontwerp van 'n BO, in die konteks van *wicked* probleme, ingestel.

Die konseptualisering van prosedurele rasionaliteit is al in verskeie studies voorgesit as 'n goeie onderliggende benadering tot *wicked* probleem ondersteuning. These studies assert that the approach focusing on the process of decision making as opposed to the substance of the decision process. Die ondersoek van BOs in die konteks van *wicked* probleme is deur middel van 'n kwalitatiewe literatuur studie gedoen.

Relevante literatuur is versamel deur sleutelwoord-soektogte, agtertoe-soektogte en voorwaardse-soektogte. Die studies is deursoek vir uitdruklike behandeling van BOs en *wicked* probleme voordat hulle as relevant gekeur kon word. Beide teoretiese- en empiriese studie benaderings is ingesluit. Die finale versameling van literatuur bestaan uit 35 joernaal artikels.

Die kwantitatiewe elemente in die literatuur studie dui daarop aan dat empiriese gevallestudies die mees algemene navorsingsontwerp in dié veld is - dit word gevolg deur teoretiese, toegepaste-konsepstudies. Die studies het ook daarop aangedui dat strategiese, besigheids, organisatoriese, omgewings en natuurlike hulpbron beplanningsprobleme die mees algemeen is. Laastens het die kwantitatiewe analise gevind dat prosedurele benaderings tot besluit ondersteuning vir *wicked* probleme die meeste voorkom in die literatuur monster, wat amper twee derdes van die literatuur monster uitmaak.

Kwalitatiewe ontleding van die literatuur monster ontbloot 'n aantal vereistes vir *wicked* probleme in die konteks van BOs. Voorbeelde van algemene kenmerke sluit

in hulpmiddels vir samewerking, onderhandeling, buigbare verkenning van die besluit ruimte, en fasilitering van organisatoriese geheue deur middel van die stoor en herwinning van die vorige redenasie prosesse.

Ten slotte, die uitkomste van al die vorige fases van die tesis is geïntegreer en 'n model vir prosedurele BOs is gesintetiseer, insluitend perspektiewe met betrekking tot argitektuur, evolusionêre ontwerp en ontwikkeling, die besluit proses vir prosedurele besluitneming, en die eienskappe van navraende organisasies wat aangevoer is as die organisatoriese perspektief mees geskik vir prosedurele BOs.

Acknowledgements

It is said that the nature of information systems research necessitates a multidisciplinary approach to solving its problems. As a result, there are a great number of individuals to whom I wish to extend my most sincere gratitude and appreciation.

Firstly, I would like to dedicate this thesis to my late professor and colleague, Prof Hans Müller. Hans was the first lecturer that I encountered from this field, and my passion for information systems was largely instigated by his presentation of the material during my first year of study. Furthermore, he brought the field of decision making theory to life in my more senior academic years, inspiring a substantial proportion of my curiosity regarding the intersection of cognitive psychology and information systems research. Hans also provided a great deal of encouragement and support to me as a young academic through his kindness and humility.

Secondly, I would like to thank my supervisor, Prof Bruce Watson, for his patience, humour and intriguing insights during the process of completing this thesis.

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No research is without its obstacles, and the process of completing this thesis is a personal testament that fact. To this end, I would like to sincerely thank my friends, family, and loved ones for their endless support throughout the duration of completing this research. In particular, I would like to express the most heartfelt gratitude to my husband, Richard Pretorius, for his quiet and calm steadfastness, particularly during the most difficult parts of this endeavour. Additionally, his willingness to talk through my ideas and musings with such interest helped me persevere after long days of teaching. Most importantly, however, I would like to thank the Lord God for granting me the privilege of tertiary study, and for providing me with a sense of purpose that underpins everything I do. All glory goes to Him.

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Nomenclature

AI Artificial Intelligence

BI Business Intelligence

CDSS Collaborative Decision Support System

DBMS Database Management System

DSS Decision Support System

EIS Executive Information System

EMS Electronic Meeting System

EUT Expected Utility Theory

GDS Group Decision System

GDSS Group Decision Support System

GSS Group Support System

IDSS Intelligent Decision Support System

IS Information System

IT Information Technology

KM Knowledge Management

MIS Management Information System

NSS Negotiation Support System

OLAP Online Analytical Processing

OLTP Online Transaction Processing

PDSS Personal Decision Support System

SDLC Systems Development Life Cycle

UI User Interface

WWW World Wide Web

Chapter 1

Introduction

1.1 Background and Rationale

Classical conceptions of human rationality portray humanity as perfectly rational (Simon, 1955, 1956). The postulated *Economic Man*, as presumed by classical economic theorists, is omniscient in that such a human possesses perfect knowledge of alternatives available in a decision, can evaluate these consistently, and possesses complete knowledge of probabilities and consequences associated with each alternative (Simon, 1979). In more recent literature, decision theorists argue that human rationality "falls short of omniscience" due to limited knowledge about decision alternatives, inability to accurately predict consequences, and the manifestation of inconsistent preferences (Simon, 1979, p. 102). This *bounded rationality*, as coined by Simon (1955), ultimately leads to the inability of human decision makers to effectively compare alternatives and arrive at a rational decision. In order to cope with uncertainty, Simon (1979) further postulates that humans utilise *heuristics* or rules of thumb to navigate the problem space and arrive at a satisfactory solution, as opposed to navigating the entire problem space and arriving at an optimal solution.

Tversky & Kahneman (1974) confirm this notion of heuristics in decision making by demonstrating that humans attempt to minimise problem complexity by decomposing the problem into individual judgements during utilisation of such heuristics. Although these heuristics are considered useful in a number of areas, their application in complex decision making contexts can lead to serious errors in judgement (Tversky & Kahneman, 1974). Further, the decision maker's *frame*, or conception of the decision problem and evaluation of associated consequences, profoundly influences the selection of an appropriate decision strategy (Tversky & Kahneman, 1981). The authors further assert that these preferences have been demonstrated to shift in a predictable ways, rendering the decision makers own conception of the decision problem inconsistent and incoherent, violating the normative requirements for rationality in decision making.

The development of decision support systems (DSSs) as artefacts can be traced back to the 1970s (Arnott & Pervan, 2008), where their development arose as a response to large-scale, complex planning problems (Power, 2002). Pragmatically, the objective of a DSS is to improve the effectiveness and efficiency of a decision process as well as the outcome of that decision (Arnott, 2006; Arnott & Pervan, 2005; Keen & Morton, 1978). Conceptually, the initial aim of these systems was to address issues regarding human rationality in decision making as outlined by Simon (1955) and other authors (Shim et al., 2002).

DSSs are typically prescribed for decision contexts where problems can be categorised as *semi-structured* or *unstructured* (Power, 2002; Sprague, 1980). These types of problems may be difficult to quantify, and may not have an optimal solution (Power, 2002). DSSs therefore exist to support the judgement of the decision maker rather than to select and implement a solution independently. However, traditional DSSs are rarely appropriate resolutions for particular breeds of unstructured problems that are ill-defined and *wicked* in nature (Mackenzie et al., 2006).

The notion of *wicked problems* as a concept was initially formulated in the literature by Horst Rittel (Rittel & Webber, 1973) in the 1970s, as a response to the perceived failure of scientific and engineering methods at resolving these problems. The term was originally applied to social and policy planning, juxtaposed with the notion of tame problems which natural scientific inquiry endeavours to solve. Wicked problems derive their name from their ambiguous nature and frequent tendency to produce suboptimal and unintended consequences (Ritchey, 2013). This is compounded by their reactive nature, which results in the definition and essence of the problem reacting or shifting when acted upon (Ritchey, 2011). Further, these so-called *problems* are not genuine problems in the true sense, as they distinctly lack a stable definition or problem statement. Rather, they are more akin to the unstructured *messes* elucidated by Ackoff (1974), where a mess refers to a collection of problem situations whose interrelationships render the strategy of decomposing these inextricable messes unsuitable. Both conceptualisations go beyond the notion of unstructured decisions postulated by Gorry & Morton (1989), as the very nature of these problems is contended to be in flux.

The objective of this chapter is to present an overview of the research conducted in this thesis. Firstly, Section 1.2 outlines the problem statement for the research in light of the preceding context. Secondly, an elucidation of the purpose of the study is explored in Section 1.3. This is followed by an exposition of the primary and secondary research questions in Section 1.4. Following this, the research design and underlying paradigm is elucidated in Section 1.5. Next, Section 1.6 discusses the various limitations and inherent weaknesses of the research design employed. Finally, Section 1.7 contextualises the study in terms of the information systems (IS) context and its corresponding relevance for research and practice.

1.2 Statement of the Problem

> *Although various traditional DSSs have been developed over the years, many of which have adequately solved the problem for which they were created, these types of DSSs are less useful in wicked contexts. An alternative approach is required.*

In light of the nature of wicked problems in organisations, it is apparent that a different type of DSS is required in order to support these kinds of problems (Mackenzie et al., 2006). As Courtney (2001, p. 17) asserts:

> Organizational decisions of the future may include social, environmental, and economical concerns, and be much more 'wicked', complex, and interconnected than those of the past. Organizations and their decision support systems must embrace procedures that can deal with this complexity and go beyond the technical orientation of previous DSSs.

According to Mackenzie et al. (2006), conventional DSSs assume and make use of what is termed *substantive* decision support. This conception of decision support, according to the authors, refers to the provision of situation-specific expertise based on knowledge about the problem domain. This is facilitated by the fact that the tame problems within these domains themselves are well-defined, although the solution may be non-trivial or complex. However, the authors argue, these substantive DSSs are not suitable for addressing wicked problems due to their inherent instability and ambiguity. Rather, they argue that the use of *procedural* DSSs is more appropriate for resolving wicked problems or messes. As opposed to attempting to *tame* wicked problems (Conklin, 2001) with the naïve view that structuring these problems renders them amenable to such substantive support, Mackenzie et al. (2006) argue that stressing the *process* rather than the *consequences* is a superior strategy. In this way, stakeholders involved in the problem are given the space to explore a range of alternatives and to negotiate conflict. This correlates with the postulation by authors such as Ritchey (2011) that define wicked problems in terms of their uncertain and fundamentally subjective nature. However, there are still a large proportion of studies that employ some variant of substantive decision support when proposing or developing a DSS for a wicked problem.

1.3 Purpose of the Study

> *The purpose of the study is to investigate the advantages of procedural decision support over substantial decision support, to explore the prevalence of each in the literature, as well as to investigate the nature of DSSs predicated on procedural rationality.*

The purpose of the study, in light of the problem statement articulated in the preceding section, is twofold. The primary intention of this thesis is to qualitatively analyse and elucidate two approaches to decision support. The secondary objectives are to present the prevalence of each approach in the literature, to determine which features of DSSs are required for supporting wicked problems, as well as to build a coherent model of procedural DSS attributes for support of wicked problems.

1.4 Research Questions

1.4.1 Primary Research Question

The primary research question is as follows:

> *R.1: What are the implications of substantive and procedural rationality for DSSs specifically in the context of wicked problems?*

The primary objective of this thesis is to qualitatively compare two fundamental approaches to decision support as proliferated in the literature. The aim of comparing the ramifications of the substantive and procedural approaches to decision support is to facilitate comprehension of the application of these approaches to wicked decision contexts, and to determine appropriateness of such approaches to these contexts.

1.4.2 Secondary Research Questions

The primary research question leads to a number of secondary questions:

> *R.2.1: What characteristics and activities facilitated by DSSs are desirable in the context of wicked problems?*

In order to design and develop any variant of DSS for supporting wicked problems, it is imperative to uncover what is required of DSSs during the process of wicked problem resolution. The objective of this question is to determine, from the literature, those features which are relevant for the development of such a DSS.

> *R.2.2: What would a procedural DSS developed specifically for resolving wicked problems look like?*

DSSs developed to support procedurally rational decision making processes are fundamentally different from substantively rational DSSs. It is therefore imperative to investigate the architecture of such a system in order to present a coherent model for procedural decision support. This secondary question aims to synthesise such a model.

> *R.2.3: Which of procedural or substantive decision support approaches are more prevalent for wicked problems in the literature?*

Simon (1976) argued that procedural decision support would become more prevalent in the years following his publication, and as reliance on pure economic theory in decision making was diminished in favour of psychological theories. The purpose of this question is to determine which of procedural or substantive decision support is currently more prevalent in the peer-reviewed literature.

> *R.2.4: What types of wicked problems are actively addressed in the literature in the context of DSSs?*

Wicked problems vary in terms of the contexts in which they arise. In order to work towards a DSS for solving wicked problems in general, it would be useful to determine the nature of the wicked problems addressed in the literature thus far. This research question aims to explore the nature of wicked problems addressed in the literature in some manner related to DSS research.

> *R.2.5: What is the level of cognisance of wicked problems and decision support in the literature?*

The notion of wicked problems has been explicitly mentioned in research for a number of years since its conceptualisation. To gain an understanding of the current state of decision support for wicked contexts, it is necessary to gain insight into the quantity of research specifically addressing these issues over time. Thus, the aim of this question is to discover the rate of publication of research articles concerning decision support for wicked problems in the literature.

> *R.2.6: What are the primary research methodologies employed in the literature?*

Any research design and methodology is fundamentally informed by the nature of the questions that the employed methodology seeks to answer (Mouton, 2001), and therefore provides a great deal of insight into the field of interest. The objective of this question is to discover which research designs and methodologies are utilised most prominently in the literature.

1.5 Research Paradigm and Design

The application of any research design is based on a number of assumptions (Babbie & Mouton, 2007). According to Mason (2002), it is imperative for research to make explicit its ontological and epistemological assumptions in order to appropriately contextualise the study. The researcher has therefore placed the study primarily within the qualitative research paradigm, with an emphasis on interpretive methods. The two primary methods employed within this paradigm in this thesis are that of theory and model-building and the qualitative literature review (Babbie & Mouton, 2007; Mouton, 2001).

In order to answer the research questions in the aforementioned section, a literature study is conducted. The nature of the literature review is primarily qualitative in nature, with a limited set of quantitative features. The phases of the literature review methodology employed are as follows:

The first phase of the literature review entails analysing the context of the various reference disciplines relevant to the research area. Prominent literature in the areas of decision making theory, procedural and substantive rationality, wicked problems, and decision support systems literature is consulted in order to synthesise the conceptual framework within which the overarching study is situated. Texts such as seminal books, journal articles, and working papers are reviewed to achieve this aim. The concept of procedural rationality is also clarified during this phase.

The second phase of the study is concerned with a content analysis of the literature in the specific discipline of DSSs for wicked problems. Trends and emergent behaviours are identified, and the prevalence of substantive and procedural approaches to decision support is noted.

The final phase of the thesis methodology involves the construction of a model for procedural DSSs, incorporating the findings of the preceding phases. This model is qualitatively evaluated in terms of the context presented from the literature.

1.6 Limitations of Research Design

As with any research design, there are a number of limitations inherent in the methodology and approach employed. These are outlined in the subsections that follow.

1.6.1 Secondary vs. Primary Data

Any study which is primarily literature-based utilises secondary sources of data as opposed to primary data actually elicited and collected for the purposes of the research (Mouton, 2001). Consequently, there are limits on the level of control which the researcher has over the data, and new insights are theoretical rather than empirical in nature. However, such insights are imperative for the creation of new models and theories as well as refinement of existing theoretical artefacts (Mason, 2002; Mouton, 2001).

1.6.2 Sampling

When selecting literature for a study relying on such research, the researcher should take care to avoid sampling bias in terms of the literature which is selected for the study (Babbie & Mouton, 2007; Mason, 2002; Mouton, 2001). This is particularly true for the snowball sampling method which is often employed during this process. Literature regarding DSSs for wicked problems was selected by means of a highly rigorous methodology outlined by Gonzalez et al. (2006), Levy & Ellis (2006), and Webster & Watson (2002).

1.6.3 Researcher Bias

The process of coding and model building in research, particularly in an interpretivist paradigm, has the propensity to be highly subjective in nature (Babbie & Mouton, 2007). It therefore becomes the responsibility of the researcher to perform coding in as rigorous a manner as can be reasonably expected, as well as to code the literature in a systematic fashion underpinned by concrete definitions of concepts utilised (Babbie & Mouton, 2007; Mouton, 2001).

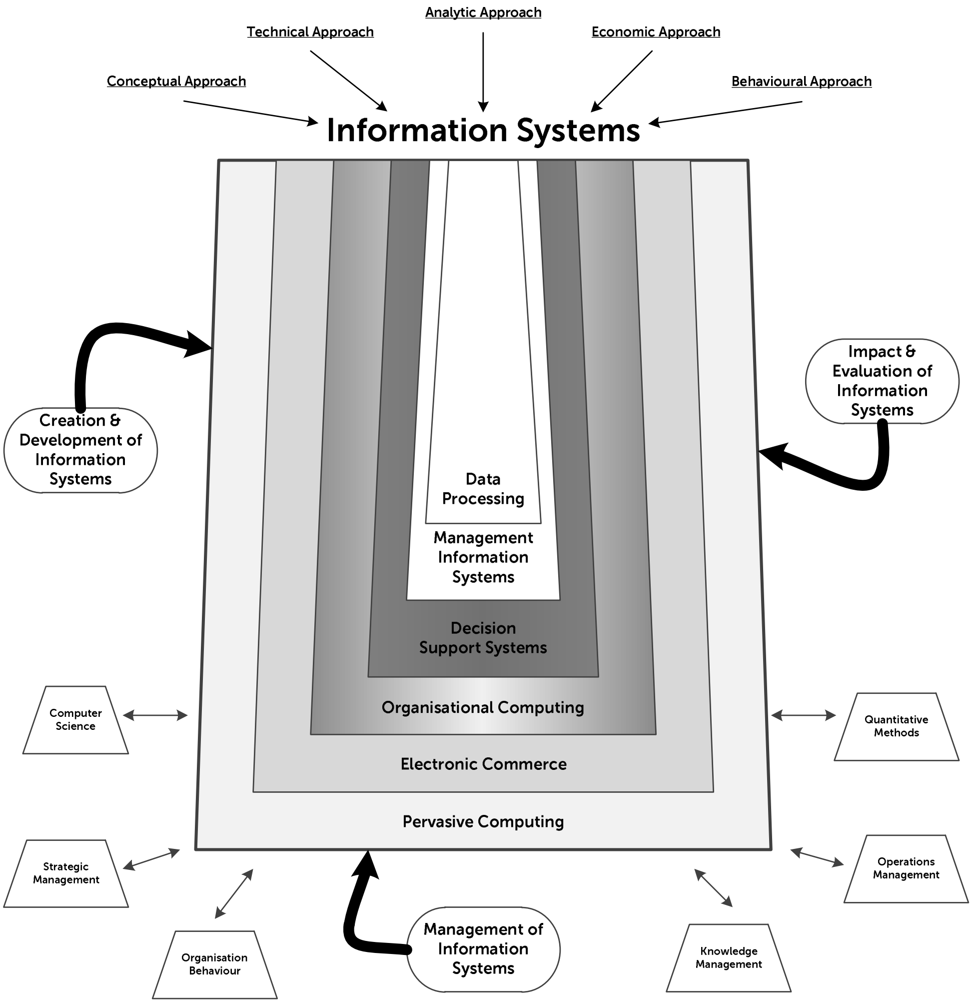

Figure 1.1: DSS and IS expansion as per Burstein & Holsapple (2008)

1.7 Relevance for IS Research and Practice

In order to effectively undertake research within the qualitative paradigm, context becomes imperative in producing a holistic overview of the domain under investigation (Babbie & Mouton, 2007). Decision support systems are widely accepted in the literature as a category of information system and are classified as such. It therefore becomes pertinent to contextualise the DSS within the IS discipline, and to explore its relevance for research and practice within the IS field.

DSSs are primarily defined as a specific variant of IS whose purpose is to support and improve the decision making performance of managers or other information and knowledge workers (Arnott & Pervan, 2005, 2008, 2014; Sprague, 1987). Here, the standard view of IS as per Avison & Fitzgerald (2002) is employed, that is, a computer-based system within an organisation that provides information as well as processes that are useful to the organisation in terms of helping said organisation to operate more effectively.

Figure 1.1 outlines the context of DSSs within the scope of the IS field as per Burstein & Holsapple (2008). Here, DSSs as a category of IS types are subjected to similar forces of expansion to that of other information systems. From this model, it is clear that DSSs are affected by forces such as organisational computing, electronic commerce, and pervasive computing. Additionally, DSSs can be analysed through the same lenses that are typically applied to ISs: conceptual, technical, analytic, economic, and behavioural approaches. Finally, the same six reference disciplines of IS research can be applied to DSS research and practice. Computer science, strategic management, organisational behaviour, knowledge management, operations management, and quantitative methods are inextricably implicated in the growth of DSSs as a field, and are themselves impacted by this growth. Hence, modern decision support is fundamentally multidisciplinary in nature, and requires interaction with a wide range of approaches and theories (Burstein & Holsapple, 2008).

1.8 Organisation of this Thesis

The purpose of this chapter was to present an overview of the research context, objectives, and research paradigm. The remainder of the thesis is structured as follows:

Chapter 2 presents a selection of literature in the broad field of decision making theory. The aim here is to contextualise the theoretical and pragmatic concerns of decision making from the individual to organisational level.

Chapter 3 conceptualises and explores the notion of wicked problems within the organisational context. The objective is to gain an understanding of wickedness, to comprehend its significance for decision making within the organisation, as well as to explore common approaches and their implications for the organisation.

Chapter 4 defines the concept of decision support systems in terms of their basic characteristics and teleology, presents a historical overview of the field from two salient perspectives in the literature, and details a number of prominent taxonomies and frameworks presented in the literature during the lifetime of the field.

Chapter 5 presents the literature concerning the support of wicked problems by means of DSSs. Additionally, the findings from the previous chapter are applied in order to ascertain the direction of decision support for wicked problems in the field. An explanatory model for procedural decision support for wicked problems is synthesised and elucidated.

Chapter 6 concludes the thesis by presenting the overarching findings and a number of associated observations. Additionally, the limitations of the research are also addressed, and implications for research and practice are outlined. Finally, opportunities for further research in this area are established.

Chapter 2

Theories of Decision Making

2.1 Introduction

Hacking (1972, p. 186) describes decision theory as:

> the theory of deciding what to do when it is uncertain what will happen. Given an exhaustive list of possible hypotheses about the way the world is, the observations or experimental data relevant to these hypotheses, together with an inventory of possible decisions, and the various utilities of making these decisions in various possible states of the world: determine the best decision.

Theories regarding decision making, therefore, address the nature of human decision making under uncertainty in terms of the state of the world, possible modes of action, consequences of these actions, and means through which each of the possible consequences may be evaluated by decision makers.

The notion of decision making theory, in its broadest form, can be traced back to ancient Greek and Chinese philosophical discourses related to epistemology, ontology and wisdom (Buchanan & O' Connell, 2006; Peterson, 2009). The field itself has been influenced by many diverse disciplines, including but not limited to economics, cognitive psychology, mathematics, sociology, political science (Bennet & Bennet, 2008), philosophy, computer science, and statistics (Peterson, 2009). Consequently, the literature related to decision making is both substantial in quantity and varied in focus. A comprehensive analysis of all the literature from each perspective, while fascinating, would prove unfeasible. Therefore, the aim of this chapter is to provide a brief overview of the history of decision making as a discipline, as well as to elucidate the themes and issues which have a notable relevance to decision support. The final section of this chapter compares and contrasts the two conceptions of rationality presented by Simon (1976), known as *substantive* and *procedural* rationality respectively.

2.2 A Note on Normative and Descriptive Theories

Prior to delving into specific theories of decision making, it is important to note that the purposes of these theories may vary. One important distinction is that of theories which are *normative* in nature, and those which endeavour to be *descriptive*, also known as *behavioural* or *positive* theories.

Normative theories within a decision making paradigm are developed with the objective of informing decision makers how the process of reasoning, judgement and decision making *ought* to occur, while descriptive theories aim to describe and elucidate *how* people reason and act in reality (Over, 2004). These descriptive theories are based on observation of decision makers and their behaviours (Baron, 2004). Decision making theories can be divided into these two categories to reflect their objective: to describe the actual or the ideal.

The definition of what constitutes normative theories of decision making is largely dependent on the definition of rationality which is employed (Over, 2004). This endeavour to develop a definition of rationality is largely a philosophical one, consisting primarily of reflection and analysis (Baron, 2004). Over (2004) argues for a view of rationality in decision making referred to as *instrumental rationality*, where the rationality of an action is evaluated in terms of its likelihood to help a decision maker achieve their own personal goals. This practical form of reasoning, therefore, is concerned with selecting rational actions which correlate with one's subjective desires and preferences. This differs from the somewhat more conventional *epistemic* view of rationality, which applies to the rationality of beliefs and inferences (Over, 2004). Normative models endeavour to evaluate actual decision making processes and to improve them in order to close the gap between the normative and descriptive accounts of the process, through the development of prescriptive models (Baron, 2004).

2.3 A Brief History

According to Peterson (2009), the history of decision theory can be broken up into three disparate phases in accordance with the time period represented by each. These are elucidated in the subsections that follow.

2.3.1 The Old Period

The first phase, known as the *old period*, refers to the period of academic study rooted in ancient Greece. Despite the fact that this period did not involve formal study regarding theories of decision making, it was clear to the Greeks that studying and understanding decision making was an endeavour that warranted further inquiry (Peterson, 2009).

The philosopher Herodotus spoke of the notion of rationality as an act which is right, and irrationality as an act which is contrary to good counsel in Herodotus VII: 10 (Peterson, 2009). The rationality of an action was therefore viewed as an intrinsic property that was independent of the consequences or outcomes of the action taken (Carabelli, 2002).

In addition to Greek philosophers exploring ideas related to the concept of rationality, others such as Aristotle grappled with the issues surrounding the logic of rational preferences and the practical implications of such evaluations (Peterson, 2009; Hansson, 2002). Although a number of logical inconsistencies existed within Aristotle's own appraisal of such comparisons, along with the absence of a comprehension of probability, the study of logic and its application in evaluating options was familiar to ancient Greek philosophers (Peterson, 2009).

2.3.2 The Pioneering Period

The second phase, referred to as the *pioneering period*, outlines the phase of decision making theory development which began in the 1600s during the Renaissance (Bernstein, 1996), and ended in the early 1900s (Peterson, 2009). This phase is characterised by an interest in the effects of *probability* on decision making.

This initial curiosity regarding probability began in 1654, when Blaise Pascal and Pierre de Fermat commenced correspondence regarding the probability of specific throws occurring, as generated by a pair of fair dice (Bernstein, 1996). This endeavour led to the development of mathematical solutions to such problems, which were later published by Christian Huygens in 1657 (Peterson, 2009). From this collaboration, the theory of probability was synthesised, which meant that humans could use numerical probabilities to forecast what might happen in the future and make decisions accordingly for the first time in recorded history (Bernstein, 1996). Additionally, Pascal developed the argument, later known as *Pascal's Wager*, which has become widely accepted as the first instance of application of decision theory (Bernstein, 1996). This wager involved the problem of deciding whether or not to believe in the existence of God, as represented by a coin toss game of chance (Bernstein, 1996). Pascal further framed the problem as existing on an infinite time scale, and providing no choice regarding one's participation in the game (Hacking, 1972). In terms of the stated decision problem, Pascal reasoned that it was better to choose to believe in God, as the consequences of failing to believe in him were far more grave if he does exist than the consequences of choosing to believe in him if he doesn't (Bernstein, 1996). Pascal also played a role regarding the notion of *utility*, or the "strength of [one's] desire for something" (Bernstein, 1996, p. 71), in the form of a book published by a number of his associates. This book, known as *La logique, ou l'art de penser* (Logic, or the art of thinking), also contained the first instance of probability, named as such, and measured. Consequently, a decision was asserted to be based on a combination of one's strength of desire for a particular outcome, as well as one's degree of belief regarding the probability of that outcome (Bernstein, 1996).

Further insight regarding the notion of utility was developed by Swiss mathematician David Bernoulli in a St. Petersburg paper published in 1738, during the height of the Enlightenment intellectual era (Bernstein, 1996). In this paper, Bernoulli set out to discover "rules [that] would be set up whereby anyone could estimate his prospects from any risky undertaking in light of one's specific financial circumstances" (Bernstein, 1996, p. 110). From this process, Bernoulli produced two important contributions to the development of decision theory. The first is that utility, rather than the expected value, of a consequence is what rational decision makers will attempt to maximise (Bernstein, 1996). The author further states that Bernoulli found this utility to be based not purely on objective numeric values, but rather on subjective intuition. The second contribution is that such a utility is inversely proportional to the value of what is already possessed by the decision maker (Bernstein, 1996; Peterson, 2009). Consequently, Bernoulli set in motion the revolutionary notion that while the objective evaluation of risk will result in a specific expected value, the subjective component of decision making is influenced by all of the stakeholders involved in that decision due to their varying experiences of utility (Bernstein, 1996).

2.3.3 The Axiomatic Period

The third and final phase, known as the axiomatic phase, refers to the period of decision making theory development which began in the early 1900s and still largely defines the modern decision making landscape (Peterson, 2009). This phase is marked by the "attempts to axiomatise the principles of rational decision making" (Peterson, 2009, p. 13).

Peterson (2009) asserts that this period in decision making theory history can be traced back to two disparate origins. The first is that of philosopher Frank Ramsay's paper, *Truth and Probability*, published in 1931 following his death (Peterson, 2009). This paper suggested that decision makers who act within the confines of eight proposed decision axioms will behave in such a way that will be consistent with the principle of maximisation of expected value (Peterson, 2009), due to implicit attribution of numerical probabilities and utilities. The second point of origin of this period is that of a book, *Theory of Games and Economic Behavior*, authored by von Neumann and Morgenstern (Peterson, 2009) published in 1944. The book presented the application of game theory, invented by von Neumann in 1926, to economic and organisational decision making (Bernstein, 1996). It also dealt with the decision maker's implicit assignment of numerical utilities to outcomes with the goal of maximising expected utility (Peterson, 2009).

The peak of the axiomatic period took place during the 1950s, resulting in a plethora of literature that formed much of the foundation for modern decision theory (Peterson, 2009). This surge continued up until the 1990s and included many prolific theorists. The contributions made by a number of these recent authors will be addressed throughout the sections that follow.

2.4 Modern Contributions to Decision Theory

The previous section outlined the three major phases of decision making theory, as identified by Peterson (2009). The aim of the sections that follow is to identify and elucidate a number of the primary contributions to decision theory originating in the present, axiomatic period.

2.4.1 Rational Choice Theory

According to March (1994), the depiction of decision making as rational is common in the decision making literature as well as in regular human expectation. This is partially due to the illusion of such a conclusion as being self-evident in nature (Simon, 1979), and therefore being accepted more readily. Consequently, a number of theories presupposing the notion of human rationality exist in the literature.

2.4.1.1 Defining Rationality

In order to explore the notion of rational theories of choice, it would be beneficial to define what is specifically intended by the term *rationality* in decision making

Table 2.1: Common conceptions of rationality as per March (1994)

Conception of Rationality	Perspective Employed
Success	The desirability of the outcomes of actions taken
Coldness	Attitude towards the decision taken
Sanity	State of mind of the decision maker taking the decision, as reflected by the actions taken in taking the decision

theory. According to March (1994), rationality has three common interpretations and associated perspectives in decision making as summarised in Table 2.1.

Although many of these conceptions appear sensible in the context within which they are used, the conception of rationality employed in this thesis is in alignment with the definition invoked by March (1994). This conception refers to what is known as *procedural* rationality, which is defined as a specific set of procedures utilised in making choices (March, 1994). In this way, the rationality of a process is separated from the intelligence or success of its outcomes, which March (1994) refers to as *substantive* rationality.

2.4.1.2 Features of Rational Choice Theories

According to March (1994), rational choice theories operate within the framework of the logic of consequences. This is due to the alleged propensity of decision makers to act in accordance with how they anticipate their actions will affect future states of the world; in other words, the perceived future consequences of present actions. Further, he asserts, alternative actions are appraised on the basis of how these consequences indulge the preferences of the decision maker. Therefore, rational decision processes are consequence as well as preference-based.

The structure of the logic of consequences, as delineated by March (1994), is framed in terms of four specific parameters:

- *Alternatives* — the actions that are available to the decision maker.
- *Expectations* — the prospective consequences of each alternative, along with associated probabilities of each consequence.
- *Preferences* — the decision maker's conception of the value of each consequence connected to an alternative.
- *Decision rule* — the means by which the decision maker chooses between the available alternatives with cognisance of the value of each of their consequences.

Table 2.2: Assumptions of pure rationality as per Simon (1955)

Parameter	Assumption
Alternatives	Decision maker is omniscient regarding the set of alternatives that are available.
Expectations	Decision maker possesses perfect knowledge or the capacity to ascertain the consequences of each available alternative.
Preferences	Decision maker's preferences are consistent.
Decision Rule	Decision maker possesses sufficient computational skill to permit determination of which alternative will result in the greatest utility in light of the decision maker's preferences and expectations.

Within this framework, decision making is analysed in terms of these parameters. However, the framework also includes what March (1994) refers to as two guesses about the future world on which the choice is reliant: the nature of the future states of the world that each alternative might create, and the decision maker's future evaluation of each of these possible states. Further, the choice is also dependent on the alternatives which are actually considered by the decision maker.

Assumptions regarding the nature of the four parameters and their interactions vary among the various existing theories of rational choice. The sections that follow will examine a number of the more prominent categories of rational choice theories that exist in the literature.

2.4.1.3 Pure Rational Choice

The most basic form of pure rationality assumes that the decision maker has perfect knowledge of all alternatives as well as their consequences, and that the decision maker possesses a consistent set of preferences (March, 1994). Consequently, in this view, decision makers are said to select the alternative that maximises their expected utility.

The most basic form of pure rationality, as delineated by Simon (1955), makes a number of substantial assumptions regarding the nature of the decision maker and the environment. These assumptions are described in the context of the aforementioned parameters involved in the logic of consequences framework March (1994) in Table 2.2.

Although there exists a widespread acknowledgement that pure theories of rational choice exhibit characteristics which seem intuitive (Simon, 1979), it has become apparent that such theories are neither accurate descriptions of reality, nor are they useful guidelines for how decisions should be made (March, 1978). As Simon eloquently puts it, these theories satisfy the *simplicity* criterion of *Occam's razor*, but make substantial assumptions regarding human decision making capabilities and are therefore difficult to accept (Simon, 1979). According to Simon (1979), the model particularly breaks down under circumstances involving some degree of uncertainty. Further, Simon (1955) states that constraints introduced through human physiological and cognitive limitations reveal a form of human rationality which is rudimentary as best.

2.4.1.4 Expected Utility Theory

The literature comprising both philosophical examinations as well as empirical investigations of pure rational choice theories conclude that such theories are inadequate for describing how decisions are made in reality (March, 1978, 1994). Consequently, a number of elaborations of rational choice theory were developed in order to accommodate empirical findings, the most prominent of which is the incorporation of uncertainty regarding consequences of alternatives (March, 1994). One such modification of rational choice theory is the notion of *expected utility theory* (EUT), which is the focus of this section.

The notion of *utility*, as discussed in Section 2.3.2, was initially formalised and described by Daniel Benoulli during the pioneering period of decision making history (Bernstein, 1996). The concept was further elucidated and adapted by von Neumann and Morgenstern in 1944 with their work on game theory (Friedman & Savage, 1952). EUT is an extension of the original notion of utility postulated by Benoulli in the following terms: firstly, decision makers will seek to maximise utility in selecting alternatives; and second, evaluation of the probability associated with each consequence has an effect on this choice. It further states that the decision maker chooses between alternatives that have uncertain consequences by comparing their expected utility values (Friedman & Savage, 1952; Mongin, 1997). Numerically, this is asserted to refer to the weighted sum of each outcome's subjective utility value multiplied by that outcome's associated probability (Mongin, 1997). The theory has been based on four principles outlined by Tversky & Kahneman (1986) in the context of decision makers choosing between lotteries or gambles. These are summarised in Table 2.3.

If the decision maker complies with these principles, such a decision maker is asserted to comply with the criteria for rationality from a normative perspective (Tversky & Kahneman, 1986). The authors also state that these principles can be ordered

Table 2.3: Principles of expected utility theory as per Tversky & Kahneman (1986)

Principle	**Elucidation**
Cancellation	If A>B, then A if it rains >B if it rains. States which yield different outcomes should be the only states which affect the choice between options.
Transitivity	If A>B and B>C, then A>C. If a decision maker must choose among three lotteries, if the first is preferred over the second, and the second is preferred over the third, then the first will always be preferred over the third.
Dominance	If an option is evaluated as being better than another in at least one state, and at least as good as the other option in all other states, then that dominant option should be chosen.
Invariance	A preference for a particular option should persist independently of the choice problem's representation or description.

from the least normatively accepted, to the principle which has the highest normative acceptance amongst scholars. This hierarchy is reflected in the aforementioned table, with the most normatively accepted principles appearing later in the list.

In addition to the principles postulated by Tversky & Kahneman (1986), EUT as a descriptive theory, makes a number of assumptions regarding human psychology. These, described by Katsikopoulos & Gigerenzer (2008), are as follows:

- Every alternative can be appraised in terms of an inherent numeric value, which allow the alternative to be evaluated independently of other options.
- The aforementioned value of a given alternative is computed in terms of all available information, e.g., probabilities and other values of outcomes.
- In calculating an alternative's value, a low score for a particular attribute can be substituted by a higher score on another attribute.

Despite the relatively ubiquitous normative acceptance of EUT, the theory has been challenged on a descriptive level due to the inherent difficulty in assigning numerical values to both utility as well as outcome probabilities (Friedman & Savage, 1952; Kahneman & Tversky, 1979; Mongin, 1997). Indeed, the pioneering work, Neumann & Morgenstern (1953), admits to much of the controversy, but nevertheless elects to operate with the assumption that representative numbers for these constructs do exist. Further, studies postulating theories such as the Ellsberg paradox (Ellsberg,

Table 2.4: Actual limited human rationality as per Simon (1979)

Parameter	**Actual Behaviour**
Alternatives	Decision maker has limited knowledge regarding the set of alternatives that are available.
Expectations	Decision maker does not necessarily know or consider the consequences of each alternative.
Preferences	Decision maker's preferences are typically inconsistent, and are not utilised in parallel during a decision.
Decision Rule	Decision maker does not always attempt to maximise utility, but attempts to find a solutions which is viewed as good enough.

1961), prospect theory (Kahneman & Tversky, 1979), the Allais paradox (Allais, 1979), and the framing effect (Tversky & Kahneman, 1981, 1986) have empirically demonstrated how actual decision making in the context of gamble selection consistently violates the principles of EUT. Consequently, much of the literature has relegated expected utility theory to the realm of normative rather than behavioural theories of human decision making (Kahneman & Tversky, 1979; Mongin, 1997). However, as Kahneman & Tversky (1979) have asserted, it is probable that theories of decision making cannot claim to possess both normative suitability and descriptive veracity.

2.4.2 Bounded Rationality

The previous sections have discussed a number of variations of rational choice theory. Underlying the bulk of these and related theories is the assumption that humans possess the ability to behave in a manner that is almost perfectly rational. However, as March (1994) asserts, studies of actual decision making behaviour demonstrate that many of these assumptions are not supported by empirical evidence. Rather, human decision makers tend to treat each parameter comprising the logic of consequences as demonstrated in Table 2.4.

Simon (1979, p. 502) asserts that humans do not behave rationally, as human rationality "falls short of omniscience". This is due to lack of knowledge regarding the alternatives that are available, as well as cognitive limitations that complicate the ability of human decision makers to compute the likelihood of consequences. These limitations include constraints on capabilities for attention; and storing, organising, and sharing information (March, 1994). In order to address the obvious discrepancies between normative and descriptive conceptions of human-decision making, Simon (1955) introduced the notion of *bounded rationality*.

Although human rationality falls far short of the requirements for rational behaviour, March (1994) states that bounded rationality assumes that human decision makers are at least intendedly rational. Consequently, human decision makers employ a number of strategies in order to cope with these constraints. The key strategy outlined by Simon specifically relates to the notion of *search and satisficing*. Classical conceptions of rational choice theory argue that human decision makers seek to maximise utility according to a predefined utility curve. Bounded rationality, conversely, asserts that humans *satisfice*, or terminate the search for alternatives once an alternative has been discovered that is deemed good enough rather than optimal (Simon, 1979). The measure of goodness of an alternative is determined by the decision maker's *aspiration*, which is in flux rather than static.

The notion of bounded rationality, as elucidated by Simon (1955), was later shown to match up to actual decision making behaviour in a number of empirical studies (Simon, 1979). Consequently, it has been extended, elaborated upon, as well as incorporated into alternative views of rationality and contemporary theories (March, 1978). Examples include the notion of *heuristics* as a means to adaptively cope with this bounded rationality (Gigerenzer, 2004) as well as the theory of the *garbage can model* to explain organisational decision making behaviour (Cohen et al., 1972).

2.4.3 Prospect Theory

Expected utility theory, as discussed in Section 2.4.1.4, dominated the field of decision making under risk for a number of years, from both a normative and descriptive perspective (Kahneman & Tversky, 1979). However, authors such as Simon (1955) and Kahneman & Tversky (1979) argue that decision makers do not conform to the axioms and principles of expected utility. Kahneman & Tversky (1979), in particular, demonstrate that human decision making behaviour is incongruent with these tenets. In order to account for these deviations, these authors developed *prospect theory* as an alternative descriptive model for decisions under risk.

As with EUT, prospect theory presents simple prospects with financial outcomes and associated explicit probabilities, but Kahneman & Tversky (1979) argue that it can be expanded to address choices with greater degrees of complexity. Prospect theory divides the decision making process into two phases, namely, *editing* and *evaluation*, each of which consist of a number of operations. The process is outlined and described in the subsections that follow.

2.4.3.1 Editing

The primary purpose of the editing phase is to reorganise and codify the available options in order to facilitate the later process of evaluating these options (Kahneman & Tversky, 1979). This is achieved through the utilisation of six operations elucidated by (Kahneman & Tversky, 1979):

- *Coding* — this operation entails the categorisation of outcomes as gains or losses against a particular reference point. This is due to the assertion by prospect theory that decision makers view outcomes as gains or losses rather than final states of welfare following the outcome. This appraisal of the outcomes as gains or losses is affected by the formulation of the prospect as well as any expectations on the part of the decision maker.
- *Combination* — combining outcomes that have identical probabilities in order to simplify prospects. The example provided by the authors is that the prospect (200, 0.25; 200, 0.25)[1] will be combined and evaluated as (200, 0.5)[2].
- *Segregation* — this involves the separation of the risk-less component of a prospect from the risky element, if such a distinction does indeed exist within the current prospect. For example, the prospect (300, 0.80; 200, 0.20) will be segregated into a certain gain 200 along with the risky prospect (100, 0.80)[3].
- *Cancellation* — components which are common to two prospects are discarded prior to evaluating the two prospects. For example, A = (200, 0.20; 100, 0.50; −50, 0.30) versus B = (200, 0.20; 150, 0.50; −100, 0.30) will be reduced to a choice between the prospects (100, 0.50; −50, 0.30) and (150, 0.50; −100, 0.30)[4].
- *Simplification* — the rounding of probabilities and outcomes; this can subsequently lead to the disposal of excessively improbable outcomes.
- *Dominance detection* — this involves the appraisal of available prospects with the goal of identifying alternatives that are completely overshadowed by other dominant options, and rejecting such alternatives.

[1]Prospects are presented as group of values and their corresponding probabilities enclosed within parentheses. Commas represent the break between value and probability, while semicolons denote the break between groups of prospects.

[2]Here, the decision maker combines the two probabilities of each prospect due to their having the same gain value.

[3]The decision maker has interpreted the value of 200 as a certain gain as both gains exceed this value, and therefore segregates the 0.2 probability and attaches it 100 gain remaining.

[4]Here, the decision maker simply discards the common gain-probability pair.

These editing operations are executed whenever the decision maker is able to do so; the order in which these are carried out may therefore assist or hinder the execution of further operations on the options (Kahneman & Tversky, 1979). Upon completion of the editing phase, the decision maker enters the evaluation phase.

2.4.3.2 Evaluation

The evaluation phase involves the process whereby the decision maker evaluates each of the edited prospects with the goal of choosing the prospect which brings about the highest value according to the decision maker (Kahneman & Tversky, 1979).

The first component of the evaluation phase involves the consideration of outcomes in terms of probability weights, or decision weights based partially on probabilities (Barberis, 2013). This is utilised in conjunction with the subjective values of each outcome uncovered in the second component of evaluation (Kahneman & Tversky, 1979). The process of evaluating and choosing an outcome occurs in terms of four important principles of prospect theory (Barberis, 2013).

- *Reference dependence* — humans do not experience utility from final states of wealth, but rather from gains or losses that occur relative to a particular, predefined reference point.
- *Loss aversion* — humans are far more sensitive to losses than to gains that are of the same significance. This is true for minuscule as well as larger losses.
- *Diminishing sensitivity* — humans tend to behave in a risk-averse fashion for moderate probability gains, but in a risk-seeking fashion where losses are concerned[5].
- *Probability weighting* — humans do not weight consequences by means of their objective probabilities, but rather by decision weights, or probabilities which have been transformed by a weighting function. This weighting function overweights low probabilities and underweights higher probabilities.

2.4.4 Heuristics and Biases

The area of decision making research concerned with heuristics and biases was established in the early 1970s by Tversky & Kahneman (1974). A heuristic, often referred to as a *rule of thumb* (Keren & Teigen, 2004), is a type of rule that is

[5] A modified example of this principle is that an individual would prefer a certain gain of R500 to a 50 percent chance of R1 000, but would prefer a 50 percent chance of losing R1 000 to definitely losing R500.

simple in nature due to its reliance or natural cognitive ability, ecological in terms of being domain-specific by exploiting the environment, and focuses on the process rather than merely the outcome of problem-solving behaviour (Gigerenzer, 2004). In this way, heuristics reduce the effort of decision making by considering fewer cues, simplifying the process of cue value retrieval and cue weighting, reducing the information integrated into the problem, and eventually evaluating fewer alternatives (Gigerenzer & Gaissmaier, 2011).

Gigerenzer (2004) elucidates a model of decision making which is purely descriptive in nature, and which the author concedes as existing within the borders of bounded rationality. The construct which acts as the cornerstone or foundation for the theory is that of heuristics. Unlike Tversky & Kahneman (1974), Gigerenzer (2004) argues that heuristics are rational in particular environmental contexts. This *ecological rationality* allows decision makers to make quick decisions without resorting to probabilities and utilities, and with limited information. He argues that this model is both descriptive and prescriptive in scope, as it focuses both on which heuristics humans use, as well as the contexts within which the heuristic strategy should be preferred over the associated statistical method.

Keren & Teigen (2004) have asserted that current research related to heuristics and biases has the effect of increasing the number of heuristics and biases discovered. He goes on to state his opinion regarding the unfortunate nature of the research performed on the area as having paired heuristics almost inextricably with *biases*, resulting in the assumption that heuristics are directly associated with producing a particular bias.

The sections that follow will discuss the three most common heuristics delineated in the literature: *representativeness*, *availability*, and *adjustment*.

2.4.4.1 Representativeness

The representativeness heuristic, according to Tversky & Kahneman (1974), refers to the evaluation of a probability through the degree to which that element is perceived to be representative of a particular category. Therefore, they assert, the probability of object A belonging to category B is judged to be high if A is believed to be highly representative of B. The same is true in reverse; if A is perceived to be dissimilar to B, then the probability of object A belonging to category B is judged to be high. An illustration similar to that postulated by Tversky & Kahneman (1974) follows below.

Consider a person who has been described as follows: "Lindsay is a loud, lively, and dramatic young women with a penchant for colourful and bohemian makeup and dress. She is outgoing, sociable, though slightly disorganised and often late for meetings.” The crux of the illustration involves the presentation of a list of possible occupations that Lindsay may currently be engaged in, and asking individuals to assess the probability of each. Examples could include that of engineer, computer scientist, farmer, marine, actress, or teacher. According to the representative heuristic, the probability that Lindsay holds each position will be assessed according to the degree to which she is believed to be representative of the individual’s stereotype of that particular vocation (Tversky & Kahneman, 1974). In this particular example, the probability of Lindsay being an actress may be interpreted as being fairly high, due to a particular cultural stereotype involving the personality traits and behaviour of individuals involved in the dramatic arts.

Although some degree of representativeness may assist in assessing probability, overreliance on this heuristic can lead to serious errors in judgement as representativeness of one object in terms of another does not necessarily increase probability of that categorisation. A number of biases may result in the overestimation of such probabilities. These are summarised, along with illustrative examples in Table 2.5.

2.4.4.2 Availability

According to Tversky & Kahneman (1974), the availability heuristic pertains to the tendency of humans to assess the probability of an event by the mental accessibility of such an event, or the level of ease with which manifestations can be conceived of in the mind. This is illustrated, in a similar fashion to that of an example postulated by the authors, by the estimation of the probability of aviation accidents and fatalities as being high amidst the individual’s knowledge of a current, random spate of aviation calamities. In this instance, the individual may estimate the probability of an aviation accident as being high due to availability, or the fact that he or she could easily bring these recent incidents to mind. Similarly to the representativeness heuristic, availability of an event or object does not necessitate a higher probability, and may therefore lead the individual toward biased judgements. These biases are outlined in Table 2.6.

2.4.4.3 Adjustment and Anchoring

Tversky & Kahneman (1974) assert that the adjustment and anchoring heuristic involves the *adjustment* of an initial starting value or *anchor* in making estimates. This anchor may be generated due to the formulation of the decision problem or incomplete calculations related to the problem. According to the authors, the adjustment is not sufficient to overcome the effect of anchoring, which results in a bias

Table 2.5: Biases related to the representativeness heuristic as per Goodwin & Wright (2009)

Bias	**Elucidation**	**Example**
Ignoring base-rate frequencies	The propensity of humans to ignore prior probabilities of events in favour of probabilities derived from representativeness.	With reference to the example involving Lindsay, individuals may choose to ignore the base-rate information that 20 percent of the sample are actresses, estimating that Lindsay is an actress with 95 percent probability.
Expecting sequences of events to appear random	The belief that small samples of events should directly exhibit the randomness which is inherent in the greater random processes generating these events.	In the event of six coin tosses, where H=heads and T=tails, the combination of HTHTHT is just as likely as TTHTHH.
Expecting chance to be self-correcting	The belief that if a particular event has not occurred for some time, that it becomes more probable as that event has become overdue. This is due to the mistaken assumption that random chance has a memory of prior events.	This bias is illustrated through the concept of lottery numbers, where participants may believe that the absence of a particular number in previous lottery draws increases the likelihood of that number appearing in subsequent draws.
Ignoring regression to the mean	Humans expect the occurrence of an extreme event to be followed by similarly extreme events, despite the maxim that events tend to regress to the average.	A classic example of such behaviour is that of an individual experiencing the extremely unlikely event of winning two consecutive roulette games and expecting further wins due to a "lucky streak".
The conjunction fallacy	The overestimation of two events occurring simultaneously as opposed to either one of those same events occurring in isolation.	Presenting an individual named "Linda" in such a way that she appears to belong to two sets, e.g. Bank teller and feminist. According to probability theory, the probability of her being either a bank teller or feminist alone should outweigh the probability of her belonging to both categories. However, individuals tend to overestimate the latter.

Table 2.6: Biases related to the availability heuristic as per Goodwin & Wright (2009)

Bias	Elucidation	Example
Ease of recall	An individual may overestimate the probability of an event due to the ease with which similar events can be recalled.	News bulletins reporting and highlighting the details of exceptionally rare events may lead to overestimation of these events.
Ease of imagination	An individual may, similarly, overestimate the probability of an event due to the ease with which the event can be imagined.	A project manager overestimating the probability of a project running late due to the ease with which circumstances leading to project delay can be envisioned.
Illusory correlation	The propensity of an individual to overestimate the prevalence of events co-occurring, often due to a pre-conception.	A factory manager overestimating the probability of foreign goods being defective as opposed to local goods due to the pre-conceived notion that foreign goods are less reliable.

towards this initial value. The types of bias that may occur are listed and elucidated in Table 2.7.

2.4.4.4 The Adaptive Toolbox

As outlined above, not all research supports the notion of heuristics as mere side-effects of faulty cognition that invariably produce biases in reasoning. Indeed, a number of authors criticise this perspective due to scepticism regarding the validity of laboratory-based experiments, where real-world empirical studies have shown more favourable results (Goodwin & Wright, 2009). The aim of this section is to address one such alternative perspective on heuristics.

In the midst of the discourse around heuristics and biases, the notion of heuristics as tools that arise out of the human state of bounded rationality, and that allow such individuals to make decisions quickly and with limited resources emerged (Gigerenzer, 2004). The authors conceptualise heuristics as a particular type of rule that exhibits three specific characteristics:

1. Heuristics leverage cognitive abilities that are either biologically innate or have been learnt by the organism. This characteristic is demonstrated in the ability of humans to visually track a moving object against a visually distracting background; young infants have the ability to direct their attention to moving objects through their gaze. This emphasises the simple nature of heuristics.

Table 2.7: Biases related to the adjustment and anchoring heuristic as per Goodwin & Wright (2009)

Bias	Elucidation	Example
Insufficient adjustment	The difficulty displayed by individuals in adjusting upwards or downwards from an anchor. This can occur even if the anchor is quite obviously irrelevant to the decision problem.	Asking participants to estimate any probability following the generation of a random number results in this random number acting as the anchor and having a significant effect on estimates.
Overestimating the probability of conjunctive events	Conjunctive events are of the form *(A AND B)*. Individuals tend to anchor on one of the co-occurring events and make insufficient adjustments from this point. This results in the decision maker overestimating the probability of conjunctive events.	Estimating the failure tolerance of a system with the knowledge of the probability of success of the points results in individuals anchoring on this probability and ignoring the fact that these probabilities should be multiplied together to gain the probability of success.
Underestimating the probability of disjunctive events	Similar to conjunctive events, but of the form *(A OR B)*. Individuals tend to anchor on one of the disjunctive events if asked to estimate the probability of either one of them happening. This results in an underestimation of disjunctive events.	The probability of a chemical plant failing may be underestimated if a decision maker is informed that any of the ten subsystems of the plant failing (1/100 probability each) will lead to the entire plant failing.
Overconfidence	When estimating confidence intervals, individuals tend to anchor on the most likely value that they expect a particular variable to assume. This is because humans tend to be overconfident that their selected range will actually contain the value.	Project managers may estimate that a project will take between 27 and 33 hours with 99% probability due to the belief that the most likely value is 3 hours. Such an individual may then be surprised when the actual value falls out of that range.

Table 2.8: Premises of the adaptive toolbox as per Gigerenzer (2002)

Premise	**Elucidation**
Psychological plausibility	The objective of developing theories involving the adaptive toolbox is to comprehend the nature of decision making in actual human behaviour rather than implausible scenarios involving unlimited knowledge, capabilities and resources
Domain specificity	The heuristics within the adaptive toolbox are domain-specific as opposed to generic. The cognitive and emotional building blocks that comprise these heuristics, however, are general in nature.
Ecological rationality	The variant of rationality involved in applying heuristics is not a form of optimisation, but of the extent of the fit between the heuristic employed and the structure of the environment.

2. Heuristics also leverage core structures of the environment in which the organism is present. Rather than heuristics being logical in the strictly rational sense, they are ecological in nature. Consequently, heuristics are not measured normatively and in isolation, but rather as a function of the environment. Accordingly, this demonstrates the ability of the environment to allow an employed heuristic the be characterised as *smart*.

3. Heuristics are not merely the outward result of inward optimisation calculations. Organisms do not employ unconscious, mathematical optimisation methods while applying heuristics.

Gigerenzer (2002) later developed the notion of the *adaptive toolbox* in order to provide a framework for heuristic solutions to decision problems. The adaptive toolbox is a construct that refers to heuristics themselves, the building blocks of which they are comprised, as well as the cognitive abilities that they exploit (Gigerenzer & Gaissmaier, 2011). The goal of the adaptive toolbox is to achieve proximal goals, through provision of cognitive, emotional and social strategies, by making quick and frugal decisions (Gigerenzer, 2002). This notion of the adaptive toolbox is based on three premises delineated by (Gigerenzer, 2002) in Table 2.8.

A number of tools with various functions exist within the adaptive toolbox. Gigerenzer (2002) lists three major functions of the building blocks of heuristics: *search rules*, *stopping rules*, and *decision rules*. Search rules involve the search for alternatives and cues to assess the alternatives. Conversely, stopping rules involve the ceasing of search strategies, while decision rules refer to the actual decision which is made based on the alternatives and cues collected during search.

Table 2.9: Models of heuristics as per Gigerenzer & Gaissmaier (2011)

Heuristic Group	**Heuristic**	**Elucidation**	**Examples**	**Real-World Empirical Studies**
Recognition-based decision making	Recognition	If, out of two alternatives, one is recognised over the other for a particular criterion, ascribe a higher value to that alternative in terms of that criterion.	Recognition of Swiss cities is an accurate predictor of the population within that city.	This heuristic has been successfully employed in predicting Wimbledon tennis match results Serwe & Frings (2006), state election results in Germany (Gaissmaier & Marewski, 2011), and consumer product preferences (Hoyer & Brown, 1990).
	Fluency	If, out of two alternatives, both are recognised for a given criterion, but one is recognised more quickly, ascribe a higher value to that alternative.	Taking the first option that comes to mind in handball players who were asked which move they would have performed in the context of a particular video recording produced, on average, better results than later options.	Alter & Oppenheimer (2006) alleges that this heuristic may predict stock performance. In this experiment, a basket of more fluently named stocks tended to outperform less fluently named stocks in the short term.
One-reason decision making	One-clever-cue	Relying on one specific cue in order to locate alternatives.	The catching of fly balls in baseball and cricket by means of the gaze heuristic.	The circle heuristic, which is merely the imposition of a circle through the two most distant sites of a serial criminal's crime locations in geographical profiling was shown to predict the location of the criminal more accurately than complex statistical software (Snook et al., 2005).
	Take-the-best	Search amongst cues in order of how valid they are, stopping once the first cue discriminating among the two is encountered. Ascribe the alternative with the higher cue value with the higher value in terms of the criterion.	When laypeople, police, and professional burglars are asked to give their opinion regarding which of two houses were most likely to be burgled, both sets of experts' responses were most accurately depicted by take-the-best.	The heuristic can be more predictively accurate than linear multiple regression models (Czerlinski et al., 1999) as well as non-linear strategies (Brighton & Gigerenzer, 2012). Take-the-best was found to be as accurate, or more so, than Bayesian models for literature search for a particular topic of interest (Lee et al., 2002).
	Fast-and-frugal-trees	Search amongst cues in a predefined sequence, stopping as soon as a particular cue results in an outlet. The object should then be classified according to this order and exit.	These trees are often utilised in order to arrive at medical diagnoses.	These trees were found to be more accurate in predicting potential heart attacks in emergency room patients than the heart disease predictive instrument (HDPI), reduced physicians' false-alarm rate by 50 percent, and had a higher usability for doctors than the statistical method (Green & Mehr, 1997). Magistrate decisions were more accurately predicted using fast-and-frugal trees than weighting and summing all information (Dhami, 2003).

Continued on next page

Table 2.9 – *Continued from previous page*

Heuristic Group	Heuristic	Elucidation	Examples	Real-World Empirical Studies
Trade-off heuristics	Tallying	Search amongst cues in whichever fashion, stopping once m out of M cues have been found (1<m<=M). Choose the alternative that was preferred by the greater number of cues.	Avoiding avalanche accidents while hiking or skiing in snow by matching observed cues with known cues that serve as a warning for avalanches.	The aforementioned skiing cues would have prevented 92 percent of historical avalanche accidents if implemented retrospectively in those cases for which the heuristic would have been applicable (McCammon & Hägeli, 2007).
	Mapping model	Taking the median criterion value of objects that have an identical number of positive cues.	The prosecution ascertaining, weighting and aggregating factors relevant to criminal sentencing in order to recommend a sentence to a judge.	The best prediction of sentences in theft, fraud, and forgery cases was found to be the mapping model utilising the aforementioned heuristic (Von Helversen & Rieskamp, 2009).
	1/N rule	Resources should be allocated uniformly amongst N alternatives.	Splitting a sum of money equally amongst participants in a game.	This strategy is the most frequent one utilised in children's group decision processes despite the predictions postulated by game theoretic models (Takezawa et al., 2006). Dividing financial resources equally across N investment option proved the superior strategy in terms of certainty of returns and the second,with regards to turnover (DeMiguel et al., 2007).
Social intelligence	Social heuristics	Leveraging the knowledge of crowds, particularly when the decision maker lacks adequate knowledge.	Imitating or averaging the judgement of groups of people in order to exploit the wisdom inherent in these groups.	Galton (1907) found that when villagers at a livestock fair estimated the weight of individual oxen, that the median of these guesses only differed from the actual weights by nine pounds, and the mean by one pound.
	Moral behaviour	Unconscious behaviour, such as peer imitation, in order to be accepted within a particular group context.	A rule of intuitive search that enables one to locate information that one has been deceived or unfairly treated in the context of a social contract.	

In order to actually test how well heuristics perform in the real world, Gigerenzer (2004) asserts that heuristics must be formally modelled. Following formalisation of a number of heuristics, it was discovered that, contrary to classical laboratory experiments, these heuristics perform better than statistical methods that make use of the same or a greater quantity of information (Gigerenzer & Gaissmaier, 2011). These models of heuristics as per the aforementioned authors are presented in Table 2.9.

Much of the current and future research in heuristics entails investigation of the effectiveness of heuristics in the real-world, as well as the study of the building blocks of heuristics, and the natural and cognitive structures they exploit (Gigerenzer & Gaissmaier, 2011).

2.4.5 Organisational Decision Theories

The majority of the decision making theories delineated thus far have dealt with decision making processes appropriate for the individual decision maker, rather than groups of individuals. The objective of this section is to address perspectives of human decision making that relate to the processes which take place within organisations. This will be achieved through the discussion of two distinct perspectives on organisational decision making described by Pinfield (1986): the *structured* perspective and the *anarchic* or *garbage can* perspective.

2.4.5.1 Structured Perspective

The structured perspective on organisational decision making is fundamentally based on the assumption that apparently unstructured decision processes are actually structured in nature (Pinfield, 1986). This alleged structure arises through the basic three-phase process of decision making as elucidated by Herbert Simon (Pinfield, 1986), but with a number of modifications proposed by Mintzberg et al. (1976). Each stage comprises a number of routines, each of which function as the basic elements or building blocks of the decision process. The supposed complexity, the authors argue, emerges from the interactions between stages, as well as the iterative nature of the progression between them. The nature of these stages is demonstrated by the general model developed by Mintzberg et al. (1976) and illustrated in Figure 2.1; each of these will be elucidated in the sections that follow.

The first phase of the decision making process is referred to as the *identification* phase. This phase fundamentally involves the recognition of the existence of an opportunity for a decision, as well as the conceptualisation of this decision problem

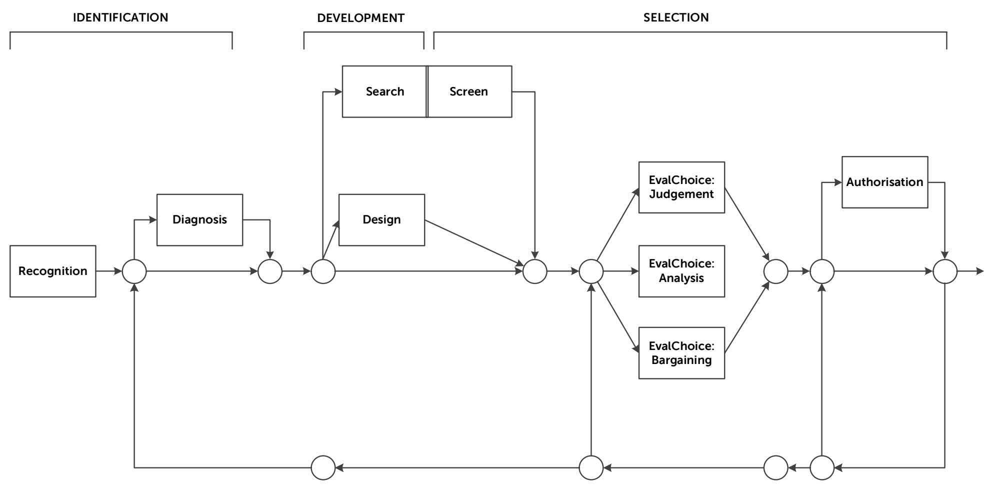

Figure 2.1: The structured decision process as per Mintzberg et al. (1976)

(Pinfield, 1986). The two routines comprising this phase, according to Mintzberg et al. (1976), are as follows:

- *Recognition routine* — involves the recognition of the gap between some set of information and a particular perceived standard. The three typical types of decisions which may arise from a given situation could be problem, opportunity, or crisis types of decisions, each dictated by particular stimuli.
- *Diagnosis routine* — follows directly from the recognition routine once the threshold level is reached for the accumulation of stimuli. This process involves the initiation of the actual decision process, as well as the acquisition and allocation of resources to be utilised during the decision process. This diagnosis is not always made explicit, and it might not even exist to a significant degree in particular types of decision processes.

The second phase of the decision making process, *development*, involves the process of searching for or development of solutions that are deemed suitable for the decision problem or opportunity under analysis (Pinfield, 1986). This is also the phase during which the greatest quantity of decision making resources are expended (Mintzberg et al., 1976). The two primary routines that exist within this phase are *search* and *design* (Mintzberg et al., 1976), and are elucidated below.

- *Search routine* — involves the process of seeking out solutions which already exist. The process is contended as being hierarchical in nature, with early failures in passive means of search giving rise to more active search behaviours.

An ultimate perceived failure in the search routine is hypothesised to lead to engagement of the design routine in order to derive a custom solution.

- *Design routine* — involves the iterative design of one or more custom solutions, or the modification of an existing solution following termination of the search routine. Most frequently, a single design is developed due to the high costs associated with design of solutions in organisations.

Selection is the final phase of the structured organisational decision process, and involves the filtering, analysis, evaluation, and negotiation that results in the selection of a particular alternative (Pinfield, 1986). The associated routines, as per Mintzberg et al. (1976), are:

- *Screen routine* — involves reducing the number of alternatives available by eliminating those alternatives which are deemed infeasible. This is a strategy that is often implemented with the goal of managing an abundance of alternatives following search.
- *Evaluation-choice routine* — the process of evaluating alternatives and choosing among them. This process is asserted to occur using one of three modes: *judgement*, *bargaining* and *analysis*. Judgement is cited as the most frequently used mode, as it involves a swift, convenient individual choice based on the decision maker's own intuitions. Bargaining involves an element of the judgement mode, but rather involves a group of decision makers with conflicting values and goals exercising their individual judgements. Analysis, the most studied mode of evaluation and choice, involves the systematic, objective evaluation of alternatives and ensuing managerial judgement or bargaining exercise.
- *Authorisation routine* — the routine that decisions must follow when the decision maker is not authorised to make a commitment on behalf of the organisation. The decision is then approved through progressive movement up the hierarchy, usually following the evaluation-choice routine, although authorisation may be sought at any stage of the decision process.

In addition to the routines included in the various phases of the decision process, there exist three sets of supporting routines which aim to support these phases (Mintzberg et al., 1976). According to the authors, the three sets of supporting routines are as follows:

- *Decision control routines* — these refer to the implicit planning and resource allocation processes regarding the decision that occur in the mind of the decision maker.
- *Decision communication routines* — these routines involve the the exploration of the decision situation, focused investigation of the decision scenario for more specific information, and dissemination regarding decision progress to interested parties.
- *Political routines* — these activities relate to the use of power by those affected by the decision in order to influence the process with the goal of satisfying their own needs.

The premise of this model of the decision process as per Mintzberg et al. (1976) is the notion that the decision process functions as a fundamentally linear process of progression through the three main phases. However, this particular model allows for cyclic processes within and between these phases. Additionally, there are various branches which allow for the decision to incorporate the various routines in each phase. This allows for illustration of decision processes that are as simple or as complex as the routines demonstrate. Indeed, Mintzberg et al. (1976) utilised this model to fit 25 specific case studies of a particular decision process to one of seven fixed paths through the model.

2.4.6 Anarchic Perspective

In contrast to the perspective of organisational decision making discussed in the previous section, the anarchic perspective suggests that organisations that are characterised as organised anarchies make decisions in a chaotic manner arising from a fortituous blend of opportunities and solutions (Mintzberg et al., 1976). Cohen et al. (1972) define organised anarchies as having three distinct properties: problematic or inconsistent preferences, unclear technology or lack of understanding about the organisation's own processes, and fluid participation in terms of the level of involvement among stakeholders over time. The authors argue that most organisations function as organised anarchies in certain contexts. Further, these anarchies produce choice situations which are inherently ambiguous and contrary to traditional theories of management, which necessitates the formation of amended theories of management (Cohen et al., 1972). The objective of this section, therefore, is to elucidate the behavioural model of organisational decision making postulated by Cohen et al. (1972).

2.4.6.1 Garbage Can Model

In order to develop an understanding of choice processes within the type of organisation described in the previous section, the *garbage can* model was synthesised. This organisational garbage can exists as a mixture of problems, solutions, and participants that only occasionally result in actual solutions that lead to the resolution of specific problems (Pinfield, 1986). In this model, the decision is an outcome that arises from the interplay between four distinct streams that exist within the organisation (Cohen et al., 1972). These streams, as described by the authors, are elucidated below:

- *Choices stream* — the stream of choices that exist, of which there is assumed to be a fixed number. Each of the choices within this stream are defined by their time of origin for a particular decision as well as the group of participants that are able to participate in the process of making the associated choice.

- *Problems stream* — much like the choices stream, the problems stream assumes the existence of a discrete number of problems. Each of these are defined by their time of origin, the quantity of energy required to make a decision regarding the choice that the problem under analysis is attached to, as well as an inventory of choices accessible to the problem.

- *Solutions rate of flow* — the rate at which solutions are entering the current system.

- *Energy stream from participants* — the number of participants within a particular garbage can is assumed to be fixed in nature. Every participant is defined by a quantity of energy available for decision making within the organisation over time.

The decision process occurs as a process of mapping of choices onto decision makers, and problems onto choices, which are connected in terms of the organisational structure access structure.

2.5 Conceptualising Rationality

In Section 2.4.1.1, the classical conception of rationality was elucidated within the context of rational choice theory. Additionally, a basic distinction between the notions of substantive and procedural rationality was expounded upon as per March (1994). However, according to Pidd (2004), this comparison was initially popularised by Simon (1976) in the context of economic theory. Here, Simon (1976) distinguishes between these two conceptions of rationality in order to argue that procedural rationality is consistent with actual human behaviour, and is therefore more relevant and imperative for the modern organisation. This view is supported by a number of authors such as Mackenzie et al. (2006) and Pidd (2004), who argue that such a view of rationality is more suitable to underpin the support of wicked problems than substantive rationality. In light of this view, the objective of this chapter is to develop more significant operationalisations of these constructs, in order to facilitate their understanding in the context of decision support and associated DSSs.

2.5.1 Substantive Rationality

Simon (1976) describes the notion of substantive rationality primarily in the context of economic theory. Here, he contends that economic theory rests on the assumption of both clear goals as well as substantive rationality. Fundamentally, this substantive rationality refers to the appropriateness of the behaviour given the goal of the decision maker. This category of rationality refers, therefore, to the *substance* of the decision (Laville, 2000). Thus, substantive rationality is most appropriate for contexts where the ends are known, but the means to these ends are uncertain (Mackenzie et al., 2006). Typical examples of such contexts include maximisation problems as well as other problems which are amenable to mathematical methods, such as differential calculus and linear programming (Simon, 1976).

2.5.2 Procedural Rationality

The field of psychology, according to Simon (1976), is the field that embraces a typically procedural view of rationality. Contrary to substantive rationality, he argues, procedural rationality refers to the appropriateness of the process of deliberation undertaken in a decision. This variant of rationality therefore refers to the *processes* of the decision rather than its substance (Laville, 2000). Hence, the appropriateness of procedural rationality is contingent on the question of the clarity of the *ends* as opposed to the question of uncertainty surrounding *means* as asserted by substantive rationality (Mackenzie et al., 2006). Thus, the cognitive deficiencies elucidated in the previous sections as well as uncertainty regarding goals in particular classes of problem necessitate an approach to decision making which is procedurally rational (Laville, 2000).

2.6 Chapter Summary

The aim of this chapter was to examine some of the most prominent normative and behavioural theories of individual and organisational decision making. The notion of decision making and the association between normative and descriptive theories was introduced in Sections 2.1 and 2.2 respectively, followed by a brief elucidation of the history and origins of decision making theory in Section 2.3. Section 2.4 explored and described a number of milestones of decision theory in modern times, addressing concepts such as rational choice theory, bounded rationality prospect theory, the notion of heuristics and biases, and important themes in organisational decision processes in Subsections 2.4.1 to 2.4.6 consecutively. From these sections, various arguments regarding the issues inherent in human and organisational decision making were elucidated. Finally, the concepts of substantive and procedural rationality, which are central to this thesis, were elucidated in terms of rationality as a concept in Section 2.5.

The chapter that follows will address the specific category of highly unstructured and messy decision problem known as the *wicked problem*.

Chapter 3

Wicked Problems

3.1 Introduction

The notion of varying levels of *structuredness* in decision problems was famously postulated by Simon (1960) in the form of *programmed* versus *unprogrammed* decisions. Gorry & Morton (1989) further refined this conceptualisation in the context of decision support through their structured-semi-structured-unstructured framework. However, the notion of unstructured problems, varies in its conceptualisation in the literature.

A number of authors describe unstructured problems as those problems which can, at least to some extent, be conceptualised. An early work by Mintzberg et al. (1976) exploring the concept of unstructured decisions formulated these as those decisions which lack an existing set of procedures that form a solution to the particular problem. The assumption underlying the aforementioned study, made explicit by the authors, is the notion that all decision processes can have order imposed on them in order to produce the structure necessary to implement a solution. Unstructured decision problems, according to these authors, are merely decisions whose lack of structure can be ascribed to their novelty rather than an intrinsic essence.

Conversely, a selection of authors argue for a differing conceptualisation of structuredness. Gorry & Morton (1989) relate the notion of structuredness of a problem to the extent of reliance on judgement on the part of the decision maker as opposed to dependence on the computer for support. Further, these authors associate structuredness with the level of structure apparent in all three decision making processes undertaken for that particular problem. Therefore, they argue, unstructured problems are unstructured in terms of all of the phases—intelligence, design, and choice—that make up the decision process. Similarly, Sprague (1980) alludes to less structured problems as being those problems which can be described as *hard*, or which lack specification.

The concept of *wicked problems* originated in an article by Rittel & Webber (1973) to refer to highly unstructured, complex societal problems which cannot be resolved using traditional processes or techniques (Camillus, 2008). The term was originally applied to the notion of social and policy planning, juxtaposed with the notion of tame problems which natural scientific inquiry endeavours to solve (Rittel & Webber, 1973). Examples of wicked problems from the literature include water resource management (Freeman, 2000), health inequalities (Blackman et al., 2006), global obesity (Swinburn et al., 2011), genetically modified food regulation (Durant & Legge, 2006), recreation management (Brooks & Champ, 2006), IT policy (KoracKakabadse et al., 2000), environmental health promotion (Kreuter et al., 2004), fisheries and coastal governance (Jentoft & Chuenpagdee, 2009), climate change (Lazarus, 2009), stakeholder networks (O'Toole, 1997), city planning (Skaburskis, 2008), system design (Buchanan, 1992), public planning (Rittel & Webber, 1973), and corporate strategy (Camillus, 2008). These decision problems are embedded in rich social, organisational and political contexts (Ritchey, 2011), and do not necessarily have a finite solution. Further, they pose a number of challenges for the development of DSSs for organisations that face these highly complex problems. Consequently, the objective of this chapter is to describe the nature of these wicked problems as outlined in the literature, as well as to determine a number of practices and principles relevant to their resolution.

3.2 The Nature of Wicked Problems

The process of traditional scientific inquiry endeavours to solve problems which can be defined, and which usually have some definitive solution. Rittel & Webber (1973) refer to these as *tame problems*; problems that have a predefined goal and whose progress and eventual achievement can be evaluated. Wicked problems, are the antithesis of such problems, as they lack such palpability. According to Churchman (1967, p. B141), Rittel asserted in one of his first seminars on the topic that wicked problems may be classified as "[the] class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing." These problems are difficult or even impossible to conceptualise, and rely on human judgement for resolution (Rittel & Webber, 1973). Implicit in this description is the notion that such problems are never fully solved, but are resolved continuously and repeatedly as the context demands. Indeed, the *wicked* descriptor expresses what Churchman (1967) describes as the fundamentally mischievous quality of these types of problems. In order to gain a further understanding of the nature of these problems, an elucidation of the concept of wicked problems will be outlined in the section that follows.

Despite the inherent difficulty in defining the essence of wicked problems, there does seem to be consensus in the literature regarding traits or features which may act as indicators that a particular problem is indeed wicked in nature, or has wicked elements (Camillus, 2008). Rittel & Webber (1973) synthesised a list of ten characteristics of wicked problems in an attempt to provide a level of exposition as to the types of problems which may be defined as wicked. As Camillus (2008) asserts, these are not intended as a checklist or a set of absolute criteria, but rather as insight which may aid the decision maker in judging whether their particular problem has some degree of wickedness associated with it. These characteristics are summarised and compared with the notion of regular or tame problems as per Rittel & Webber (1973) in Table 3.1, and will be expounded further below.

Rittel & Webber (1973) state that wicked problems do not have a fixed or definitive problem statement. This means that their very substance is unstable and subject to fluctuation, as the rich social, political and organisational context in which they are embedded shifts in time and space (Ritchey, 2011). Additionally, the problem tends to involve a number of stakeholders with divergent goals, values and preferences (Camillus, 2008). Therefore, the complexity of the problem is compounded by differing perceptions of its nature in relation to decision makers and other entities involved. This contrasts strongly with scientific or engineering type problems, in which the aims of a specific endeavour are usually clearly stated or self-evident.

In addition to the ill-defined nature of wicked problems, the authors assert, there are a number of issues in selecting, implementing and evaluating solutions to these problems. The first issue relates to the difficulty in determining whether a solution has been found. In the context of a regular, tame decision, it is usually clear when a suitable solution has been discovered. However, in the case of a wicked problem, the search is usually terminated when a "good enough" solution has been found, rather than an optimal solution. Therefore, there may always be a "better", unknown solution that exists. Further, the actual implemented resolution cannot be evaluated in terms of objective criteria that allow appraisal of a proposed solution as correct or incorrect (Rittel & Webber, 1973). Rather, stakeholders involved in the problem are more likely to subjectively describe the solution in terms of good-bad or better-worse constructs. Additionally, the implemented solution can never be evaluated either completely or ultimately (Camillus, 2008). The waves of consequences that

Table 3.1: Ten characteristics of wicked problems versus regular problems as per Rittel & Webber (1973)

Tame Problems	Wicked Problems
Tame problems have a definite nature that can be sensibly formulated.	Wicked problems cannot be definitively formulated; their very essence is in flux (Skaburskis, 2008).
It is clear when a suitable solution for a tame problem has been found.	There are no stopping rules for wicked problems; the termination point of solution search is unclear.
There potentially exists a correct solution for a given tame problem.	Solutions to wicked problems are not correct or incorrect, but good or bad.
The outcome of an implemented solution can be evaluated immediately and fairly accurately.	The outcome of an implemented solution cannot be evaluated immediately or ultimately.
Multiple attempts at a solution may be implemented without significant cost.	Solutions are *one-shot operations*; there is no opportunity to learn via trial and error.
Most tame problems, to some extent, are governed by a finite set of rules.	Potential solutions as well as possible courses of actions do not exist as definitive sets.
There exist rules for classifying collections of tame problems.	Wicked problems are unique; experience isn't necessarily relevant (Camillus, 2008).
A tame problem can potentially have a natural level at which it can be addressed.	Every wicked problem may be viewed as symptomatic of another, greater problem.
The root of a tame problem exists objectively, and plausible explanations can be refuted to arrive at the most likely hypothesis.	The root of a wicked problem may be explained in a number of equally acceptable ways.
Solutions to these problems are only hypotheses offered in order for be refuted (Popper, 2002).	The decision maker has no intrinsic right to be absolved of the consequences of an implemented solution.

are generated from such solutions extend over an almost infinite period of time, and may also extend in different directions, rendering any attempt to trace their effect fruitless. Consequently, it is virtually impossible to fully appreciate the effect of a particular solution, and as a result, to evaluate its effectiveness. Further, any solution applied to a wicked problem is a *one-shot operation* (Rittel & Webber, 1973, p. 163), in that such a solution does not provide an opportunity to learn from such an application; every attempt has a long-term and irreversible effect on the problem itself. These consequences themselves can alter the already ill-defined problem situation, and even create further sets of wicked problems which are subject to similar challenges (Camillus, 2008). Finally, the authors assert, both potential solutions and possible courses of action are not limited to a comprehensive, predefined set. Accordingly, it is impossible to deduce whether all potential solutions for a particular wicked problem have been included in the solution set, or whether a solution indeed exists at all. The judgement of the decision maker is an imperative feature in ending the expansion of the solution space in order to implement a selected solution.

A further characteristic of wicked problems that Rittel & Webber (1973) describe is the assertion that every wicked problem has a unique nature. They state that ordinary problems can often be compared to each other by virtue of their common traits. However, this is not the case for wicked problems, as there exists no sensible method of classifying wicked problems in terms of the categories of solution which may be applied to all members of such a class. As a result, each wicked problem must be treated as a distinct entity with its own defining characteristics and potential solutions; there is no advantage to be had from experience with a seemingly related problem.

Once a solution has been sought, selected and applied to the problem under scrutiny, it may be the case that the problem was merely a symptom of a greater wicked problem (Rittel & Webber, 1973). Thus, despite the removal of the alleged cause of a problem, a problem at a higher level may emerge. Therefore, wicked problems cannot be solved immediately at all levels. Rather, the level at which the problem is solved is dependent on the will of the decision maker.

In addition to the cause of a wicked problem being an issue of symptom, the very choice of explanation of a wicked problem's causes, along with corresponding solutions, is highly diverse in nature (Rittel & Webber, 1973). There exist no objective or logical processes for selecting the most plausible explanation; therefore, the explanation selected by a particular decision maker is due to appraisal of that explanation as having the greatest explanatory power. Such a persuasiveness is partially determined by the intrinsic characteristics, world view and goals of the decision maker.

The final characteristic of wicked problems as outlined by Rittel & Webber (1973) pertains to the liability of decision makers for the consequences of the solutions that are selected and implemented. The authors strongly contrast this nuance with that of scientific problems, where refutation of a postulated hypothesis is forgiven, even encouraged in the process of scientific inquiry. Conversely, the objective of solving a wicked problem is to attempt to improve aspect of the world which is relevant to the problem situation. Consequently, decision makers are ultimately responsible for the repercussions of their decisions (Ritchey, 2013).

3.3 Resolving Wicked Problems

The nature of wicked problems dictates that an alternative approach is necessary for their resolution than that of tame problems (Mackenzie et al., 2006). As outlined in the previous section, typical problems with defined problem statements tend to also have predefined solution sets. Wicked problems, however, are inherently challenging to resolve due to the absence of linearity present in the progression from problem definition to solution. Consequently, consensus on their resolution is not ubiquitous in the literature. Rather, there exist both descriptive and prescriptive elucidations of a diverse array of strategies and principles that individuals and organisations might employ in order to address the wicked aspects of problems.

3.3.1 Positive Approaches

According to Conklin (2001), there are two general methods that organisations usually employ to cope with wicked problems: *studying* and *taming*.

Studying the wicked problem is often a necessary strategy at some stage of the problem resolution process. Analysing the problem and gathering data regarding its context is imperative in gaining insight into an unfamiliar and complex problem. However, the author states, the time pressure on such an endeavour is extensive due to the shifting nature of wicked problems. Additionally, the inaction fostered by this process can cultivate further inertia, exacerbating the problem considerably. Wicked problems necessitate a cycle of preliminary action in terms of experiments and testing in addition to responsive information-gathering (Conklin, 2001).

Attempting to tame the problem is another typical organisational strategy for managing wicked problems that Conklin (2001) describes. This approach entails the endeavour to reduce the wickedness of the problem in order to make the problem more manageable, or ideally, even solvable. Each characteristic of the problem that

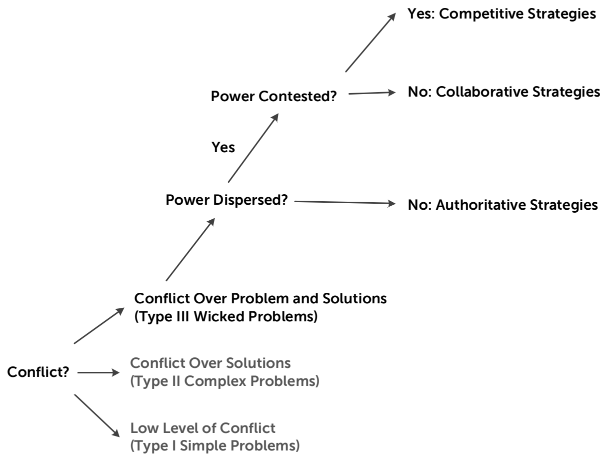

Figure 3.1: Path of strategies to cope with wicked problems as per Roberts (2000)

is wicked in nature is transformed into the tame version of that characteristic. However, these approaches only work in the short term, and either cause the problem to reappear in a different form or to be aggravated and intensified. These two strategies act as coping mechanisms for those faced with wicked problems, the selection of which corresponds to the natural preferences of the stakeholders directly involved with the problem. As expressed in each case, neither of these strategies is ultimately effective in managing or resolving wicked problems.

Roberts (2000) developed a model based on conflict and power dynamics within organisations to arrive at three potential strategies that stakeholders may use to manage wicked problems. The model involves the selection of a strategy based on the level of conflict and power dynamics within the problem context. Figure 3.1 demonstrates this path selection.

The first question pertains to the level of conflict present in the problem. Low levels of conflict, or conflict related only to the problem solution are consistent with non-wicked problem situations. Wicked problem situations involve conflict over the problem definition as well as potential solutions. If power is concentrated and not dispersed among stakeholders, then an authoritative strategy is suitable to determine the nature of the problem along with prospective solutions. If power is dispersed among stakeholders but is also contested, then a competitive strategy may be employed. If power is both dispersed and not contested, then a collaborative strategy is more appropriate. Each of these strategy types are outlined in Table 3.2.

Table 3.2: Strategies to combat wicked problems as per Roberts (2000)

Strategy	Description	Advantages	Disadvantages
Authoritative	There is an attempt to tame the problem by limiting stakeholder involvement to a small group. Those selected as participants on this group may have greater expertise in the context of the problem situation. e.g. The Supreme Court makes decisions regarding the outcome of trials.	Fewer stakeholders may equate to minimised complexity. Consequently, the process of seeking out and reaching consensus on a solution may be achieved more quickly and with less conflict taking place. Reliance on a small group of stakeholders that have expert knowledge of the problem may increase the objectivity of and speed with which solutions are selected and implemented.	Experts are not always correct about the problem or the solution to that problem. Confining a problem to a group of homogeneous stakeholders can narrow the scope of solution search, with the risk of experts ignoring information or alternative views of the problem that do not fit into their frame. Stakeholders excluded from the process lose out on the opportunity to learn, engage with the problem, and potentially become experts themselves.
Competitive	Stakeholders are involved in a "zero-sum game". The right to define the problem situation and select a solution becomes an award granted to the "winners" in the power game. The "losers" gain no such privilege. The pursuit for power becomes the fundamental task of competitive strategies. Once power has been attained, the "winning" stakeholder(s) may resort to authoritative strategies to tame the problem in the context of their frame. e.g. Countries at war over land.	Competition drives the search for novel information and accelerates innovation. It is also a driver of action versus inertia; with the threat of power being taken, stakeholders are motivated to make decisions and take strong stances on important issues. Competition can challenge the status quo of institutionalised and concentrated power, as truly competitive strategies generate constant threat of impending power shifts.	Intense competition can ultimately lead to disorder and violence between stakeholders. Resources that could be better utilised in solving the problem are squandered during the conflict. The stand-offs caused by stakeholders blocking each others' efforts can prevent the progress towards resolution of the problem.
Collaborative	Based on a "win-win" view of problem solving; teaming up to face the problem together will yield a more favourable outcome than any one stakeholder on their own. All parties involved in the decision gain a share of the profits. e.g. Military alliances between governments in order to achieve a common goal.	Costs and benefits are shared among stakeholders. Strength in numbers; burdens are shared. More profitable outcomes can be gained by parties seeking a common end. Greater efficiency can be achieved due to reduction of redundancies and appropriate concentration of plentiful resources.	The increased number of involved stakeholders raises transaction costs as well as the difficulty in reaching agreement. Collaboration requires practice, which costs additional resources.

Table 3.3: Approaches and principles for solving wicked problems

Authors	Principles					
	Recognise wickedness	Avoid taming the problem	Define and measure progress	Involve stakeholders and facilitate communication	Facilitate debate and argumentation	Implement opportunity-driven problem solving
Blackman et al. (2006)				×	×	
Brooks & Champ (2006)				×		
Calton & Payne (2003)				×	×	
Camillus (2008)	×			×		×
Churchman (1967)		×				
Conklin (2001)	×	×		×	×	×
Freeman (2000)				×		
Jentoft & Chuenpagdee (2009)	×	×		×	×	
Karacapilidis & Papadias (2001)				×	×	
Kreuter et al. (2004)	×	×	×	×		
Kunz & Rittel (1970)				×	×	
Mackenzie et al. (2006)				×	×	
Munneke et al. (2007)				×	×	
Ritchey (2013)				×		×
Rittel & Webber (1973)	×	×				
Roberts (2000)		×	×	×	×	

3.3.2 Normative Approaches and Principles

Roberts (2000) proposes that collaborative strategies are superior alternatives for the management and resolution of wicked problems, with cognisance of the fact that this flavour of strategy is intrinsically more challenging to implement. However, despite the alleged advantage, collaboration is a strategy that is often not selected initially, but rather only following the failure of one or more of the other two strategies. At this stage, stakeholders are more willing to attempt an alternative approach and forego the higher costs associated with such a strategy.

Within the literature, a number of suggestions regarding management of wicked problems are made by a various authors in a number of diverse wicked problem contexts. These are summarised in Table 3.3.

3.3.2.1 Recognising Wickedness

Rittel & Webber (1973) state that in order to address a wicked problem in any capacity, it is imperative to acknowledge the presence of wickedness inherent in the aforementioned problem. Problems need not be classified in terms of wickedness in a binary fashion (Conklin, 2001), but rather fall along a continuum in accordance with the degree of wickedness which is present (Kreuter et al., 2004). It is this wickedness which should be perceived and interpreted within the problem context. Failure to acknowledge the endemic issues of these types of problems may ultimately lead to the erroneous utilisation of unsuitable methods and tools in order to address the problem (Conklin, 2001).

3.3.2.2 Abstaining from Taming the Problem

Roberts (2000) asserts that efforts to tame a wicked problem are unlikely to be effective, as the problem will either reassert itself, or exacerbate the wickedness present in a particular problem situation. Generally, attempts to tame a wicked problem involve the manipulation of one or more of its wicked features in order to generate the appearance of the problem being tame in nature (Conklin, 2001). In addition to such behaviour having a pragmatically profound impact, a number of authors, such as Rittel & Webber (1973) as well as Churchman (1967) have asserted that claiming to have tamed a wicked problem is deceitful in the morally reprehensible sense, as it is misleading to other individuals who are affected by the problem.

3.3.2.3 Defining and Measuring Progress

Despite the futility inherent in attempting to objectively define the constitution of "success" in a wicked problem situation and associated quantitative markers of progress (Conklin, 2001), there should exist some flexible, self-regulating, and collaborate process that tends towards resolution (Roberts, 2000). This should entail the monitoring of the problem and its proximity to collaboratively defined benchmarks (Kreuter et al., 2004).

3.3.2.4 Involving Stakeholders and Facilitating Communication

A fairly sizeable portion of the literature suggests that the involvement of a diverse assortment of problem stakeholders should be facilitated in order to foster dialogue and communication among these parties. Collaboration regarding definition of the problem statement, as well as possible actions to be taken, increases the likelihood of support and commitment from these stakeholders, and increases diversity of perspectives (Brooks & Champ, 2006) and greater utilisation of tacit knowledge (Camillus, 2008). Exchange of information occurs between participants, experts, systems and decision makers (Kunz & Rittel, 1970), enabling a collective understanding of the problem situation (Kreuter et al., 2004) and facilitating understanding of the social context (Brooks & Champ, 2006). Ultimately, the collaborative process should lead to the emergence of common objectives, language and vision for the group of stakeholders (Brooks & Champ, 2006), and fundamentally assist stakeholders in establishing a common identity for the organisation (Camillus, 2008). This identity, in turn, provides direction and focuses attention on opportunities and threats (Camillus, 2008). Further, creating a mutual understanding of the wicked problem through respectful and transparent dialogue (Jentoft & Chuenpagdee, 2009; Kreuter et al., 2004) fosters stakeholder commitment towards taking action to resolve the problem (Camillus, 2008; Brooks & Champ, 2006). Perhaps ironic, however, is the inevitable wickedness inherent in the very process of collaboration itself (Jentoft & Chuenpagdee, 2009); complexity is greatly increased in relation to the number of stakeholders involved (Roberts, 2000).

3.3.2.5 Facilitating debate and argumentation

Perceptions regarding the objectives of facilitating the discussion of diverse and contrasting views vary among the authors of the literature reviewed. A subset of authors contend that the contribution of this process lies in the negotiation of the problem statement, possible solutions, and goals, with the aim of reaching what Ritchey (2013) describes as *first-order consensus*, or agreement regarding these issues

(Karacapilidis & Papadias, 2001). However, a number of authors oppose this view, arguing that the objective should not be to arrive at a consensus, but rather for stakeholders to comprehend and acknowledge each others' positions and reasoning behind these positions (Mackenzie et al., 2006), reaching *second-order consensus* (Ritchey, 2013). The process can also be supported by capturing and documenting these opinions, issues, and ideas (Camillus, 2008; Kunz & Rittel, 1970), plausibly leading to a more thorough understanding of the problem situation, alternatives, and outcomes associated with each of these alternatives (Ritchey, 2013).

3.3.2.6 Implementing Opportunity-Driven Problem Solving

Conklin (2001) asserts that the continuous process of studying a wicked problem can be counter-productive to the resolution of said problem, as it can lead to paralysis and inaction among decision makers. Camillus (2008) proposes that taking action, even solely at a pilot or prototypical level, is a more effective strategy than relentless study. This opportunity-driven behaviour assists in promoting a creative thinking process and increased learning about the problem domain (Conklin, 2001). This is partly due to the proposition that natural human problem solving is not linear in nature, but involves oscillation between studying, or furthering understanding of the problem situation, and attempts at resolution (Conklin, 2001).

3.4 Chapter Summary

The objective of this chapter was to explore the notion of wicked problems in various contexts. Section 3.1 provided an introduction to and contextualisation of the concept, followed by Section 3.2, which described and elucidated their nature. It was found that the concept of wicked problems itself is rather elusive, though there do exist a number of characteristics which may designate the level of wickedness present in a particular problem. Wickedness is therefore not a discrete category, but may be present at a minor or major level within any given problem. Strategies for coping with these levels of wickedness were elucidated in Section 3.3, both in descriptive terms as well as prescriptive terms. Subsection 3.3.2 specifically derived a list of principles for coping with wicked problems as extrapolated from the literature.

The chapter that follows will address prominent themes in the literature related to DSSs.

Chapter 4

Decision Support Systems

4.1 Introduction

According to Arnott & Pervan (2008), initial DSS development originated in the 1970s as a response to highly complex and massive planning problems (Power, 2002). Initially, the aim of these systems was to address perceived deficiencies inherent in human decision making (Shim et al., 2002; Simon, 1955). In more recent literature, DSSs are asserted to have the goal of improving the decision process itself, as well as impacting the outcome of such a decision (Arnott & Pervan, 2005; Arnott, 2006; Keen & Morton, 1978). In this way, the purpose of a DSS may involve improving any combination of both of the procedural as well as the substantive varieties of human rationality discussed in Chapter 2. Sections 4.2 and 4.3 address the conceptual definition and historical development of DSSs respectively.

Along with the evolution of computing technology, the varying levels of focus of the DSS has resulted in DSSs increasing in both variety and complexity. Section 4.4 explores a number of prominent frameworks and taxonomies of DSSs presented in the literature. Finally, Section 4.5 summarises the primary findings of the chapter.

4.2 Definition

In early literature, there exist a number of apparent identity crises experienced by DSS research during its emergence during the 1980s (Pearson & Shim, 1995). Firstly, there existed the presupposition that the DSS as a concept was either partially or fully encapsulated in the demarcation of MIS research, and not necessarily an entity in its own right (Sprague, 1980). Alternatively, the view of DSSs as a radical reaction to MISs also existed (Arnott, 2006). Second, there existed some uncertainty regarding the scope of DSSs in the overall decision making process (Sprague, 1980), with the frequent side-effect being the assumption that any application which in some sense addresses decision making in any context is in fact a DSS (Hayen, 2006). Third, the ever-changing nature of IT in IS necessarily implies the dynamic, ever-changing nature of DSS applications (Hayen, 2006). Consequently, the term *DSS* has become inherently difficult to reach consensus on, both in theory and in practice. Therefore, it seems prudent to develop a working definition in this thesis, for the sake of both consistency and clarity.

For the purposes of this thesis, a DSS is defined as some computer or IT-based (Arnott & Pervan, 2008; Hayen, 2006; Keen & Morton, 1978; Power, 2001; Shim et al., 2002) information system (Arnott & Pervan, 2005; Arnott, 2006; Arnott & Pervan, 2008; Power, 2001) that fulfils the purposes of supporting one or more stages of the semistructured or unstructured decision making process (Keen & Morton, 1978; Power, 2001; Sprague, 1980) rather than replacing decision maker judgement (Hayen, 2006). The primary aim of this endeavour is to increase the effectiveness of this process rather than operational efficiency, though efficiency may exist as a secondary goal (Arnott & Pervan, 2005; Arnott, 2006; Arnott & Pervan, 2008; Hayen, 2006; Keen & Morton, 1978; Pearson & Shim, 1995).

A variety of further refinements are made to parts or the whole of this definition in terms of the alleged structure and functionality of DSSs. This has led to the development of a number of frameworks and taxonomies by an assortment of authors; these are explored in Section 4.4. The following section will highlight important elements of the history and evolution of DSSs in theory and in practice described in the literature.

4.3 Historical Overview and DSS Types

4.3.1 DSS Origins

According to Shim et al. (2002), the field of DSSs has predominantly evolved from two disparate research areas: theoretical decision making conducted during the 1950s and early 1960s, and technical activities and exploration conducted during the 1960s. It was during this period of technical study that the term *decision support systems* was first used; allegedly in a paper authored by Gorry and Scott Morton in 1971 (Gorry & Morton, 1989), despite prior research related to decision support undertaken in the previous decade (Arnott & Pervan, 2005). In this paper, the authors developed a framework for DSSs through the combination of Anthony's managerial activity categories Anthony (1965) and Simon's decision type taxonomy (Simon, 1973). This led to the conceptual synthesis of a DSS as a computer system that supported managerial decisions that were unstructured or semi-structured in nature (Arnott & Pervan, 2005; Courtney, 2001; Shim et al., 2002). Implicit in this definition was also the notion that the objective of DSSs was to support the more structured portion of the decision, leaving the important task of judgement to the human decision maker. The result was an integrated man-machine decision system (Arnott & Pervan, 2005; Shim et al., 2002; Te'eni & Ginzberg, 1991). Further, the task of the DSS was further characterised by Gorry & Morton (1989) through Simon's conception of the decision process phases (Simon, 1960): intelligence, design, and choice (Courtney, 2001; Shim et al., 2002).

Much of the history which follows this early period is inextricably linked to various types or classes of DSSs, due to the aforementioned effects of IT developments on the field over time. These historical developments will therefore be discussed in this context in the sections that follow, though the reader should note that there will be considerable overlap with the framework and taxonomy section that follows as a result. However, it is imperative to appreciate, as Power (2008) notes, the fact that the history of the field is essentially non-linear in nature, and that the various points of evolution within the field will differ based on the vantage point occupied. Therefore, in some sense, the framework or classification used may inform one's perception of the development of the field. The two conceptions of DSS history that will be delineated are those of Arnott & Pervan (2005) and the subsequently revised Arnott & Pervan (2014), and Power (2008), each of which are demonstrated in Figures 4.1 and 4.2 respectively.

4.3.2 An Account of DSS History by Arnott & Pervan (2005)

Arnott & Pervan (2005) delineate a history of DSSs that stems from a somewhat radical reaction to MIS, and evolves towards a structure of interconnected DSSs approaches and types. An exposition of each are presented in the sections that follow.

4.3.2.1 Personal Decision Support Systems (PDSSs)

According to the authors, PDSSs emerged as a reaction of sorts to the exceptionally large, corporation-focused systems at the time, known as MISs in the 1970s. PDSSs endeavoured to empower individual managers by supporting particular decision tasks. The evolution of such systems was largely enabled by the development of the microcomputer and corresponding advancements in application development. The resulting applications were far more user-friendly than MISs and therefore adopted more successfully to the extent that they are still largely prevalent in man-

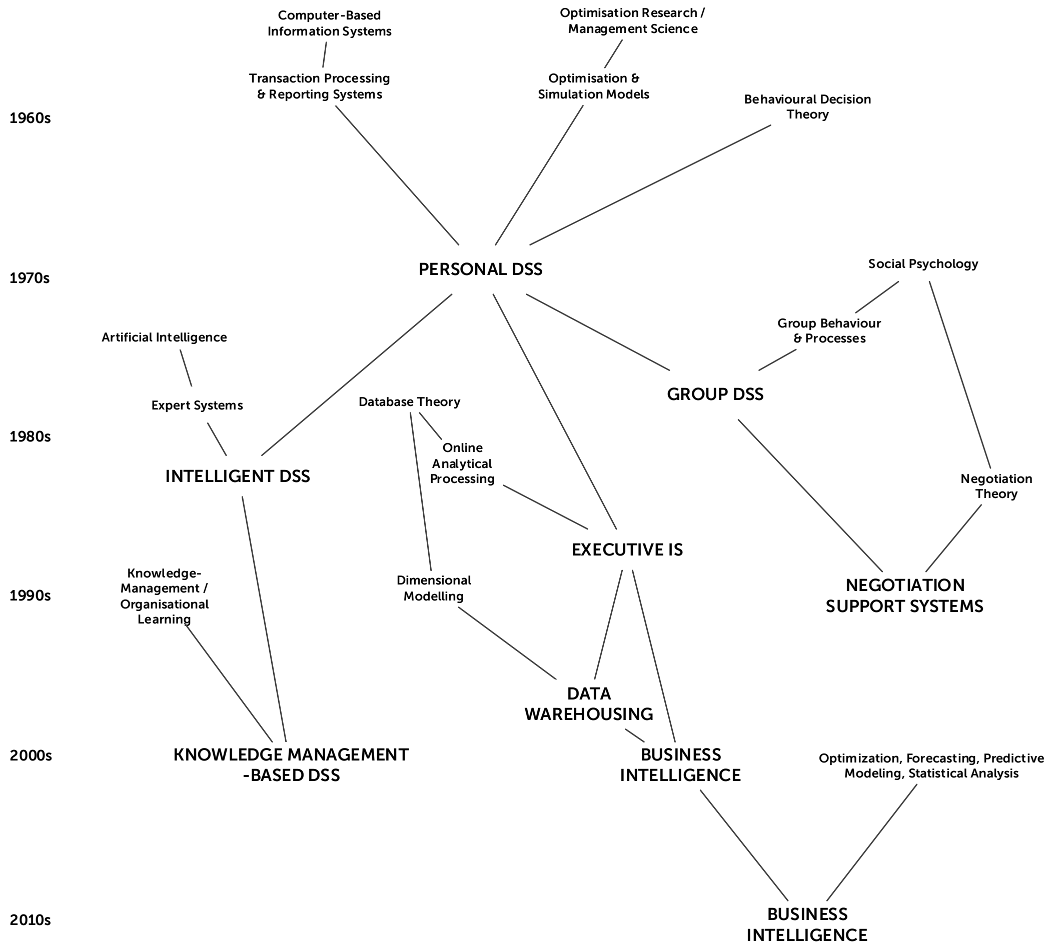

Figure 4.1: Evolution of DSSs as per Arnott & Pervan (2005)

agement. Arnott & Pervan (2005) further asserts that PDSSs can be further classified into two additional categories as elucidated by Alter (1977): *data-oriented* and *model-oriented* DSSs. In modern DSSs, these two orientations are merged to form powerful DSSs that are largely model-driven, with the additional advantage of having access to immense datasets. These modern DSSs are currently referred to as *analytics* in industry.

4.3.2.2 Group Support Systems (GSSs)

A GSS differs from PDSSs primarily in the sense that the responsibility for the supported decision is shared by a number of managers (Arnott & Pervan, 2005). A GSS therefore consists of various software, hardware, and procedures that are amalgamated to supported a group of individuals involved in a meeting regarding a particular decision or group of decisions. Generally, GSSs can be developed as one of two types: electronic meeting systems (EMSs) or group decision systems (GDSs).

Implicit in the outcome of decisions taken using such systems are the attributes of the group itself, nature of the task at hand, the context of the group and organisation, as well as the system itself. These types of systems, according to Arnott & Pervan (2005), emerged during the late 1970s and early 1980s.

4.3.2.3 Negotiation Support Systems (NSSs)

NSSs refers to a type of DSS that is implemented to facilitate negotiation in decision contexts requiring such an activity. Therefore, NSSs can, in some sense, be considered a conceptual branch of GSSs due to the similarity of task orientation. However, these DSSs are theoretically rooted in fields such as game theory and social choice theory originating in the early 1940s, and themselves only emerged during the mid 1980s and early 1990s.

4.3.2.4 Intelligent Decision Support Systems (IDSSs)

According to Arnott & Pervan (2005), IDSSs are the variant of DSSs whose objectives frequently exist in tension with the typical objectives of DSSs. The logic of particular IDSSs that are rooted in AI techniques aim to replace human reasoning, rather than to augment the decision making process as per classical DSSs. IDSS endeavours can be divided into two generations as per Turban et al. (2005): rule-based expert systems (first generation) and neural networks, genetic algorithms, and fuzzy logic (second generation). The first generation emerged as early as the 1970s.

4.3.2.5 Executive Information Systems (EISs) and Business Intelligence (BI)

Fitzgerald (1992) define an EIS as a DSS which is data-oriented in nature, and that provides reporting capabilities about the state of the organisation to managers of that organisation. Arnott & Pervan (2005) assert that the notion of EISs originated in the mid to late 1980s due to enabling technologies which emerged at the time. Data cubes[1] and dashboard interfaces[2] provide insight into the health of the organisation through the visualisation of critical success factors (Rockart, 1978).

4.3.2.6 Data Warehouses

The rise of EISs along with the nature of the corporation in the 1990s necessitated the availability of enormous quantities of data for managers that was also of high

[1]Data cubes are hierarchical layers of reports that allow managers or other stakeholders access to a multi-dimensional view of the data and associated variances (Arnott & Pervan, 2005).

[2]Dashboard interfaces refer to a web-based style of presenting reports to the user that revolutionised the look and feel of EISs (Arnott & Pervan, 2005).

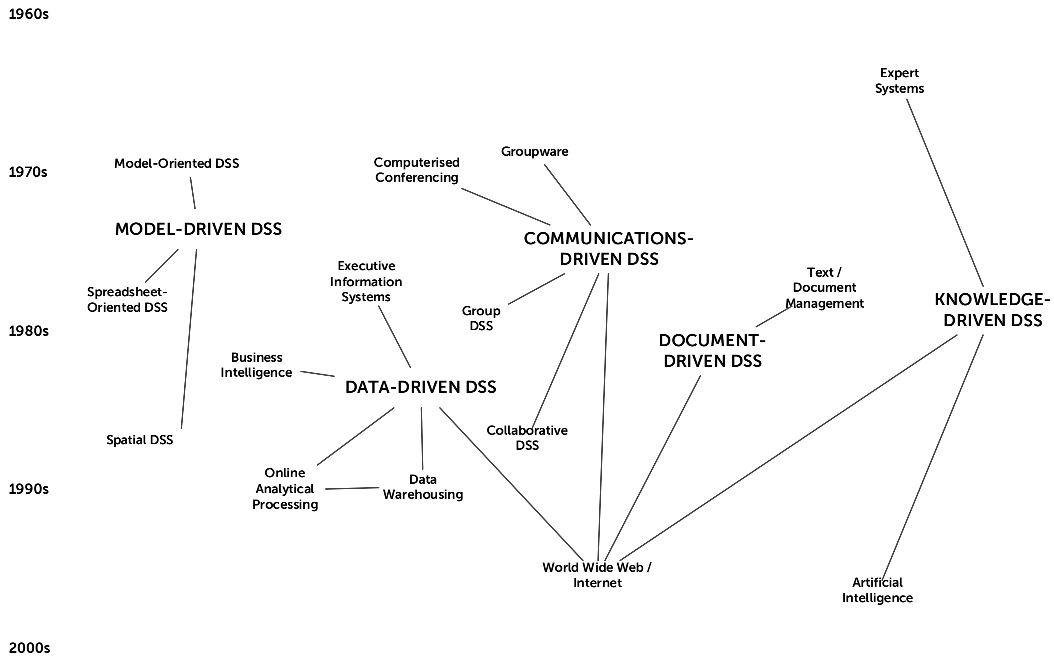

Figure 4.2: Evolution of DSSs as per Power (2008)

quality (Arnott & Pervan, 2005). Data warehouses emerged as the technology to provide such data for decision making by means of a set of databases organised in an efficient and useful manner through dimensional modelling[3].

4.3.2.7 Knowledge Management-Based Decision Support Systems

KM-based DSSs rose to prominence in the 1990s due to the focus on organisational KM which was salient at the time (Arnott & Pervan, 2005). These types of DSS focus on supporting KM activities throughout the organisation, such as knowledge storage, retrieval, transfer, and application (Arnott & Pervan, 2008). This is achieved through supporting of both individual as well as organisational memory and access to knowledge across groups.

4.3.3 An Account of DSS History by Power (2008)

Power (2008) sketches the pragmatic history of DSSs in terms of five broad DSS application types, each of which were enabled by technological and theoretical developments at the time. The author asserts that the purpose of utilising this expanded

[3]Dimensional modelling refers to a means of organising data within a data warehouse that places the unit of analysis at the centre of focus along various dimensions represented as linked tables (Garcia-Molina et al., 2009).

framework is to "retrospectively discuss the historical evolution of [DSSs]" (Power, 2008, p. 132). An elucidation of each of these follows below.

4.3.3.1 Model-Driven DSSs

According to Power (2008), the earliest DSSs of the late 1960s and early 1970s were primarily model-driven in nature. This DSS variant refers to those systems that are concerned with the leveraging and utilisation of stored model definitions to perform optimisation or simulation activities. This class of DSS has led to the development of specialised applications such as spreadsheet software and spatially-oriented DSSs.

4.3.3.2 Data-Driven DSSs

The author, similarly to Arnott & Pervan (2005), describes a class of DSS which is heavily reliant on enormous quantities of data related to the organisation at different points in time. These systems, which Power (2008) refers to as data-driven DSSs, consist of systems such as EIS and BI systems underpinned by extensive data warehousing and OLAP technologies. This variant of DSS emerged during the mid 1970s, with advances in database technology such as OLAP in the 1990s fuelling further adoption of such decision support in large corporations such as Wal-Mart.

4.3.3.3 Communications-Driven DSSs

Communications-driven DSSs are those DSSs which make use of various tools and technologies to facilitate the process of communication and collaboration related to decision making activities. Early examples in the 1970s included computerised conferencing, while the 1980s brought the advent of GDSSs and CDSSs to encourage negotiation and problem-solving in teams.

4.3.3.4 Document-Driven DSSs

Power (2008) presents document-driven DSSs as tools that utilise computer-based storage and retrieval techniques to support the process of document retrieval and analysis. These systems originated in the 1970s in the form of document management, or text-oriented DSSs. A search engine is a modern variant of document-driven DSSs, where extensive collections of hyperlinked documents are indexed and made available.

4.3.3.5 Knowledge-Driven DSSs

Knowledge-driven DSSs perform a somewhat different function from typical DSSs in that the goal is to provide suggestions for further action on the part of the decision maker (Power, 2008). These DSSs contain domain-specific expertise and various approaches to solving problems within that domain. Expert systems are an early example of such DSSs that emerged during the mid 1960s with rule-based expert systems, along with AI technologies augmenting these abilities in fields such as fraud detection, medical diagnostics, and scheduling.

4.3.3.6 The Impact of WWW / Internet Technologies

When discussing each of the five DSS application types, Power (2008) makes reference to the impact of the WWW / Internet on each DSS application other than model-driven DSSs explicitly. In each case, the protocols of the Internet, along with the display and structuring properties of web-based systems are raised as enabling factors for these DSS types. Further, in Bhargava & Power (2001), the authors make the statement that WWW technologies have greatly transformed the manner in which all DSSs are designed, developed, and implemented.

4.4 Frameworks and Taxonomies

A key theme in DSSs literature is that of classifying DSSs with regards to some defined criterion. According to Hayen (2006), the frameworks that arise as a result of this process aid in exploring relationships within and between DSSs, thereby enabling acquisition of perspective in the field of DSSs. Further, these frameworks provide focus for the field and increase effectiveness of efforts in IS (Gorry & Morton, 1989). A number of frameworks outlined in the literature will be elucidated in the sections that follow.

4.4.1 Framework of Gorry & Morton (1989)

This framework, originally published in 1971, applies a decision making frame to the concept of the MIS, which was exceptionally prevalent in organisations at the time. It also explores the types of decisions that are made in an organisation, and attempts to postulate the nature of information and corresponding information system that would best suit each type of decision respectively. These dimensions are illustrated in Figure 4.3.

This framework is synthesised by juxtaposing the classifications of managerial activity postulated by Anthony (1965) and an extension of the classification of the structuredness of decision problems outlined by Simon (1960). The author defines structured decisions as those decisions in which the three phases of the decision process as outlined by Simon (1960) - intelligence, design, and choice - are structured. Un-

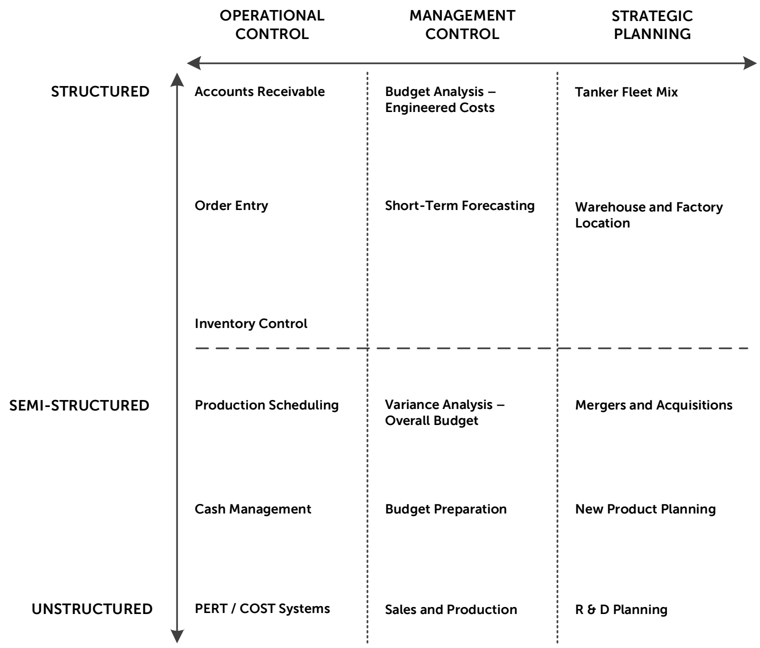

Figure 4.3: Framework for IS as per Gorry & Morton (1989)

structured decisions comprise no structured phases, while semi-structured decisions possess at least one structured phase. The authors of this framework argue that it demonstrates an intrinsic truth about the level of problem and its relation to MIS at the time: "To the extent that a given problem is semi-structured or unstructured, there is an absence of a routine procedure for dealing with it." (Gorry & Morton, 1989, p. 54). Consequently, MISs address structured problems with great effectiveness, while unstructured problems are primarily the domain of management.

4.4.2 Taxonomy of Alter (1977)

Alter (1977) describes a taxonomy that categorises DSSs in accordance with the level of influence that the system has on the final decision, as well as the generic operations that the system performs (Power, 2002). Each of these DSS types are presented, along with descriptions and examples of each respectively, in Table 4.1.

In order to develop this taxonomy, the authors compiled small case studies for each of 56 individual DSSs. The eventual classification methodology groups the various DSSs in terms of the level of decision support each provides, from the most basic retrieval and presentation of information, consequences of various actions, to actual decision making activities. The various items in the taxonomy are presented in order of increasing responsibility of the DSS in the decision task.

Table 4.1: Alter's taxonomy of DSSs as per Alter (1977)

DSS Type	Elucidation	Examples
File drawer systems	Essentially automated versions of manual filing systems that provide access to particular items.	OLTP
Data analysis systems	Allow computerised analysis and manipulation of data.	Data warehouses
Analysis information systems	Provide management information through access to a series of decision-oriented databases and simple models.	OLAP, BI
Accounting and financial model-based DSSs	Utilise built-in formulas to determine the consequences of conceivable actions.	Goal-seeking, estimation
Representational model-based DSSs	Determine the consequences of conceivable actions through the use of simulation models.	Market response models, budgeting based on fluctuating costs
Optimisation model-based DSSs	Enable attainment of a specific objective, i.e., optimal solution, that is mathematically complicated to calculate, and in light of various constraints.	Linear programming models
Suggestion DSSs based on logic models	Similar to optimisation models, but supply a specific suggestion based on formulas, mathematical procedures, or models.	Insurance renewal rate calculations, optimal bond-bidding models

4.4.3 Framework of Keen (1980)

The framework proposed by Keen (1980), unlike many of the other frameworks investigated in this section, proposes a DSS design approach. This *adaptive design* approach is arguably the most widely cited, and subsequently most influential, description of the evolutionary approach to DSS design and development (Arnott & Pervan, 2005). An illustration of this approach is presented in Figure 4.4.

The framework comprises the three major actors that are involved in DSS development - the user (U), the builder / designer (B), and the system itself (S). The framework also includes the influences flowing between these three actors. An explanation of each of the three pairs of resulting links follows:

- *System-user link* — this link, known as the *cognitive loop*, demonstrates how the system influences managerial learning ($S \rightarrow U$) while the user leverages the system's capabilities ($U \rightarrow S$).

- *User-builder link* — the *implementation loop* refers to the relationship between the user and the builder during the design and development process. Here, the user informs the builder what is required from the system ($U \rightarrow B$), thereby facilitating a middle-out design approach, encouraging user-driven design. The builder must comprehend the user's perspective and respond appropriately ($B \rightarrow U$) in order for this middle-out approach to operate effectively.

- *System-builder link* — the so-called *evolution loop* demonstrates the actual evolutionary system design and development process. By virtue of the user using the system via ($U \rightarrow S$), pressure is placed indirectly by the system on the designer ($S \rightarrow B$). The builder then adds the required novel functionality to the system via ($B \rightarrow S$).

4.4.4 Framework of Sprague (1980)

Sprague (1980) takes a characteristics-based approach to defining and delineating DSSs, with the goal of drawing sufficiently succinct, yet inclusive boundaries around the construct. From this perspective, DSSs are viewed as consisting of multiple levels of technology and user roles within the organisation. The nature of these levels and their relationships are displayed in Figure 4.5.

According to the author, there exist three technology levels:

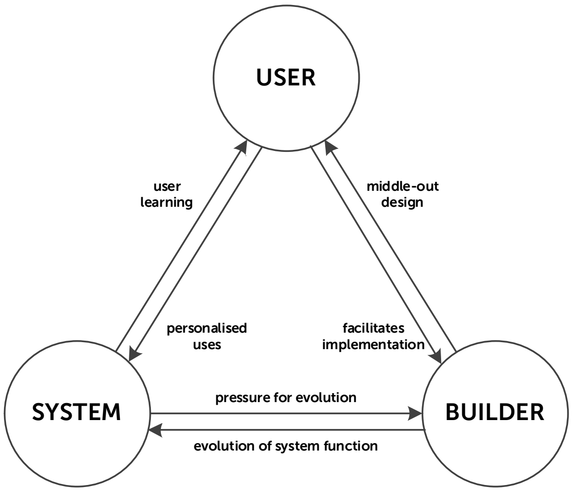

Figure 4.4: Framework for adaptive DSS design as per Keen (1980)

- *Specific DSS* — this refers to the actual DSS system which performs the task of supporting the decision process of a decision maker or group of decision makers.
- *DSS generator* — a DSS generator is a group of hardware and software components which enable development of a specific DSS.
- *DSS tools* — this level refers to hardware and software components which enable the development of either of the two technological components described above, that is, a specific DSS or a DSS generator.

These three technology levels interact directly with five user roles in the organisation.

- *Manager / user* — the individual who is actually responsible for the taking of a particular decision and its associated consequence(s).
- *Intermediary* — an individual who assists the user in the decision task, either at a conceptual or pragmatic level.
- *DSS builder* — the DSS builder develops the specific DSS for the user by compiling the appropriate components from the DSS generator.
- *Technical supporter* — this individual develops further functionality comprising the DSS generator as necessary.
- *Toolsmith* — the individual who fulfils the role of developing new technologies and languages, as well as novel hardware and software which may be leveraged to develop further DSS applications.

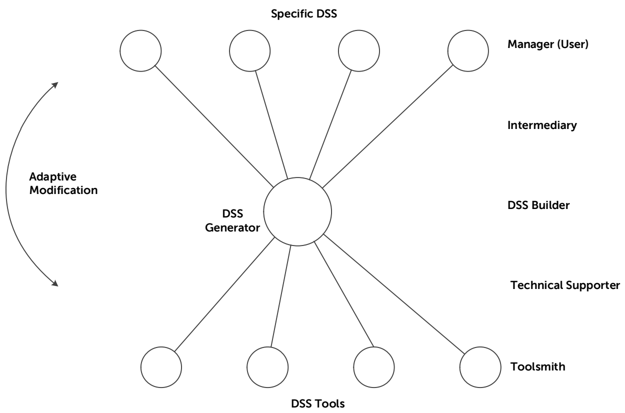

Figure 4.5: Levels of DSSs and and associated user roles as per Sprague (1980)

In addition to technological and organisational characteristics, Sprague (1980) also describes DSSs in terms of their performance objectives and capabilities. Perhaps the most notable of these is the technical capabilities of the DSS from the perspective of the builder. This is delineated in Figure 4.6, and demonstrates the various components of a DSS in relation to the task and environment. The three major components are elucidated below:

- *Data subsystem* — this subsystem consists of the DBMS along with its associated database. These facilitate combination of a wide variety of data sources, management of data in terms of capturing, adding, and deleting data, as well as enabling individual analysis and manipulation of data.
- *Model subsystem* — the model subsystem allows for the creation of models through integration with the database, and to enable appropriate storage, cataloguing and linking of models.
- *User system interface* — the user system interface manages the interface between the user and the system. This should be achieved in a manner which allows for a variety of display styles, user actions, and presentation formats.

4.4.5 Framework of Bonczek et al. (1981)

Bonczek et al. (1981) define a framework for DSSs in terms of the types of specialised functions each component of the system performs. These are illustrated in Figure 4.7 and outlined as follows:

- *Language system (LS)* — the language system comprises all of the syntax that the decision maker is permitted to use within the DSS. The languages

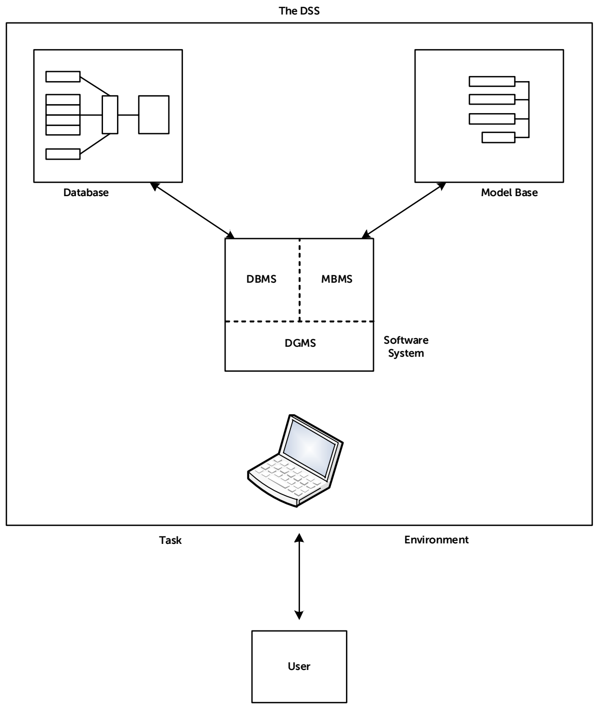

Figure 4.6: Components of a DSS as per Sprague (1980)

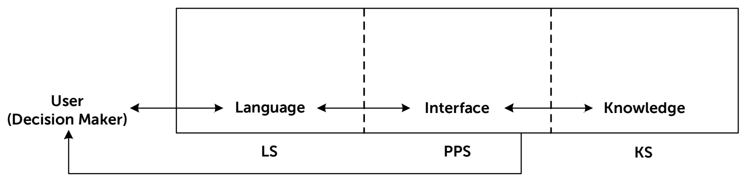

Figure 4.7: Structure of a DSS as per Bonczek et al. (1981)

allow said decision maker to express themselves, as well as limit the range of expression that may be articulated.

- *Problem processing system (PPS)* — this system acts as an interface between the LS and KS by synthesising information from the symbolic representations produced by the two systems. The nature of this information is such that it enables and supports the decision process.

- *Knowledge system (KS)* — the system that contains the entire compendium of knowledge that the system possesses in the problem domain. This knowledge is represented and organised in a systematic manner so as to enable retrieval.

4.4.6 Framework of Hackathorn & Keen (1981)

The framework postulated by Hackathorn & Keen (1981) extends the early framework presented by Gorry & Morton (1989) in 1971. The authors, adopting a particularly organisational perspective, categorise DSSs in terms of the level of user support provided by a particular system. The addition of the third axis, *task interdependency*, further classifies a given DSS in terms of the level of entanglement between the actors involved in a decision given a particular decision task. This framework is presented in Figure 4.8 and elucidated as follows.

According to the authors, the framework of Gorry & Morton (1989) combines a version of Simon's notion of task structuredness with Anthony's managerial activity classification. However, they argue that this framework does no account for the interactions between individuals within an organisation. They therefore extend the framework to include the dimension of *task interdependency* as presented by Thomson (2011), which consists of three levels:

- *Independent* — the task which is independent can be performed without the actor interacting with other individuals.
- *Pooled* — this task is defined as those which require two or more people interacting in order for them to all complete their associated tasks.
- *Sequential* — the sequential task refers to the task where a number of individuals must complete their associated tasks in a particular sequence, with outputs from one task acting as inputs for subsequent tasks in the sequence.

In light of this additional dimension, the authors assert that decision support can take on one or a combination of three levels:

- *Personal support* — for independent problems that do not require interdependencies, personal support places a focus on a single user, or group of users involved in a single task.
- *Group support* — group support focuses on a group of users engaging in disparate, yet interdependent tasks. Pooled interdependency is the variant of dependency that exists, which requires a system that can be utilised collaboratively for planning and analysis.
- *Organisational support* — the most interdependent of decision support levels, organisational support focuses on a group of sequential tasks that involve multiple actors.

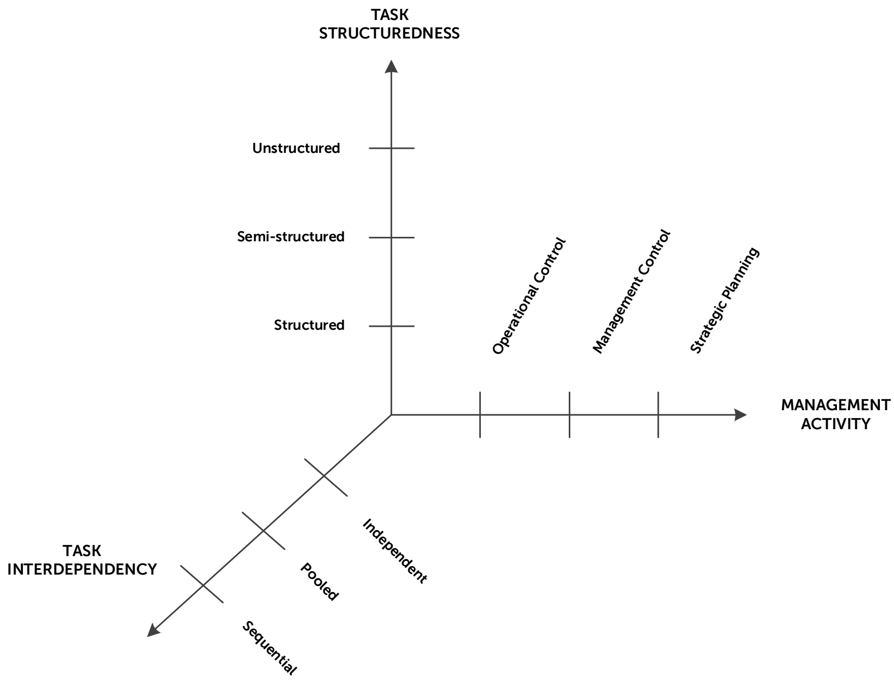

Figure 4.8: DSS framework in terms of task interdependency as per Hackathorn & Keen (1981)

Hackathorn & Keen (1981) further argue that personal support is still relevant in the organisational context, but that these should be leveraged appropriately in the correct situations in order to be effective.

4.4.7 Framework of Mackenzie et al. (2006)

Mackenzie et al. (2006) provide a novel frame for DSS classification in that there exists a differentiation between two types of DSSs based on the complexity of the decision or problem situation that the system attempts to support. The authors assert that conventional, or substantive DSSs focus on support through provision of knowledge-based expertise, relying primarily on a knowledge base embedded in the system. Conversely, they argue, a procedural DSS provides processes and tools that support decision makers in the actual process of decision making by encouraging and facilitating the search for alternatives, systematic analysis, conflict resolution and transparency of deliberation to stakeholders. Fundamentally, the procedural DSS is suitable for the exploration of wicked problems, as decision makers are provided with a framework that acts as a boundary for such an individual to navigate the complex decision space (Mackenzie et al., 2006). The emphasis is on support of the entire life cycle of the decision process, allowing decision makers to capture and change decision processes and associated information in relation to the instability inherent in the associated wicked problems.

4.5 Chapter Summary

The aim of this chapter was to to explore the concept of DSSs in order to present their common features and origins within the IS field. In Section 4.2, a working definition of a DSS as an IT-based information system for supporting human decision maker(s) facing problems of an unstructured nature, was synthesised. This was followed by a historical overview of the conceptual and practical development of DSSs as a field in terms of two perspectives in the literature in Section 4.3. This historical outline, being primarily taxonomic in nature, was extended through an elucidation of a number of other DSS taxonomies and frameworks for conceptualisation, design, and development in Section 4.4.

The chapter that follows outlines the actual research process undertaken, and discusses and details the results of the study.

Chapter 5

Supporting Wicked Problems

5.1 Introduction

As highlighted in previous chapters, it has been suggested that wicked or highly unstructured problems require an approach to decision support that is quite different from that of semi-structured problems. Additionally, it is asserted that a comprehensive literature study concerning the nature of decision support in the context of wicked problems is lacking in the literature. Further, the rationale behind the research paradigm and approach was presented in Chapter 1. The aim of this study, therefore, is to develop a relatively complete overview of the research regarding DSSs supporting wicked problems. In order to achieve this, one primary and six secondary research questions were synthesised in Chapter 1. The aim of this chapter is to provide a description and exposition of the research design and methods used to collect data with the goal of answering these research questions. The research questions are also addressed in terms of the findings from the literature.

5.2 Literature Search and Review Strategy

The search and review strategy for the applied literature review was undertaken in an iterative fashion. In each cycle, a keyword search revealed a number of different sources. Each of these studies was scanned for relevance, and retained or discarded accordingly. Following this, a snowball sampling approach was employed in order to locate additional related and relevant research. Each of these cycles revealed additional plausible keyword combinations which were then utilised in another cycle of keyword searching and snowball sampling. Levy & Ellis (2006) relates the metaphorical structure of such search as a *concertina*, with cycles of gradual narrowing and subsequent enlargement of the search. This process is illustrated in Figure 5.1.

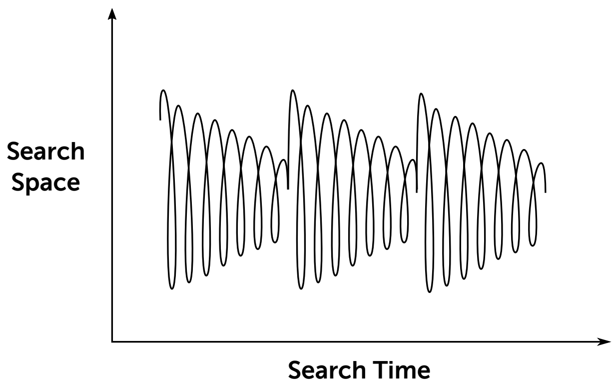

Figure 5.1: Metaphorical concertina structure of literature search as per Levy & Ellis (2006)

Table 5.1: Keywords used in literature search

Search Terms		
decision support system	AND	wicked problem
decision support	AND	wicked problem
decision support	AND	unstructured problem
decision support	AND	ill-structured problem
decision support	AND	complex problem

5.2.1 Initial Keyword Search

In order to conduct the initial search for literature pertaining specifically to DSSs for wicked problems, a number of keyword combinations were utilised. These are listed in Table 5.1. The objective of utilising these pairs of search times joined by the *AND* operator was to locate studies that made some mention of DSSs or decision support, and also considered an element of the given problem situation as wicked, unstructured, ill-structured, or complex.

These keyword searches were conducted in the EBSCOhost (EBSCO Industries Inc, 2015) and Web of Science (Thomson Reuters, 2015) databases through Stellenbosch University's library services. These databases were selected for the primary literature search due to their wide scope and availability of options for limiting and refining search results. Additionally, due to the interdisciplinary nature of the IS field in general, it is imperative to consider journals that exist outside of the field as well as those that exist explicitly within the field (Webster & Watson, 2002). Therefore, studies implementing decision support principles in an applied wicked problem context were also located.

Keywords were initially applied only to the title and topic of the search fields, and later applied to the full text of the indexed articles in order to expand the search space. As per the literature selection strategy outlined by Levy & Ellis (2006), the search was limited to peer-reviewed journal articles available within these databases. Professional magazines and conference proceedings were not included in the search as the nature of this phase required a homogeneous set of high quality studies.

5.2.2 Snowball Sampling

Once an initial set of quality literature has been collected, additional strategies should be utilised to gather additional, related research (Levy & Ellis, 2006). Upon termination of the initial search, systematic strategies for further data collection were implemented as initially suggested by (Webster & Watson, 2002) for IS research, and reiterated by Levy & Ellis (2006) along with further suggestions. Two major strategies were utilised:

- *Backward search* — this process involves reviewing citations within the collected literature in order to locate research works that were relevant to each of these studies. Additionally, prominent author names that emerge are utilised in further keyword searches by author to locate prior research by authors. For backward citation search, Google Scholar (Google Inc, 2015) was employed in order to swiftly locate each study by title. The Web of Science (Thomson Reuters, 2015) database was utilised to locate further high quality research outputs from specific authors.

- *Forward search* — this involves the search for studies that have cited a particular article under scrutiny, as well as the search for newer literature by prominent authors. Web of Science (Thomson Reuters, 2015) was utilised to locate studies that cited each article by searching for the article by title and using the citation counter link to access other research citing the current study.

5.2.3 Literature Selection

Following a number of iterations of the abovementioned cycle, there emerged a high incidence of the same studies and arguments reappearing, and a lack of novel citations emerging from forward searching discovered literature. Accordingly, following the advice of Levy & Ellis (2006) and Webster & Watson (2002), the literature search was deemed complete within its narrow scope. The next phase of the literature review involved the selection of relevant studies from the gathered literature.

The sample size of the collected literature was initially *n=104* peer-reviewed journal articles that matched the criteria specified above. The articles were subsequently analysed in terms of their actual topic or research area to ensure that the problem area was indeed deemed by the researchers to be wicked in nature, and that the notion of IT-based decision support was addressed in a conceptual or empirical capacity. A substantial quantity of this literature was discarded due to the primary aim of these articles being far removed from resolving wicked problems in particular. The final sample consisted of *n=35* peer-reviewed articles from major journals in the IS and DSS literature, as well as a number of applied fields.

5.3 Coding the Literature

The final 35 articles were classified and coded using a number of qualifiers and concepts deemed relevant to the study. The initial classification involved the epistemological and methodological paradigms under which each of these studies fell. The analysis of these paradigms and methods drew on the study performed by Gonzalez et al. (2006), who incorporated the works of Claver et al. (2000) and Van Horn (1973) in order to present a coherent framework for classification of theoretical and empirical studies respectively.

According to the authors, theoretical studies can be further classified as *conceptual*, *illustrative*, and *applied-concept* studies:

- *Conceptual studies* — these studies perform a primarily descriptive role, where theories, models, or other structures are presented along with relevant explanation.
- *Illustrative studies* — provide recommendations for action and attempt to provide guidance for the relevant field. These studies focus on *what* should be done and *how* things should be done, rather than providing reasons.
- *Applied-concept studies* — combine the two abovementioned approaches in order to provide both conceptual as well as explanatory recommendations.

Empirical studies can similarly be broken down into a number of categories, these being *case studies*, *field studies*, *field experiments*, and *laboratory experiments*:

- *Case studies* — these studies analyse one or a number of cases of a particular phenomenon within the context of its natural environment, obtaining data about it through direct interaction.

Table 5.2: Literature sample articles by research paradigm and method

Paradigm	Method	Authors
Empirical	Case Study	Applegate et al. (1987), Arias (1996), Biermann (2011), Chen & Lee (2003), Cil et al. (2005), Dhar (1983), El-Gayar & Fritz (2010), Giordano et al. (2007), Giupponi (2007), Jankowski et al. (1997), Klashner & Sabet (2007), Lourenço & Costa (2007), Mackenzie et al. (2006), Marashi & Davis (2007), Pinson et al. (1997), Renton & Macintosh (2007)
	Field Experiment	Karacapilidis & Papadias (2001), Jarvenpaa et al. (1988), Munneke et al. (2007), Van Kouwen et al. (2009)
	Laboratory Experiment	Fan et al. (2010), Goslar (1986), Jankowski & Nyerges (2001), Jarupathirun & Zahedi (2007), Mclain (2009)
Theoretical	Conceptual	Balram & Dragicevic (2006)
	Illustrative	Kulinich (2012), McIntosh et al. (2011), Van Delden et al. (2011)
	Applied-Concept	Conklin & Begeman (1989), Coorey & Jupp (2014), Druckenmiller (2009), Gu & Tang (2005), Karacapilidis (2000), Ritchey (2006)

- *Field studies* — analyse several cases of phenomena within its natural environment utilising an experimental design and quantitative data analysis methods. However, there is little actual experimental control.

- *Field experiment studies* — utilise both experimental design as well as experimental control, but still operates within the context of the phenomenon under study.

- *Laboratory experiment studies* — study the phenomenon in a completely controlled environment divorced from its natural context. This method has the highest level of control.

The final literature sample is presented in Table 5.2 in terms of each of these categories. Additionally, the literature was coded in terms of the category of wicked problem that was explored, the period in which it was published, as well as whether the underlying perspective of rationality was procedural or substantive in nature. Classification was achieved by allowing categories to emerge organically as further studies were analysed as per Gonzalez et al. (2006), without forcing preconceived codifications onto any of the sources reviewed.

5.4 Quantitative Analysis

In order to address research questions, *R.2.3–R.2.6* from Chapter 1, which pertain to various quantifiable themes in the literature, a number of quantitative analyses are performed. Each of these are discussed in the relevant sections that follow.

5.4.1 Categories of Wicked Problems in the Literature

The research question *R.2.4* synthesised in Chapter 1 aims to discover the types of wicked problems addressed in the literature sample. To this end, the studies were coded in terms of a number of categories of wicked problem that were identified in the literature. These are presented in Figure 5.2 and are as follows:

- *Business, organisational, and strategic* — these types of decision contexts refer to problems that typical middle and upper managers face, such as marketing decisions (Goslar, 1986), organisational planning (Applegate et al., 1987), and scenario management (Pinson et al., 1997).

- *Environmental and natural resource planning* — wicked problems in this area aim to address the management of finite natural resources such as water

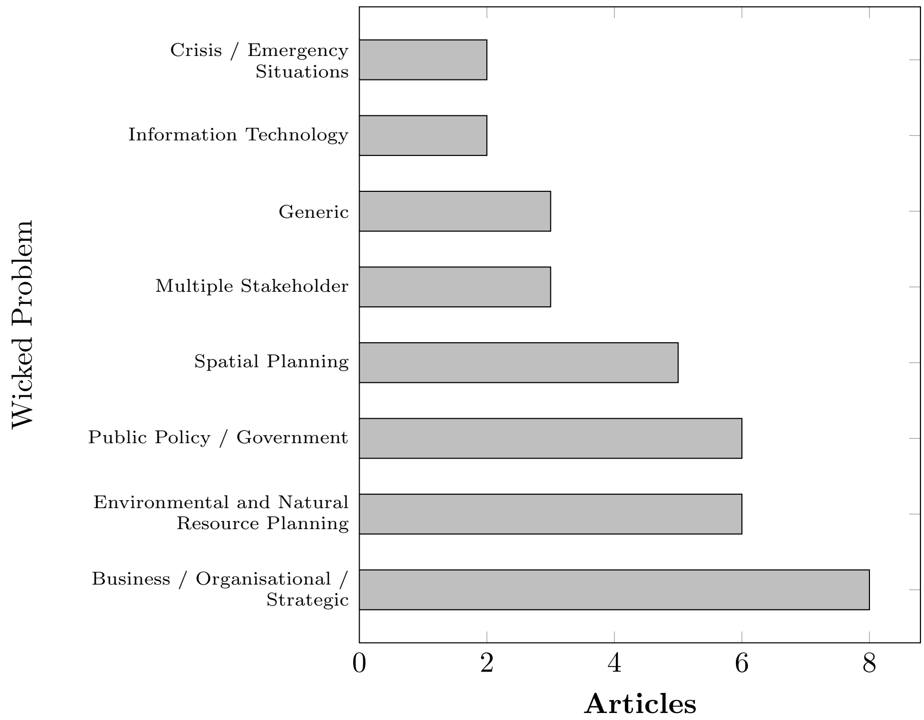

Figure 5.2: Distribution of wicked problem types in the literature

(Giordano et al., 2007; Giupponi, 2007), general environmental policy planning (Van Kouwen et al., 2009), and global warming challenges (Marashi & Davis, 2007). Although there is some crossover with spatial planning in terms of a shared artefact design strategy, the aforementioned problems emphasise the environmental as opposed to the spatial.

- *Public policy and government* — in addition to policies regarding environmental issues, a number of studies identify other types of policy making problems, such as smoking laws (Renton & Macintosh, 2007) and generic policy issues such as engagement in policy planning (Lourenço & Costa, 2007).

- *Spatial planning* — problems in this category focus on the problem of planning in a spatial context, such as urban planning (Arias, 1996), architectural planning (Coorey & Jupp, 2014), habitat restoration (Jankowski et al., 1997), and service delivery (Biermann, 2011).

- *Multiple stakeholder* — although Rittel & Webber (1973) points out that all wicked problems derive a substantial proportion of their wickedness from the multiplicity of stakeholders involved, a number of studies such as Cil et al. (2005) and Karacapilidis & Papadias (2001) explicitly address collaboration as a wicked problem.

- *Generic* — a handful of studies such as Jarupathirun & Zahedi (2007) do not address a specific wicked problem, but address the concept generically.
- *Information technology* — wicked problems in this category address issues such as software design (Jarvenpaa et al., 1988) and IT security (El-Gayar & Fritz, 2010).
- *Crisis and emergency situations* — these problems include humanitarian and combat missions in urban areas (Fan et al., 2010) and mission-critical decisions (Klashner & Sabet, 2007).

According to the literature sample, the most commonly addressed wicked problems in terms of IT-based decision support are business, organisational and strategic decisions. This might be described as unsurprising due to the fact that initial wicked problems recognised in the literature in the 1970s were that of organisational planning (Rittel & Webber, 1973). Other types of planning, such as environmental and natural resource planning as well as spatial planning, are also common.

5.4.2 Integration of DSS and Wicked Problem Research Over Time

Research question *R.2.5* from Chapter 1 sought to explore the cognisance of wicked problems in the context of DSSs over the lifespan of the literature. The findings are summarised in Figure 5.3 in relation to each five-year period.

The literature regarding DSSs for wicked problems only reached prominence in the early 1980's following a number of publications exploring conceptual issues around wicked problems, such as Kunz & Rittel (1970) and Rittel & Webber (1973). Two conspicuous outliers appear in the bar chart presented. The first outlier relates to the period of 1991 to 1995, where zero articles matching the rigorous criteria outlined in Section 5.2.3 were collected. The second outlier, which is far more prominent than the first, refers to the sudden increase to seventeen articles published in this area in the period of 2006 to 2010. Aside from these two exceptions, the literature published per year remains relatively consistent. The trend demonstrates a slow start, slight dip, and a peak late during the first decade of the 2000s. It should be noted, however, that the literature sampling process was conducted during the latter half of 2015. Due to plausible delays in article publication in general, the sample for the final period may therefore be somewhat incomplete.

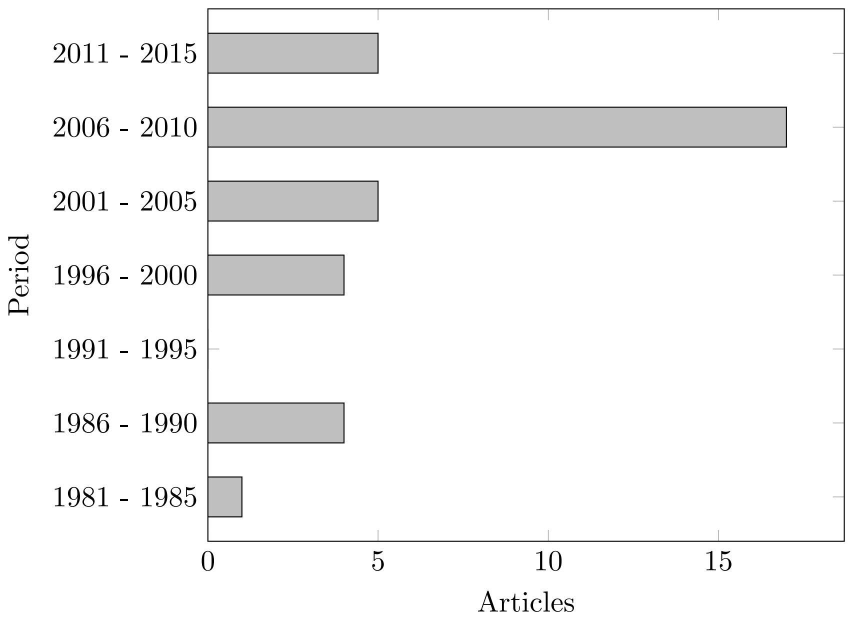

Figure 5.3: Number of articles on DSSs for wicked problems per period

5.4.3 Distribution of Research Designs and Methods

In addition to the two aforementioned research questions synthesised in Chapter 1, *R.2.5* is also addressed by means of analysing the literature sample. The research designs and methodologies elucidated in the earlier sections are presented along with the quantity of articles and proportion alongside in Table 5.3.

Almost three-quarters (71.6%) of all of the literature sampled is of empirical design, with almost half (45.7%) of all of the literature taking on a case study methodology. This appears to be very much in line with the observation by Gonzalez et al. (2006) that case studies are increasing in prevalence and popularity in IS research. The remainder of the empirical literature is almost evenly divided between field experiments and laboratory experiments, corresponding to the findings of Orlikowski & Baroudi (1991) that demonstrate the emphasis on empirical methods with extensive control in IS literature in general.

Just over one quarter (28.6%) of all literature sampled was classified as theoretical in design. Applied-concept studies are the most common in this category, contributing to a total of almost one fifth (17.1%) of the total literature sample. Illustrative and conceptual studies are the least prevalent studies of all studies that were actually represented in the sample at 8.6% and 2.9% respectively.

Table 5.3: Proportion of literature per research methodology

Methodology	Total	%
Total empirical	**25**	**71.4**
Case studies	16	45.7
Field studies	0	0.0
Field experiments	4	11.4
Laboratory experiments	5	14.3
Total theoretical	**10**	**28.6**
Conceptual	1	2.9
Illustrative	3	8.6
Applied-concept	6	17.1
Total	**35**	**100.0**

5.4.4 Substantive and Procedural Support

The final research question that will be answered quantitatively is that of *R.2.3*, which inquires as to whether procedural or substantive approaches to decision support are more prevalent in the literature. Substantial and procedural decision support are underpinned by the notions of substantive and procedural rationality outlined in Chapter 2 respectively. *Substantial decision support*, according to Mackenzie et al. (2006), has the following properties:

- Focus on goals.
- Contains a knowledge base of options.
- Contains a knowledge base of known algorithms and calculations.
- Algorithms or calculations may be non-trivial, but aim to derive optimal or at least "most preferred" solutions.

Likewise, the authors assert that the following properties are characteristic of *procedural decision support*:

- Focus on processes.
- Contains tools and processes to support search for alternatives, information gathering and analysis, and conflict resolution.

Table 5.4: Conceptions of rationality prevalent in literature

Conception of Rationality	**Number of Articles**	**%**
Procedural	23	65.7
Substantive	4	11.4
Mixed	5	14.3
Not Applicable	3	8.6

- Provide a framework to explore a given decision situation.
- Rely on the reason of the decision maker to "find a way through" the decision situation.

The literature was analysed utilising these definitions with the aim of categorising each study as primarily viewed through the lens of substantive or procedural decision support. Heuristically, studies utilising methods to calculate or determine "optimal" solutions were generally classed as substantive, while studies emphasising the process of deliberation were typically characterised as procedural in nature. The findings are summarised in Table 5.4.

From the literature sample, it is clear that procedural decision support is the most common strategy implemented in DSSs for wicked problems, constituting almost two thirds of the total number of studies (65.7%). Substantive decision support by itself is the most rarely employed form of decision support utilised in these DSSs at just over one tenth of the literature (11.4%). A proportion of the literature (14.3%) utilises both strategies in DSS conceptualisation, design, or development, usually combining methods for increasing stakeholder collaboration and alternative generation, with mathematical methods employed at a later stage in the decision making process to reach a preferable solution.

5.5 Qualitative Analysis

Qualitative methods were employed for the next phase of the analysis for research questions, *R.2.1–R.2.2* from Chapter 1, which inquire about subjects that are more complex in nature and require interpretation.

5.5.1 DSS Features for Wicked Problems

To design and develop a quality information system, it is necessary to determine what is required of such a system either as part of a sequential development methodology or in a number of iterations in an evolutionary approach (Avison & Fitzgerald, 2002). *R.2.1* seeks to discover such requirements for the development of DSSs for wicked problems in general. A number of these requirements were identified in the literature:

- *Participation and collaboration* — probably the most widely cited requirement for wicked problems resolution in the literature, this requirement emphasises the necessity of mechanisms for collaborative understanding of the wicked problem. This includes but not limited to discussion facilitation, articulating preferences, enrichment of collective knowledge, and negotiating the strategy to be selected via consensus. The emphasis is on subjective perspectives and assumptions (Balram & Dragicevic, 2006; Cil et al., 2005; Conklin & Begeman, 1989; Giordano et al., 2007; Gu & Tang, 2005; Jankowski et al., 1997; Jarupathirun & Zahedi, 2007; Jarvenpaa et al., 1988; Karacapilidis, 2000; Karacapilidis & Papadias, 2001; Klashner & Sabet, 2007; Lourenço & Costa, 2007; Mackenzie et al., 2006; McIntosh et al., 2011; Munneke et al., 2007; Renton & Macintosh, 2007; Ritchey, 2006; Van Kouwen et al., 2009).

- *Conflict management* — the subjective essence of wicked problem resolution necessarily leads to conflict. There is a consensus in the literature that these conflicting views should not simply be ignored, but should be explored and reasoned through (El-Gayar & Fritz, 2010; Giordano et al., 2007; Jankowski et al., 1997; Jarupathirun & Zahedi, 2007; Karacapilidis, 2000; Karacapilidis & Papadias, 2001).

- *Scenario exploration and situation analysis* — this involves the analysis of the problem situation in order to further refine and conceptualise possible goals and alternatives (Biermann, 2011; Giordano et al., 2007; Goslar, 1986; Jankowski et al., 1997; Marashi & Davis, 2007; Van Kouwen et al., 2009).

- *Reduction of cognitive load* — a number of studies demonstrate the need for reducing information overload in contexts with large amounts of issues that required attention from decision makers (Druckenmiller, 2009; Fan et al., 2010).

- *Transparency and accessibility of evidence* — ability to capture evidence for perspectives or positions and make this available to all stakeholders (Biermann, 2011; Renton & Macintosh, 2007; Ritchey, 2006).

- *User interface and visual feedback* — the entire decision process should be presented in a manner that is user-friendly and that provides clear visual representations of the problem situation and activities involved (Balram & Dragicevic, 2006; Biermann, 2011; Coorey & Jupp, 2014; Druckenmiller, 2009;

Giordano et al., 2007; Jankowski et al., 1997; Jankowski & Nyerges, 2001; Jarupathirun & Zahedi, 2007; Kulinich, 2012; Mackenzie et al., 2006; Marashi & Davis, 2007; McIntosh et al., 2011; Munneke et al., 2007; Renton & Macintosh, 2007; Ritchey, 2006; Van Delden et al., 2011; Van Kouwen et al., 2009).

- *Facilitation of organisational memory* — past scenarios should be stored in an effective manner which facilitates recall and application to current contexts (Conklin & Begeman, 1989; Chen & Lee, 2003; El-Gayar & Fritz, 2010; Renton & Macintosh, 2007).

- *Flexibility of phases and iterations* — the process of wicked problem exploration and capturing of information should not be a once-off, sequential process, but may require many iterations to create a cohesive picture as well as to reach consensus amongst participants. The movements between various phases should also be flexible as a result (Applegate et al., 1987; Cil et al., 2005; Kulinich, 2012).

- *Reduction of erroneous logic* — a characteristic of many DSSs in general, it is imperative to reveal instances where cognitive biases result in oversights in the decision process. Consistency checking of information also falls into this category (Chen & Lee, 2003; Karacapilidis, 2000; Karacapilidis & Papadias, 2001).

- *Decision analysis methods* — this is a decision analytic aid which relies on mathematical methods to weight preferences and analyse alternatives (Cil et al., 2005; Giupponi, 2007; Goslar, 1986; Gu & Tang, 2005; Jankowski et al., 1997; Jankowski & Nyerges, 2001).

Many of these findings are consistent with the findings made by other authors for general wicked problem resolution in Chapter 3. Additionally, a great number of these features match up with the procedural approach to decision support elucidated in Section 5.4.4. This shows that procedural decision support, which was conceptually argued by authors such as Simon (1976) and Mackenzie et al. (2006) to be the most appropriate for the resolution of wicked problems, is also supported by the literature as being more suitable than substantive decision support.

5.5.2 A Procedural DSS for Wicked Problems

As a result of the findings regarding the suitability of procedural decision support over substantive or mixed approaches, a model for the development of a DSS for resolving wicked problems is presented in order to address the final secondary research question *R.2.1.* To produce this model, the 23 articles specifically considering procedural decision support in the literature were analysed for common themes and patterns regarding the architecture of such a DSS, as well as the *soft* factors that were identified.

5.5.2.1 Architecture

The conceptual architectural model is presented in Figure 5.4. The components are as follows:

- *Repository* — a number of studies noted the requirement for the creation and facilitation of organisational memory. The repository is a generic term for the storage of previous deliberations, scenarios, and their outcomes. This allows previous scenarios to be revisited and utilised to inform present concerns surrounding a particular wicked problem.

- *Decision space* — this space behaves in a manner analogous to that of a virtual whiteboard, permitting the capturing of multiple perspectives and facts related to the problem at hand. This context can be navigated by individuals or groups in order to make sense of the problem under scrutiny. The movement between ideas, perspectives, and possible strategies is not strictly enforced as this process relies on the process of collaboration and negotiation, both of which can be facilitated by means of a number of useful tools embedded within the decision space.

- *Decision tools* — this suite of tools can be used in a standalone fashion or in tandem in order to explore, analyse, and simulate various issues within the wicked problem space. Mapping and modelling tools can be used by one or a number of participants to explore the problem situation linguistically, semantically, or visually. Simulation tools can be utilised to predict the effects of particular alternatives in the decision space, and analysis tools can be utilised to evaluate one or a number of alternatives in terms of the preferences captured in the decision space.

- *User interface* — this element of the DSS is imperative to allow stakeholders to interact with the system in various ways. The UI also allows for various levels of analysis at which the decision space can be viewed and manipulated.

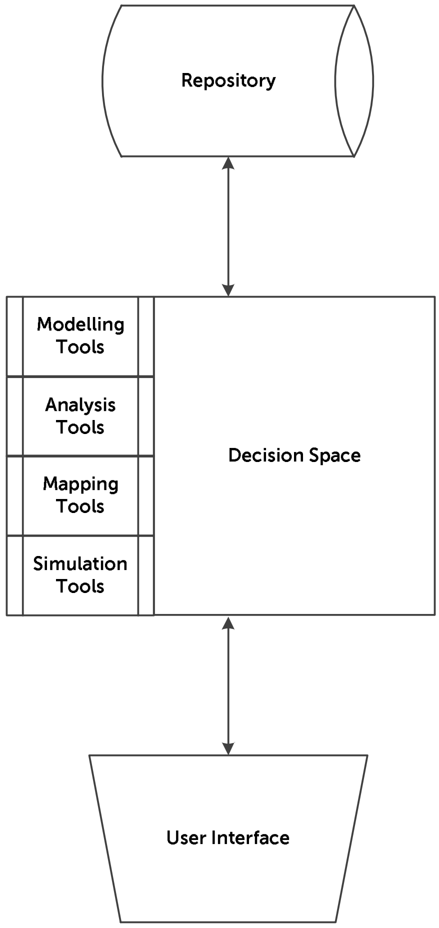

Figure 5.4: Synthesised conceptual model of procedural DSSs

5.5.2.2 DSS Design and Development Process

Klashner & Sabet (2007) argue that the traditional SDLC as per Avison & Fitzgerald (2002) approach is deterministic in the sense that it presupposes the existence of tangible and definitive goals of the system under development. Instead, they argue for a design and development process for DSSs for wicked problems that is evolutionary in nature, such as the spiral model (Boehm, 1988) and the evolutionary DSS model (Arnott, 2004) in the general IS literature. The plausible irony that the design and development of such a DSS for wicked problems may itself constitute a wicked problem is not always acknowledged in the literature, but it is implicitly recognised in a number of sources that focus on this process. Thus, it is imperative to constantly refine the DSS design as new information becomes available.

In addition to the evolutionary nature of the DSS design and development, it is argued that stakeholder involvement in the design and development process is imperative in creating DSSs that adequately address the extreme complexities inherent in the relevant wicked problem set.

5.5.2.3 Decision Process

The traditional view of the decision making process developed by Simon (1960) and elucidated in Chapter 4 involves three discrete phases: intelligence, design, and choice. Later additions to the model included the phases of implementation of the decision and review of the decision and its associated consequences. Although the original intention of the phase model was recursive and iterative movement through and between the phases (Arnott & Pervan, 2014), it is often treated as a sequential process very much like the SDLC. Since wicked problems have a non-deterministic nature, it is not a sensible endeavour to attempt to force these problems to fit a sequential process of deliberation. Consequently, the actual process of deliberation undertaken with a procedural DSS is itself cyclical and evolutionary. Stakeholders can add multiple perspectives, query the decision space, apply analysis and simulation to the space, and evaluate the alternatives in an iterative process, revisiting activities as necessary.

5.5.2.4 Organisational Structure

El-Gayar & Fritz (2010) as well as a number of other authors argue for organisations facing wicked problems and implementing DSSs to adopt a *Singerian* perspective within the organisation. This perspective, popularised by Courtney (2001), emphases the *inquiring* nature of organisations, and is subsequently suitable in contexts facing any number of wicked problems. Fundamentally, a Singerian organisation views reality as holistic in nature, and as a highly interconnected and indivisible system. Practically, problem solving is therefore undertaken in a holistic manner, with complex and wicked problems viewed as integrated *wholes*.

The second important point regarding the Singerian view is closely related to the heart of the subjective nature of wicked problems. Courtney (2001, p. 29) summarises this defining characteristic with the following quote by Mitroff & Linstone (1993, p. 99):

> All complex problems — especially social ones — involve a multiplicity of actors, various scientific/technical disciplines, and various organizations and diverse individuals. In principle, each sees a problem differently and thus generates a distinct perspective on it.

Therefore, an inquiring, Singerian, organisational context that effectively supports the procedural DSS will take into account not only the technical elements of a wicked problem, but also organisational, personal, ethical, and even aesthetic perspectives. This corresponds with the requirements for wicked problem resolution, as well as for procedural decision support presented in the literature.

5.6 Chapter Summary

The aim of this chapter was to elucidate the data collection and analysis methodology utilised for the literature, as well as to present the findings from this process in terms of the research questions synthesised in Chapter 1. Section 5.1 contextualised and introduced the literature study, followed by Section 5.2, which outlined the literature data collection and review strategy employed in this thesis. Section 5.3 elucidated the method employed in coding the literature for further analysis. Finally, Section 5.4 presented the quantitative results associated with research questions *R.2.3 – R.2.6* and the nature of wicked problems in the literature, followed by the final qualitative analysis and results related to procedural DSSs addressing research questions *R.2.1 – R.2.2* in Section 5.5.

Chapter 6

Conclusion

6.1 Introduction

The overarching objective of this thesis, as stated in Chapter 1, is to investigate the advantages of procedural decision support over substantial decision support, to explore the prevalence of each in the literature, as well as to investigate the nature of procedural decision support both in the literature and conceptually. To this end, one primary (*R.1*) and six secondary research questions (*R.2.1 – R2.6*), were synthesised.

In order to answer these research questions, a three-phase research design was implemented. The first phase comprised the analysis of key themes in the three reference disciplines of decision making theory, wicked problems, and decision support systems in Chapters 2, 3, and 4 respectively. These three chapters built the case for the shortcomings of human rationality, the intense difficulty of wicked decision contexts, and the notion of supporting these problems utilising DSSs. The second phase of this research involved the quantitative and qualitative analyses of the literature pertaining specifically to DSSs in the context of wicked problems. The nature of wicked problems supported by DSSs as well as the characteristics of procedural decision support were elucidated. The final phase of the study comprised integrating these perspectives into a cohesive model for procedural decision support. The second and third phases were both completed in Chapter 5.

Following from this process, this chapter concludes this thesis by summarising the literature review findings in Section 6.2, delineating a number of limitations inherent in the research in Section 6.3, as well as providing recommendations for further research in Section 6.4. Section 6.5. provides the final concluding remarks for this thesis.

6.2 Summary of Main Findings

The objective of this section of the chapter is to briefly summarise the primary findings from the literature in terms of the seven research questions posed in Chapter 1 of this thesis. The findings are presented sequentially in association with each research question.

6.2.1 Primary Research Question

The primary research question, *R.1*, was comprised of a number of secondary questions. Therefore, the findings for each of the corresponding secondary questions together form the overall findings for this thesis.

6.2.2 Secondary Research Questions

- *R.2.1* — the characteristics of DSSs required in the context of wicked problem resolution in the literature was discovered by qualitatively analysing the features emphasised in the literature and grouping these together. The following requirements were discovered: participation and collaboration, conflict management, scenario exploration and situation analysis, reduction of cognitive load, transparency and accessibility of evidence, user interface and visual feedback, facilitation of organisational memory, flexibility of phases and iterations, reduction of erroneous logic, and decision analysis methods.

- *R.2.2* — presenting the essence of a procedural DSS for resolving wicked problems involved the synthesis of a model for this purpose by qualitatively analysing the sampled literature. The architecture consists of a repository for decision storage and retrieval; a virtual decision space for navigation through and exploration of the problem; decision tools for presenting, structuring, analysing, and simulating elements of the problem situation; and a user interface to display snapshots of the decision problem at a given point and at a specific level of analysis. The design and development process for such a DSS was argued to be evolutionary and participatory in nature, and the decision process was also classed as iterative. Finally, the organisational context was presented as being inquiring in nature, emphasising collaboration and holistic reasoning.

- *R.2.3* — the proportion of procedural v.s. substantive decision support in the literature was investigated by quantitatively analysing the literature to determine the variant of rationality employed in each study. It was found that procedural decision support was over five times more prevalent in the literature

- *R.2.4* — similarly, the types of wicked problems addressed by means of DSSs were discovered by codifying different categories of wicked problem in the literature, and simply determining the number of studies which fell into each category. Strategy and business decisions are the most common, followed by environmental and resource planning problems.

- *R.2.5* — the level of cognisance of wicked problems and their associated modes of IT-based support was determined by counting the number of articles published per five-year period between 1981 and 2015. The period with the greatest number of publications is 2005 - 2010, with almost half of all of the articles in the sample.

- *R.2.6* — prevalence of research designs and methodologies in the literature involved determining the number of studies that fell into each codified category. Empirical case studies are the most common research design and methodology.

6.3 Limitations of the Research

The objective of this section is to address and acknowledge the weaknesses inherent in this research that were outlined in Chapter 1. These limitations will be discussed in terms of the research design and literature sampling methods respectively.

6.3.1 Research Design

This thesis made use of a theoretical literature study in order to answer the research questions synthesised. The perspective employed in analysing the literature data was interpretive in nature rather than positivist or critical (Orlikowski & Baroudi, 1991). Two possible limitations arise from this fact.

The first limitation of utilising the aforementioned research design is inherent in the nature of non-empirical approaches for research, where sources are secondary in nature and therefore don't represent a first hand account of the phenomena under observation (Mouton, 2001). Consequently, results are plausibly not as reliable as they would have been if there had been primary sources of information in addition to the literature data (Babbie & Mouton, 2007). However, the objective of this study was to contribute to the theoretical landscape of DSSs for wicked problems with the goal of furthering development of the field, as argued by Webster & Watson (2002). The literature review, then, serves as the preliminary first step in the greater intellectual process of defining the field.

The second limitation of the research design refers specifically to the interpretive nature of the qualitative and quantitative methods employed in this thesis. Each set of analyses relied on interpretation and codification of the literature in terms of a concept analysis. Codification related to the different research designs and methodologies employed in the literature was performed in terms of the strategy outlined by Gonzalez et al. (2006). However, other codes related to the nature of wicked problems, their requirements, and procedural decision support were allowed to emerge organically from cumulative study of the literature. Hence, there is a degree of subjectivity inherent in the categorisation of all emergent themes that must be admitted. An attempt was made to circumvent a level of bias by utilising the non-discriminatory approach suggested by Gonzalez et al. (2006), where categories were not pre-empted prior to analysis of the literature or forced on any of the studies.

6.3.2 Literature Sample and Sampling

A number of issues are evident in the literature sampling strategy. The first issue is related to the criteria employed in the search for and final selection of the studies for the sample, specifically, the fact that only those studies explicitly addressing the notion of wicked or highly unstructured problems in DSS research and practice were included. Therefore, studies not making reference to decision support and wicked problems explicitly were excluded, meaning that a significant scope of actual wicked problems in the literature were not included in the sample. Therefore, the findings are only realistically applicable to contexts where there is cognisance of the wicked problem situation as being wicked in nature. For the scope of this thesis, however, it was considered infeasible to search the literature for all problems which are wicked regardless of how they are described.

The second limitation of the literature sample relates to its final size. Following the application of definitive criteria, an initial sample of over 100 studies was reduced to 35. This is problematic in terms of the reliability of results, although it is argued that a large proportion of patterns discovered in the literature were significant in terms of percentages. This is promising for further research which seeks to gather a larger collection of literature for analysis. Additionally, there is a slight increase in reliability of findings due to the homogeneity of the studies over a selection of attributes such as publication type and journal quality.

6.4 Future Work

There exist a number of opportunities for further research in the context of the research area. The first involves addressing the possible deficiency in sampling, where further research can be completed utilising a larger sample of literature selected by characteristics that suggest the wickedness of the problem situation as opposed to explicit recognition of the problem as wicked.

A second possible avenue for further work involves supplementing and triangulating the conceptual findings of this study by means of an empirical study. Such research could involve the investigation of procedural decision support in terms of stakeholders in the problem, as well as the organisational context in which the problem is embedded.

The final plausible opportunity for further research could address questions regarding the usability or suitability of procedural decision support for wicked problems in an empirical fashion. Such a study might involve the design development of a generic procedural DSS artefact and testing of the DSS by means of quantitative or qualitative surveys.

6.5 Overall Conclusions

In this thesis, a comprehensive literature study was undertaken in order to analyse and describe the nature of decision support for wicked problems, and to further elucidate the approach of procedural decision support in such contexts. A number of findings were presented that demonstrate the prevalence of procedural support in wicked problem decision support, and describe the essence of a general procedural DSS for wicked problem resolution. The advantages of such a DSS and its suitability for addressing wicked problems was also presented in the form of an integrated model.

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