The development of a fuzzy expert system to aid in the adoption and use of systems development methodologies

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Abstract

A topic of great interest to the field of information system (IS) development is the concept of systems development methodologies (SDMs) and their successful adoption by, and use in, an organisation. Therefore, there exists a need for the developing of software and tools to aid in the adoption and use of SDMs. The focus of this study was to develop a fuzzy expert system that could aid in the adoption and use of SDMs. The study will focus on those factors that influence the adoption and use of SDMs in an organisation, as well as those factors that influence the submitting of rules to a fuzzy expert system to aid organisations in the decision-making process. Due to the fragmented nature of the research available in the field of study, an intensive literature study was undertaken to obtain the available rules. After the rules were identified, the rules were summarised to form the foundation for the development model of the fuzzy expert system. The research design for the study identified the positivism philosophical paradigm as being the most applicable for this study. The research method that was found to be most applicable to the study was the design and creation research method, which was, therefore, employed to conduct the research. The data collection method that was used in the research design was the literature review, which formed the basis of the fuzzy expert system. The fuzzy expert system was developed in two different programming languages, namely FuzzyCLIPS and C#. The fuzzy expert system part of the system was developed in FuzzyCLIPS and the user interface was developed in the procedural language C#.

Keywords: Adoption; diffusion; fuzzy expert system; systems development methodologies (SDMs); use.

Opsomming

Een van die onderwerpe wat van groot belang is op die gebied van inligtingstelsel-ontwikkeling, is stelselontwikkelingmetodologieë en die suksesvolle aanneem en gebruik *daarvan in* 'n organisasie. Daar bestaan dus 'n behoefte aan die ontwikkeling van sagteware en hulpmiddels om te help met die aanneem en gebruik van stelselontwikkeling-metodologieë. Die fokus van hierdie studie was om 'n newelagtige-ekspert-stelsel te ontwikkel wat sou kon help met die aanneem en gebruiksproses van stelselontwikkelingmetodologieë. Hierdie studie sal fokus op die faktore wat 'n invloed sal hê op die aanneem en gebruik van stelselontwikkelingmetodologieë in 'n organisasie en sal die reëls in 'n newelagtige-ekspert-stelsel invoeg om organisasies te help tydens die besluitnemingsproses. Weens die gefragmenteerde aard van die navorsing beskikbaar op hierdie spesifieke gebied is 'n intensiewe literatuurstudie gedoen om die beskikbare reëls te bekom. Ná die reëls geïdentifiseer is, is die reëls opgesom om die grondslag te vorm vir die ontwikkelingsmodel van die newelagtige-ekspert-stelsel. Die navorsing wat vir hierdie studie gedoen is het die positivistiese filosofiese paradigma as die beste metode vir hierdie studie aangedui. Die navorsingsmetode wat vir hierdie studie die geskikste was, is die ontwerp-en-skep-navorsingsmetode en hierdie metode is gebruik om die navorsing te doen. Die data-insamelingsmetode wat gebruik is in die navorsingsontwerp was die literatuurstudie wat die basis van die newelagtige-ekspert-stelsel uitgemaak het. Die newelagtige-ekspert-stelsel is in twee verskillende programmeringstale ontwikkel, naamlik, FuzzyCLIPS en C#. Die newelagtige-ekspert-stelselgedeelte van die stelsel is in FuzzyCLIPS ontwikkel en die gebruikerskoppelvlak is in die prosedurele taal C# ontwikkel. Die newelagtige-ekspert-stelsel kon voorspel of 'n organisasie 'n stelselontwikkelingsmetodologie moet aanneem en gebruik.

Sleutelwoorde: Aanneem; diffusie; newelagtige-ekspert-stelsel; stelselontwikkelings-metodologieë; gebruik.

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IS	information system
IT	information technology
SDM	system development methodology

Chapter 1: Introduction

1.1 Motivation for the study

Of great interest to the field of information system (IS) development is the concept of systems development methodologies (SDMs) and their successful adoption and use in an organisation (Huisman & Iivari, 2006:29-30). Most of the literature on SDMs is fragmented, consisting largely of prescriptive and normative textbooks. Limited scientific studies have been done on the adoption and use of SDMs (Kautz *et al.*, 2004:1-2). Theoretical research in the field of IS development methodologies shows that a methodology should improve effectiveness of development (Vavpotič *et al.*, 2004:1-2). Further investigation has shown that such is not always the case, and that 60% of companies do not use SDMs (Vavpotič *et al.*, 2004:1). The reason for such a high percentage is that SDMs do not fit specific social, cultural, organisational, technological, task-related and environmental characteristics or factors.

As shown by Vavpotič *et al.* (2004:2-3) and Huisman & Iivari (2002a:141-142), the cultural and social factors that impact the development team of the organisation describe the coexistence of such factors and their impact on the developers. For better understanding and the improvement of the adoption and use of an SDM, the measurement of how appropriate the envisaged methodology would be in regards to the development team and the project is required (Vavpotič *et al.*, 2004:2-3). Equally important are those organisational, technological, task-related and environmental factors which have been described by Huisman and Iivari (2002a:137-138) and used with the previously mentioned factors to form an enlarged model of factors that affect the deployment of methodologies. The model or conceptual model describes the relationship between the factors and interaction with each other to describe or measure the adoption of SDMs.

1.2 Problem statement

Organisations need to select an SDM, based on an examination of the organisational needs. Despite the need for SDMs, there are a large number of methodologies available, so that evaluating and comparing different methodologies is difficult (Fitzgerald, 1994:691-693). This contingency in systems development methodologies makes the selection of the right methodology a challenging task (Fitzgerald, 1994:691-693). Therefore it is important for an organization to select the right SDM to fit the organisation, so as to enable it to fully utilise the methodology. Another crucial factor in successfully adopting and using SDMs is selecting the methodology based on the projects in the IS department.

The research into the adoption and use of SDMs is fragmented and only examines some of the factors that influence the adoption and use of methodologies. The importance of selecting the right methodology is based on those factors that influence its adoption and use, as well as on those that can contribute to both academic and commercial practitioners. The study aims to combine the fragmented research into an artefact that can help practitioners to evaluate whether or not to adopt and use an SDM.

The evaluation of adoption and use factors for an SDM will be aided by the use of a fuzzy expert system, which has been developed for the sole purpose of auditing an organisation and for making recommendations based on a knowledge base which is constructed of rules that will be gleaned from a literature study. The rules represent the findings of previous studies on the subject of SDM adoption and successful usage.

1.3 Aim and objectives

The aim of the study is to develop a fuzzy expert system, which will be able to advise an organisation on the adoption and use of an SDM suited to its needs.

The objectives of this research study are:

- to conduct a literature study to establish rules for the adoption and use of an SDM in an organisation;
- to convert the above-mentioned rules into a knowledge base on which the fuzzy expert system can base its decisions; and
- to develop and test the fuzzy expert system.

1.4 Methodology

For the purpose of the study, the philosophical paradigm of positivism, which underlines the scientific approach (Oates, 2006:286), will be followed in researching the different rules in the existing research that are needed to construct the knowledge base for the fuzzy expert system. The rules will be derived from the literature study and will enable the fuzzy expert system to make accurate and informed decisions. The design and creation of the fuzzy expert system will follow a method artefact approach (Oates, 2006:108).

According to Oates (2006:286), positivism, which underlines the scientific method, can be defined as a shared assumption about the nature of the world. The shared worldview is fitting to the research, because no empirical data collections or hypothesis tests characterise a purely scientific method. The literature study will survey the existing literature about SDMs and their adoption or use, from which it will extract rules that led to the successful adoption or use of the methodologies concerned.

Designing and creating artefacts, according to Oates (2006:108-109), results in the solving of intricate problems. An instantiation artefact will be constructed for the production of a working system that presents constructs, models, methods, ideas, genres and theories that can be implemented in an IS (Oates, 2006:108). The artefact, which will be a fuzzy expert system, will be constructed using a knowledge base that consists of the rules extracted from the literature study to do with decision making and support in the adoption and use of SDMs.

1.5 Conceptual framework

A conceptual framework has been devised for the information gathered in this study. The framework will help to explain the diffusion process with regards to the adoption and use of an SDM. Furthermore, the framework (see Figure 1.1) will allow for the organisation of the information relating to the different factors that influence the adoption and use of an SDM. The framework is based on Rogers' framework for the innovation–decision process (Rogers, 1995:162; Raghavan & Chand, 1989:81-90; Kautz & Larsen, 2000:12-16), as well as on the conceptual research model for the deployment of SDMs, as developed by Huisman and Iivari (2002a:136; 2002b:89). The conceptual framework will deliberate on the different factors that influence the adoption and use of SDMs.

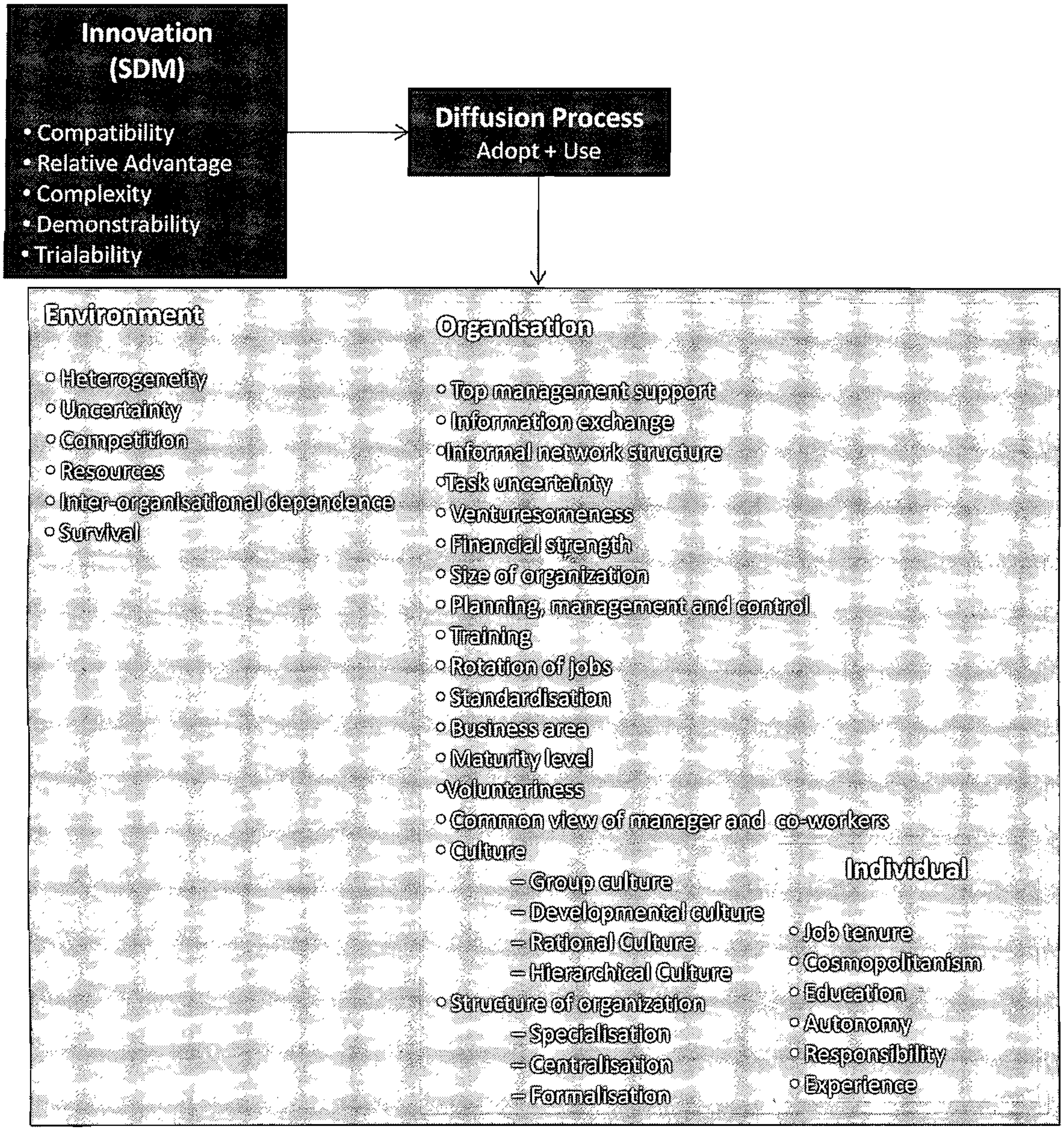

Figure 1.1: Conceptual framework

1.6 Fuzzy expert system

The main objective of the current study was to develop a fuzzy expert system that is capable of predicting whether or not an organisation is ready to adopt and use an SDM. The knowledge base of the fuzzy expert system was based on information gleaned from the literature.

Combinations of the two different SDMs namely that for the general development of a fuzzy expert system (Giarratano & Riley, 2005:359) and the linear model for developing such a system (Giarratano & Riley, 2005:374), were used to develop the fuzzy expert system. The best features of the SDMs were combined to create a new developmental methodology that was used for this study. The reason for developing a new methodology was to capture the best features of each methodology, and to choose the features that were applicable to this study.

The fuzzy expert system was developed in two different programming languages, namely FuzzyCLIPS and C#. The fuzzy expert system part of the system was developed in FuzzyCLIPS, with the user interface being developed in the procedural language C#. The fuzzy expert system portion of the system acts like a template. In other words, the fuzzy expert portion of the system is a fully working system, lacking the input added to execute the system. The user interface receives the user input from the user. Following this, the user interface copies the fuzzy expert system template and adds input at the end of the system for each new entry in the system. The user interface then executes the FuzzyCLIPS complier with the changed fuzzy expert system. After the fuzzy expert system has completed its execution, all of the results are written in a file, which is used by the user interface to display the results.

1.7 Outline of chapters

Chapter 1 provides the motivation, the problem statement and the objectives that were predetermined for the current study. This chapter gives an overview of the study.

The literature review that was conducted is described in Chapter 2, along with the conceptual framework. The method of how the study was conducted is deliberated in Chapter 3. The philosophical paradigm, research method, data collection and an introduction of the fuzzy expert system are deliberated on in the chapter. Chapter 4 describes the fuzzy expert system that was developed, and the method which was followed to develop the system. Chapter 5 concludes the study with the results, contributions, limitations and further research.

1.8 Summary

The development of tools and software aids professionals in the adoption and use of SDMs. Therefore, the focus of the current study is to develop a tool to contribute to the process. Chapter 2 provides a detailed description of the development of a fuzzy expert system that is capable of facilitating the adoption and use of SDMs.

Chapter 1: Introduction

Chapter 2: Literature review

In the IS field, one area of interest is the adoption and use of SDMs. SDMs can be defined as the totality of systems development approaches, including the process model, specified methods and specific techniques (Huisman & Iivari, 2002b:90). Research has shown that an SDM can improve the quality of the systems development process and the quality of systems developed in an organisation, if the SDM is implemented correctly and certain factors are taken into account (Burns *et al.*, 2008:394). The factors that influence the decision to adopt and use an SDM can be classified as follows: organisation; individual, environmental, and innovation. The factors will be dealt with in this chapter. Most of the research that has been conducted into the adoption and use of SDMs is focused on a segment of the factors, so that the outcome of such research is fragmented. An overview of the research that has been done to date in the field of SDMs is provided in this chapter, resulting in the production of a list of factors that might influence the decision to adopt and use an SDM in an organisation. These factors will then be used to build a fuzzy expert system.

2.1 Framework of the study

A conceptual framework has been devised to collate the data collected for this study. The framework will facilitate explaining the diffusion process with regards to the adoption and use of an SDM. Furthermore, the framework (see Figure 2.2) will allow for the organisation of the different factors that influence the adoption and use of an SDM. The framework is based on Rogers' framework for the innovation–decision process (Rogers, 1995:162; Raghavan & Chand, 1989:81-90; Kautz & Larsen, 2000:12-16), as well as on the conceptual research model for the deployment of SDMs, as developed by Huisman and Iivari (2002a:136; 2002b:89). The conceptual framework will allow for the discussion of the different factors that influence the adoption and use of SDMs.

Rogers' innovation–decision framework depicts five stages, consisting of knowledge, persuasion, decision, implementation and confirmation (see Figure 2.1) (Rogers, 1995:162-163; Raghavan & Chand, 1989:81-83; Kautz & Larsen, 2000:12). This framework has served as the starting point for research into information technology (IT) and ISs (Kautz & Larsen, 2000:12). Diffusion, according to Rogers (1995:10-11), is the process of communicating innovations to social systems, consisting of an information-seeking and processing activity (Kautz & Larsen, 2000:12). The diffusion process, as described by Rogers (1995:162), occurs in the following way. The decisions which are made about innovations are not made instantaneously, but are rather taken over time, including, as they do, certain actions and considerations. The decision making and other innovative stages are depicted in Figure 2.1. The knowledge stage occurs when an individual is exposed to an innovation for the first time. In this stage of the process, an individual becomes aware of the existence of an innovation and accumulates information pertaining to it. Persuasion occurs when the individual forms an opinion about whether the innovation is positive or negative. After forming such an opinion, a decision is taken that will result in either the adoption or rejection of the innovation concerned. If the decision is made to adopt an innovation, the implementation stage follows, in which the innovation is put into use. The final evaluative stage of the innovation–decision process involves the seeking out of confirmation to reinforce that the decision already made has been the correct one.

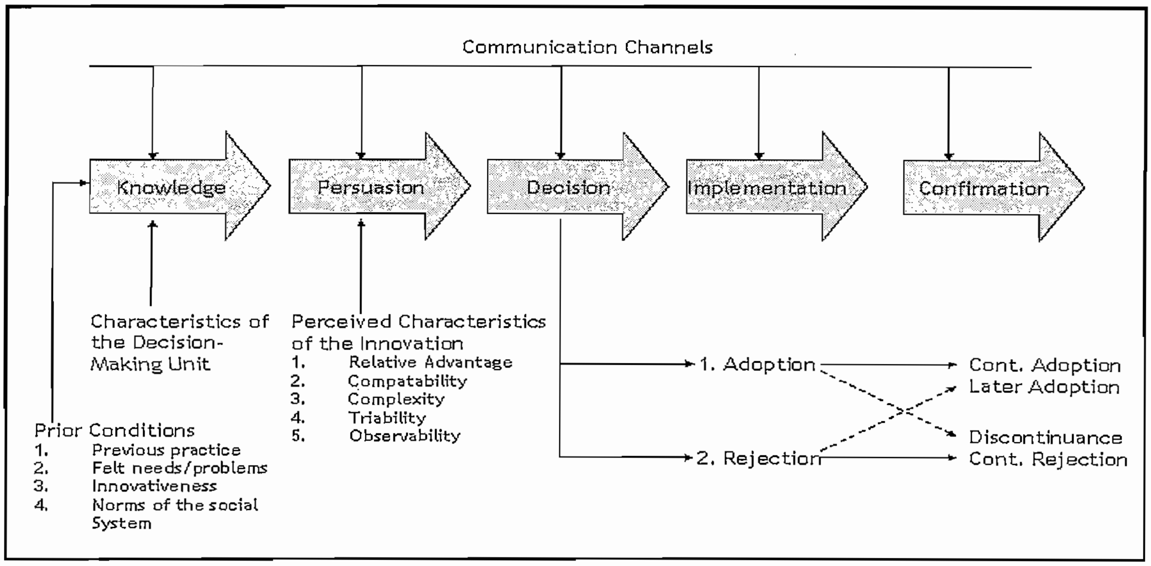

Figure 2.1: Innovation–decision process (Rogers, 1995:162)

Furthermore, Rogers (1995:10-23) has defined four key elements that influence the diffusion process: innovation; communication channels; time; and social systems. Innovation can be described as any idea, object or practice that is perceived to be new to an individual. Communication channels refer to the mediums used by individuals for participating in, and sharing information about, a new innovation, in an attempt to secure mutual understanding about the innovation concerned. The time dimensions describe the amount of time that an individual takes to pass through the stages of the innovation–decision process in order to adopt or reject an innovation. A social system consists of related units, which focus on solving problems by means of a joint effort which is exerted to accomplish the same goal. The decision-making process, as well as the four key elements listed above that play a role in the diffusion of an innovation, will be used to formulate the diffusion portion of the conceptual framework to be used in this study.

The conceptual framework (see Figure 2.2) starts with the innovation. An innovation is an idea, practice or object that influences the employees in an organisation to adopt it (Raghavan & Chand, 1989:83; Kautz & Larsen, 2000:12; Rogers, 1995:11). Furthermore, according to Jayanthi and Sinha (1998:472), an innovation is an idea that is perceived to be new to an organisation, although it might be an imitation of what already exists. In this study, the innovation studied is SDM. The characteristics of an innovation play a crucial role in deciding whether or not an organisation should adopt it (Kautz & Larsen, 2000:12; Jayanthi & Sinha, 1998:471-472). Five key characteristics that influence the rate of adoption of a new innovation, according to Rogers (1995:206-208), are relative advantage, compatibility, complexity, the ability to try out new innovations; and visibility (Raghavan & Chand, 1989:83; Kautz & Larsen, 2000:15; Rogers, 1995:206-208). The characteristics are enumerated in section 2.2.

In the conceptual framework (see Figure 2.2), becoming aware of an innovation is followed by the diffusion phase (see Rogers' decision–innovation framework, as depicted in Figure 2.1). The elements of the diffusion phase are based on the conceptual research model, which is used in the deployment of SDMs by Huisman and Iivari (2002a:136; 2002b:89). The elements are divided into different phases, which flow chronologically from one another.

The first phase is adoption, of which the primary goal is to decide whether to adopt or reject the new innovation, as well as to commit to the choice regarding the innovation (Jayanthi & Sinha, 1998:472; Raghavan & Chand, 1989:83). During this phase, the potential adopter learns about the innovation and its workings (Raghavan & Chand, 1989:83). After the relevant information has been analysed, the potential adopter either decides to continue with the diffusion process or to reject the innovation, and so terminate the diffusion process (Raghavan & Chand, 1989:83). The adoption phase that follows the becoming aware of an innovation is one of the main focus areas of this study and is influenced by those factors that are pertinent to the innovation.

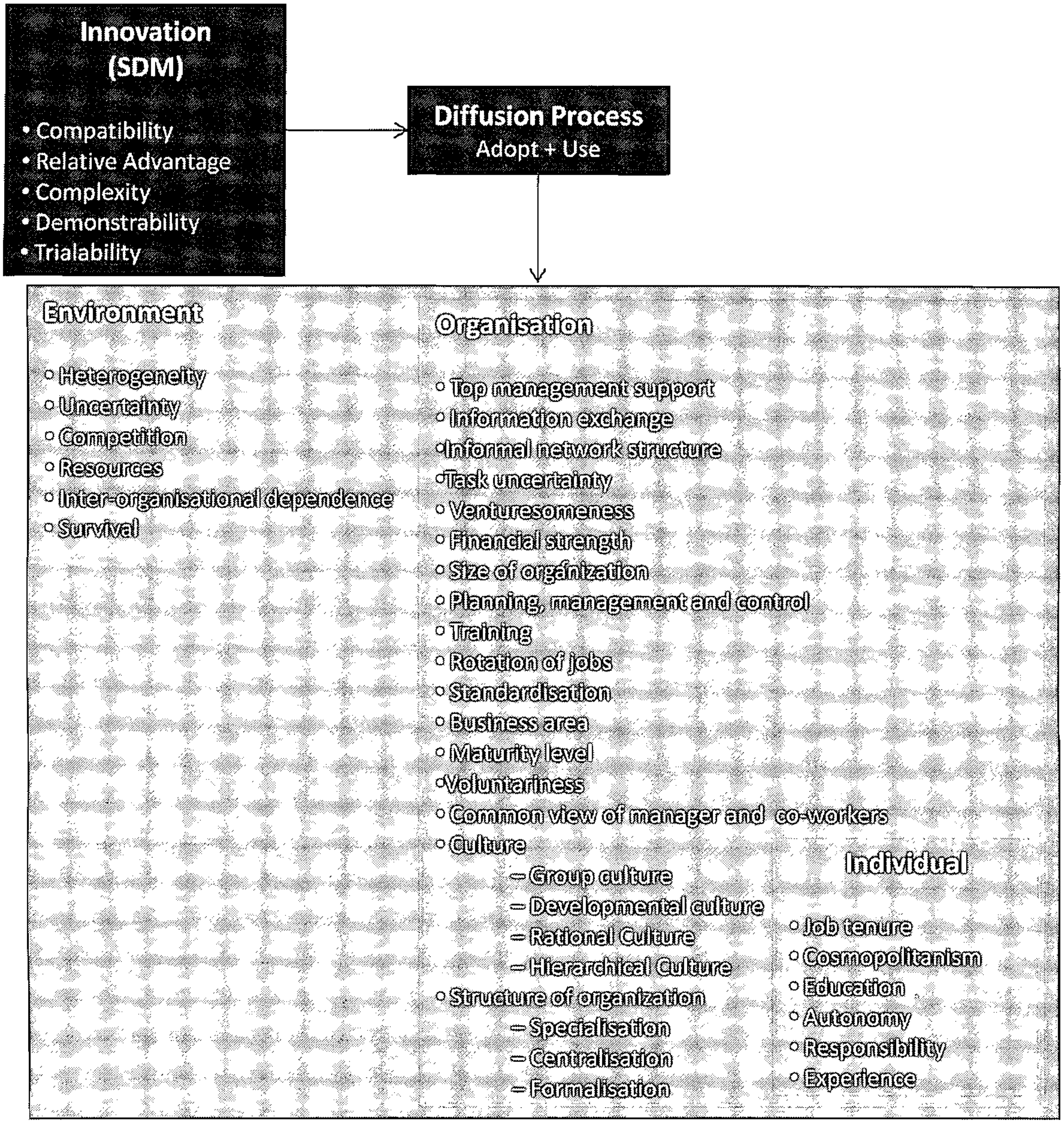

Figure 2.2: Conceptual framework

Subsequent to the formal adoption of the innovation, an organisation might have reservations about the use of such an innovation (Fichman, 1999:18). Thus, the post-adoption process affects the extent to which the technology is accepted in the organisation (Fichman, 1999:8-15). The use phase consists of two dimensions: frequency of use of the innovation, and the intensity of its use (Huisman & Iivari 2002a:136-138; Huisman & Iivari 2002b:90-92). The use of an innovation is the other focus area of the current study.

The *final* part of the conceptual framework (see Figure 2.2) consists of the adopting units and the environment in which such units function. An SDM is a continuous innovation, meaning that an organisation must first adopt an SDM before it is adopted by the employees in an organisation. For this reason, it is important that the study focuses on the two adopting units. Furthermore, the adopting units function in a specified environment that influences them. Due to such an influence, the characteristics of the environment must be taken into account in the study. Such characteristics influence the adoption and use of SDMs. The adopting units are both organisational and individual. The following sections of this dissertation will discuss the innovation characteristics; the organisational adopting unit; the individual adopting unit; and the environment.

2.2 Innovation factors (SDM characteristics)

An innovation is the idea, practice or object which will influence people in an organization to adopt these new ideas, practise or objects (Raghavan & Chand, 1989:83; Kautz & Larsen, 2000:12; Rogers, 1995:11). The adoption and use of an innovation depends on the factors of compatibility, relative advantage, complexity, demonstrability and trialability (Kautz & Larsen, 2000:12; Jayanthi & Sinha, 1998:471-472). The named characteristics are discussed in this section.

2.2.1 Compatibility

The compatibility of the innovation in terms of the organisation has a significant influence on whether the innovation is adopted (Bonner, 2008:53; Kwon & Zmud, 1987:237). Equally important is the compatibility of an SDM, which refers to its consistency with the developer's previous software development (Chan & Thong, 2009: 809). This factor, which is called the innovation's organisational 'fit', matters on both the organisational and the individual level (Kwon & Zmud, 1987:237; Ramiller, 1994:5). Furthermore, compatibility is the degree to which an innovation is consistent with the values, experiences and needs of an organisation, which impacts on whether the innovation is adopted (Huisman & Iivari, 2002a:138; Huisman & Iivari, 2002b:90; White *et al.,* 2007:76). Huisman and Iivari (2002a:138; 2002b:90) also describe the compatibility of an innovation and organisation as the 'fit' between the innovation and the adoptees, which implies that the innovation should match the context of the organisation to be successful (Huisman & Iivari, 2002a:147; Huisman & Iivari, 2002b:99).

At an individual level, the compatibility of an SDM is related to the perceived impact of the methodology on the development of a system and the development process (Huisman & Iivari, 2002a:138). Compatibility does seem to influence the individuals' compliance to the adoption and use of an SDM (Huisman & Iivari, 2002a:138). When methodologies are highly compatible with the developers' way of work, the individual can perceive the SDM as routine (Huisman & Iivari, 2002a:147). At an organisational level, compatibility describes the lack of gap between the social–technical systems structure and the way in which the structure can accommodate the innovations, which can also be referred to as the innovation's 'fit' to an organisation (Ramiller, 1994:5). If an innovation is compatible with an organisation, adopting such an innovation is likely to be more *profitable* for it (Kwon & Zmud 1987:237). Furthermore, the compatibility of an SDM has been shown to have a positive effect on the adoption and use of the methodology concerned. Such a finding is supported by Bonner's (2008:93) study, which concluded that compatibility positively affects individual competence. If a methodology is compatible with an organisation, those employees concerned should feel encouraged to use it (Bonner, 2008:70). Compatibility, accordingly, has a positive role to play in the adoption and use of SDMs.

2.2.2 Relative advantage

The perceived benefit that an innovation can provide to an organisation is called the relative advantage of the innovation (Bonner, 2008:53; Kwon & Zmud, 1987:237). Such costs and benefits can include economic, social and political legitimacy. According to Huisman and Iivari (2002a:141, 2002b:90) and White *et al.* (2007:76), relative advantage refers to the degree to which an innovation is better than the idea which it supersedes.

According to Kwon and Zmud (1987:237) and Bradley and Hauser (1995:161-163), the more relative advantage an innovation has for an organisation, the better are the chances of its adoption. Furthermore, in a study conducted to establish the relationship between relative advantage and individuals, relative advantage was found to relate positively to an individual's innovativeness (Karahanna *et al.,* 2002:336). The existence of relative advantage encourages individuals to be more open to the adoption and use of innovations. If an SDM provides an advantage for an individual, the individual is then prepared to use the SDM to gain the advantages of the use of such a methodology (Huisman & Iivari, 2002a:147; White *et al.,* 2007:76). Furthermore, an innovation is positively accepted in an organisation due to the relative advantage of the innovation for the organisation (Huisman & Iivari, 2002a:141; Huisman & Iivari, 2002b:99). Huisman and Iivari (2002a:141; 2002b:99) also found that a strong positive relationship exists between deployment and relative advantage with respect to the use and acceptance of an SDM in an organisation. Relative advantage encourages the adoption and use of an SDM in an organisation.

2.2.3 Complexity

Complexity refers to the degree of difficulty involved in understanding and using an innovation (Bonner, 2008:53; Kwon & Zmud, 1987:237). The likelihood of an innovation being adopted and implemented decreases if the innovation is too complex for the organisation concerned (Huisman & Iivari, 2002b:90; White *et al.,* 2007:76). If the SDM is perceived as requiring a lengthy learning curve by the adoptees, the SDM will, most probably, not be used (Huisman & Iivari, 2003a:59-60).

The difficulties experienced by the adopter and users have a negative effect on the adoption and use of an innovation. The more complex an innovation is, the more difficult it is for the organisation to adopt it (Kwon & Zmud, 1987:237). Huisman and Iivari (2002b:99) discovered that no significant negative relationship existed between the deployment of an SDM and its complexity. Furthermore, in Huisman and Iivari's (2003a:59) later study, they listed several factors, including complexity, that could negatively influence the adoption of an SDM. However, the study also showed that organisations tended not to find methodologies too hard or complex to understand (Huisman & Iivari, 2003a:59). In support of such an argument, Bonner (2008:69-70) found that the complexity of an SDM negatively affects individual competency. Accordingly, complexity negatively impacts on the individual use of an SDM (Bonner, 2008:69-70). Therefore, the complexity of an SDM, as perceived by an organisation, negatively affects the adoption of an SDM, requiring it, as an organisational factor, to be taken into account in the adoption and use of an SDM.

2.2.4 Demonstrability

Demonstrability refers to the visibility of the results of an innovation (Huisman & Iivari, 2002a:139). Furthermore, demonstrability can also be referred to as the signs of tangible advantage (Chan & Thong, 2009: 809). The easier it is to see the results of the use of an SDM, the easier it is for an individual to adopt such a methodology (Huisman & Iivari, 2002a:139). The results achieved in terms of demonstrability are the same as those achieved in terms of complexity, with it not having a significant effect on the individual in the adoption of a methodology (Huisman & Iivari, 2002a:147). Therefore, demonstrability will not be treated as a relevant factor in the adoption process in the current study.

2.2.5 Trialability

The trialability of an SDM is the degree to which a methodology can undergo experimentation on a trial basis (Huisman & Iivari, 2002a:147; Bonner, 2008:69-70). The more trialable a SDM is, the greater are the chances that it will be adopted (Huisman & Iivari, 2002a:147). Huisman and Iivari found that the trialability of an innovation relates positively to its adoption and use. In addition, White *et al.* (2007:76) found that trialability positively affects the adoption of an SDM. Trialability will be considered to have a positive effect on adoption of a SDM.

2.3 Organisational factors

According to Huisman and Iivari (2002a:141), an organisation consists of different influences and social groups that cooperate in achieving the organisational goals. Such influences and social groups can consist of top management, supervisors, peers and friends. In this study, such influences and social groups will be referred to as organisational factors. In this section, such factors are described in regards to the influence that they have on the adoption and use of SDMs.

2.3.1 Top management support

Top management support consists of the support provided by top management for the adoption and use of an innovation. Such support helps to ensure the successful implementation of an IS (Chen & Thong, 2009: 809; Kwon & Zmud, 1987:228; Bradley & Hauser, 1995:163). According to Roberts *et al.* (1998:644), an IS manager is one who is empowered with the responsibility for implementing an SDM. An IS manager who wishes to implement a new SDM should be directly involved with the implementation process (Roberts *et al.,* 1998:644). The lack of management support is considered as one of the major obstacles to the successful deployment of an SDM (Huisman & Iivari, 2002a:141). Such a lack of support has a significantly negative effect on the deployment of an SDM at an individual and organisational level (Huisman & Iivari, 2002a:147; Huisman & Iivari, 2003a:59-60). Furthermore, Huisman and Iivari (2002a:147) identified a positive relationship between top manager support and the deployment of an SDM, resulting in their conclusion that such support positively influences the use of SDMs. Managerial involvement encourages the adoption of a positive attitude among employees regarding their adoption, acceptance and satisfaction of the SDM concerned (Kwon & Zmud, 1987:234). Opinion leaders or authoritative individuals influence the diffusion of innovations and help to determine the outcome of such diffusion (Raghavan & Chand, 1989:85). The managerial support of SDMs is crucial to their successful adoption and use.

2.3.2 Information exchange among designers and users

Information exchange among system designers and users aids in the successful implementation of an IS (Kwon & Zmud, 1987:229). Such exchange includes consideration of the purpose, objectives, and impact of the system, aimed at helping both designers and users to reach a mutual understanding about the IS concerned (Kwon & Zmud, 1987:229). The SDM can be used for such an exchange (Kwon & Zmud, 1987:229-232). Bygstad *et al.* (2008:382), found in their investigation of the relationship between development methodologies and the usability of systems, that such usability was very important to organisations. Furthermore, they found that SDMs and system usability integrally contributed to the understanding of user requirements (Bygstad *et al.,* 2008:382). Information exchange among designers and users, therefore, is taken as positively affecting the adoption and use of SDMs.

2.3.3 Informal network structures

Informal network structures are viewed as the communication of innovations and information transfer, in which individuals communicate the idea of adoption among the adopters (White *et al.,* 2007:76; Kwon & Zmud, 1987:236). The existence of such a network is a key contributing factor to the diffusion of new innovations among adopters (Kwon & Zmud, 1987:236). To encourage understanding of an innovation among employees in an organisation, such a network can serve as a reliable and legitimate way in which to spread the word about the coming change among them (Kwon & Zmud, 1987:236). A positive association with adoption has been found in the adopters' behaviour if a change is communicated in such a way (Kwon & Zmud, 1987:236). In support of such an argument, Joshi *el al.* (2007:330) showed that knowledge transfer by means of frequent communication among developers positively affects individuals. Furthermore, the knowledge transferred from the team leader to the development team improves the visibility of team performance (Joshi *et al.*, 2007:330). The diffusion of innovation requires a communication channel that transmits information about innovations (Raghavan & Chand, 1989:83). The communication process used to communicate information about the innovations adopted, or the informal network, as indicated by Kwon and Zmud (1987:236), should consist of different users, potential adopters, and the communication channels, which will allow the relevant information to be spread throughout the organisation (Raghavan & Chand, 1989:83). The informal network structures which are in place to communicate information about innovations are taken as facilitating the adoption of an innovation.

2.3.4 Task uncertainty

Task uncertainty relates to the routine and programmable nature of the tasks that an organisation has to execute to complete its day-to-day functions as well as to conduct its decision-making activities (Kwon & Zmud, 1987:238). The more routine a task becomes, the more resistant to change individuals grow (Kwon & Zmud, 1987:238-239). The more routine the tasks, the easier it is to obtain satisfaction from the adoption of a new SDM.

However, due to resistance to change, such adoption remains problematic (Kwon & Zmud, 1987:238-239). In contrast, if the task at hand is difficult and breaks the routine, the individual concerned would most likely be motivated to initiate a solution for the problem (Kwon & Zmud, 1987:238-239). Therefore, task uncertainty can positively influence the implementation and use of an innovation if the difficulty of the task at hand precedes the normal activates of an organisation, especially in relation to IT (Kwon & Zmud, 1987:237). Task uncertainty, therefore, can have a positive effect on the adoption and use of SDMs.

2.3.5 Venturesomeness

Venturesomeness is the capacity of an organisation to foster the trying out of new and different things (Raghavan & Chand, 1989:84-85). Such an organisation usually falls into the early adopters' category, according to Rogers' innovation–adoption curve, which indicates the rate and stages at which an innovation is likely to be adopted in an organisation (Raghavan & Chand, 1989:84-85). The early adopters are those organisations that stand to profit from the innovation, which results in the facilitation and speeding up of the process (Raghavan & Chand, 1989:84-85). The venturesomeness of an organisation positively affects the adoption and use of an SDM.

2.3.6 Financial strength

Financial strength refers to the possession of extensive resources by an organisation. Financially strong organisations usually invest more in research and development (Raghavan & Chand, 1989:85). Such organisations are defined as early adopters in terms of Rogers' innovation–adoption curve, as they are likely to profit substantially from such a move (Raghavan & Chand, 1989:85). Financial concerns are important to an organisation considering the adoption of an SDM, especially considering the large amount of investment that such an adoption takes (Huisman & Iivari, 2003a:57). Investment in an SDM is long-term, whereas costs are inherently short-term (Huisman &

Iivari, 2003a:57-59). For such reasons, an organisation with a strong financial background is more likely to adopt a new SDM.

2.3.7 Size of the organisation

The size of an organisation refers to the amount of resources and the number of people in the organisation. (Raghavan & Chand, 1989:85). If an organisation is the largest in the marketplace, the chances of adoption increase dramatically, with the organisation concerned being classified as an early adopter, according to Rogers' innovation–adoption curve (Raghavan & Chand, 1989:85). Larger organisations tend to have more resources available for supporting the investment that is required for the adoption of an innovation (Rai & Howards, 1994:135; Rahim *et al.,* 1998:952). Rai and Howards (1994:143) indicate the positive relationship between the size of an organisation and the adoption of innovation (Rai & Howards, 1994:135). They found that the larger the firm, the more likely it was to adopt an innovation (Rai & Howards, 1994:135).

The size of an organisation refers to, among other factors, the number and amount of available resources (Huisman & Iivari, 2002b:92; Rahim *et al.,* 1998:952). Small organisations generally do not adopt SDMs because their IS departments are too small to execute the methodology properly (Huisman & Iivari, 2003a:57-58; Rahim *et al.,* 1998:953). In addition, Fitzgerald (1998:322) found that usage of SDMs were significantly influenced by the size of the organisation and the IS department. The study indicated that the larger the organisation and IS department the more likely it was that the organisation would use SDMs (Fitzgerald, 1998:322). Therefore, the size of the organisation is taken as playing a significant role in the adoption and use of innovations.

In contrast to the size of an organisation, Huisman and Iivari (2002b:99) found no relationship between the size of an IS department and the deployment of an SDM. Although a negative relationship was indicated between the size of an IS department and the use of an SDM, it was also found that the smaller the size of an organisation, the

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more likely it was to use the SDM (Huisman & Iivari 2002b:98-99). Although SDMs are usually developed for large IS departments, the use of innovations is usually the same throughout IS departments. The outcome of such innovations tends to increase the quality and productiveness of development in small IS departments (Huisman & Iivari 2002b:98-99). The larger an organisation is, the greater the positive affect tends to be on the adoption and use of SDMs.

2.3.8 Planning, management and control

Planning, management and control in IS projects has been found to play a significant role in the adoption of methodologies (Burkhard, 1990:419). Generally, planning tends to be a prerequisite for quality control in the development of an IS, but adopting a methodology might make planning mandatory (Burkhard, 1990:419-420). Organisations try to counteract industry and global economic pressures, with the objective of remaining competitive. Planning and control is one method of achieving such a goal (Burkhard, 1990:419).

The planning and management of an IS department tends also to be directed at preventing maintenance costs, which, on average, consume 80% of available resources (Burkhard, 1990:425). To achieve such goals, a methodology might help with the planning, management and control of an IS project, usually leading to the adoption of the methodology concerned (Grant & Ngwenyama, 2003:31; Burkhard, 1990:421-425). Furthermore, in a study conducted by Fitzgerald (1998:320), the results showed that SDMs were more used for corporate planning management and project control where the project development was to continue for a long time (Grant & Ngwenyama, 2003:31; Fitzgerald, 1998:230).

2.3.9 Training

A negative relationship between technology and innovations might be overcome by training, which is the formal procedure by which an organisation standardises the learning of its employees to ensure that the goals and objectives of the organisation are reached (Chan & Thong, 2009:809). The organisation might show a symbolic commitment to the use of innovations and technology by the training that it provides its employees (Rai & Howards, 1994:136).

An increase in the acceptance of innovations and the use of technology in organisations can be achieved by training designers and analysts (Bradley & Hauser, 1995:163). Such increased acceptance also helps the designers and analysts to learn skills and techniques for using the innovations more productively and for increasing the acceptability of the innovation (Rai & Howards, 1994:136). In addition, Huisman and Iivari (2003a:58), as well as Lee and Truex (2000:360-361), stipulated that formal training was essential and that a lack of software engineering methods or engineering tools training could lead to SDMs not being used in an organisation. Educating and training system developers in the new methodology to prevent the developers from reverting to the previous development practices should provide a good start for introducing and enforcing new SDMs in an organisation (Lee & Truex, 2000:360-361; Huisman & Iivari, 2006:41; Grant & Ngwenyama, 2003:31). Thus, training in the specific SDM is important and increases the chances of the methodology being both accepted and used by the system designers and analysts after the training.

2.3.10 Rotation of jobs or roles

The degree to which an organisation rotates job or roles in an information department impacts on the extent to which innovations are used (Rai & Howards, 1994:143). If individuals rotate job descriptions, they can develop an appreciation of the different tasks and functions in the information department and of the way in which they relate to each other (Rai & Howards, 1994:137). Developing such an appreciation might help the individuals in the organisation to be more open to change in respect of any organisational structure, such as the adoption of an innovation (Rai & Howards, 1994:137). Furthermore, the blending of job roles might diversify the degree to which an information department might be encouraged to specialise (Rai & Howards, 1994:137–138,143). Finally, individuals are more likely to be open to change, in that they will not feel as though their skills are obsolete and restricted and that they might be retrenched, due to their experience in other areas of the department (Rai & Howards, 1994:136-137). The rotation of jobs has a positive effect on the adoption and use of SDMs.

2.3.11 Standardisation

The implementation of SDMs aids in the standardisation of development and helps with system backlogs in an organisation (Roberts *et al.,* 1998:641). In standardising development, an organisation needs to implement an SDM (Roberts *et al.,* 1998:644). Such implementation would help an organisation to integrate business and IS design models (Roberts *et al.,* 1998:644). It would also allow for the successful use of automated tools for the development of the system (Roberts *et al.,* 1998:644). To improve the standardisation of systems development, an organisation should implement an SDM. The need for the standardisation of an organisation positively influences the adoption and use of SDMs.

2.3.12 Business areas

The type of business conducted has a significant influence on the IS structures used in an organisation (Huisman & Iivari, 2002b:97). Business areas include administrative services; manufacturing; finance\banking\insurance; retail\wholesale; and software housing\manufacturing (Huisman & Iivari, 2002b:91-92). The existence of such an influence is supported by various research studies, which have found that the financial sector in which the business is engaged has a significant influence on the IS operations concerned (Huisman & Iivari, 2002b:91-92; Rahim *et al.,* 1998:952). It was found that the nature of the business sector in which the organisation operates is significantly related to the use of systems development methodologies (Huisman & Iivari, 2002b:92). Fitzgerald (1998:230) agrees that the relationship between business areas and the use of SDMs is significant, with some business areas using SDMs more than others do (Fitzgerald, 1998:230).

Seyal *et al.* (2000:10) found that different business sectors have different uses for SDMs. Rahim *et al.* (1998:952) found that those government agencies that are involved in the administration and financial services sectors are major users of SDMs (Huisman & Iivari, 2002b:92). Furthermore, classifying the business areas of an organisation is important; as such classification affects the adoption of SDMs of each business area differently (Rahim *et al.,* 1998:952). The business area involved affects the frequency of use of SDMs (Huisman & Iivari, 2002b:99).

2.3.13 Maturity level

Paulk *et al.* (1993:20) define the maturity of an organisation as "the extent to which a specific process is explicitly defined, managed, measured, controlled, and effective." The maturity level of IS development in an organisation plays a role in the adoption and use of SDMs (Fitzgerald *et al.,* 2002:82; Huisman & Iivari, 2002b:92-93). According to Huisman and Iivari (2002b:92-93), an organisation can be at any one of a number of different levels of maturity, which impacts on whether the adoption and use of an SDM will be successful. If an organisation is in the initial level of maturity, it would be highly unlikely to be able to adopt and use and SDM, due to the lack of structure and planning (Fitzgerald *et al.,* 2002:82; Huisman & Iivari, 2002b:92-93; Huisman & Iivari, 2003a:58). As an organisation matures, the more likely it is that it will use an SDM (Fitzgerald *et al.,* 2002:83; Huisman & Iivari, 2002b:99; Huisman & Iivari 2003b:383). The maturity level of the organisation also influences the cultural factors in adoption, which will be discussed in subsection 2.4 of this dissertation. As has been indicated, the more mature an organisation is, the more likely it is that the organisation will adopt and use an SDM (Huisman & Iivari, 2007:39,46; Huisman & Iivari 2003b:383).

2.3.14 Voluntariness

Voluntariness is the extent of voluntary use and acceptance of an innovation, which indicates the free will to use it (Huisman & Iivari, 2002b:94; Huisman & Iivari, 2002a:141-142). In addition, voluntariness can also be described as the extent to which an innovation is perceived to be non-mandatory by its adopters (Chan & Thong, 2009:809). Voluntariness affects the degree of acceptance and use of SDMs at both the individual and the organisational level (Huisman & Iivari, 2002b:94). SDMs of which the use is not mandated by management are unlikely to be used, because the developers will not fit them into their schedules (Huisman & Iivari, 2002b:94; Huisman & Iivari, 2006:44). Thus, the factor requires consideration and plays a major role at organisational level in the use of an SDM, though its effect on the acceptance of a methodology is minimal (Huisman & Iivari, 2002b:99). Furthermore, Huisman & Iivari (2002a:147) found, at the individual level, that voluntariness has no influence on the adoption and use of an SDM. Accordingly, voluntariness is taken to have a positive effect on the adoption of an SDM.

2.3.15 Common view of managers and co-workers

A critical success factor for the implementation of SDMs is the view that is held in common by both managers and workers, which is also called perceptual congruence (Huisman & Iivari 2006:31). Perceptual congruence has a positive effect on an organisation regarding SDMs, as any uncertainty and ambiguity between individuals is then minimised (Huisman & Iivari, 2006:30). Equally important are the findings of Kautz *et al.* (2004:16), who say that such a view facilitates the use of SDMs. Furthermore, the developer's desire for involvement and cooperation with managers regarding SDMs promotes the use of the methodology (Kautz *et al.,* 2004:13). In conclusion, the view that is held in common by both managers and workers advances the adoption and use of SDMs.

2.4 Organisational culture

Two frameworks exist in terms of which the culture of an organisation can be measured, that of competing values and that of the dimensionalising of cultures, the latter of which can also be referred to as the Hofstede dimensions (Hofstede, 2009). The five dimensions of the latter are power distance; uncertainty avoidance; individualism versus collectivism; masculinity versus femininity; and long term versus short term (Hofstede, 2009). The competing value framework consists of four dimensions, namely group culture; developmental culture; rational culture; and hierarchal culture (Cameron *et al.,* 2006:46; Dastmalchian *et al.,* 2000:390).

As organisational culture can be interpreted as consisting of almost everything in an organisation, it can play a significant role in the adoption process (Fitzgerald *et al.,* 2002 114; Huisman & Iivari, 2007:36; Chen & Thong, 2009:809). This study uses the competing values framework, because such a framework is more applicable in the IS research field (Dastmalchian *et al.,* 2000:390-392). The dimensions of the competing value framework will be discussed in the next section of this dissertation.

2.4.1 Group culture

The group culture is primarily focused on human relations and flexibility (Huisman & Iivari, 2002b:93, Huisman & Iivari, 2007:37; Cameron *et al.*, 2006:41; Dastmalchian *et al.,* 2000:390). The core values associated with such a culture are those of the individual, trust and participation. Another aspect of the group culture consists of effectiveness, including the development of human potential and the commitment of the members of a specific IS department (Huisman & Iivari, 2002b:93, Huisman & Iivari, 2007:37; Cameron *et al.*, 2006:41; Dastmalchian *et al.,* 2000:390). According to the findings of Huisman and Iivari (2002b:99; 2007:47), the group culture plays no significant role in the adoption of SDMs. Group culture will, therefore, be treated as a neutral factor, with no significant influence on the adoption of SDMs.

2.4.2 Developmental culture

Developmental cultures focuses on what might happen in the future (Huisman & Iivari, 2002b:93, Huisman & Iivari, 2007:37; Cameron *et al.*, 2006:39-40; Dastmalchian *et al.,* 2000:390). The effectiveness aspect of such a culture includes an emphasis on growth, the acquisition of resources, the creative capabilities of individuals, and the adoptive aspects of the external environment (Huisman & Iivari, 2002b:93, Huisman & Iivari, 2007:37; Cameron *et al.*, 2006:39-40; Dastmalchian *et al.*, 2000:390). The developmental culture was found not to impact on the adoption and deployment of SDMs as drastically as was envisaged (Huisman & Iivari, 2002b:99). However, it was found that a positive correlation could be drawn between the developmental culture and the deployment of SDMs, though not systematically (Huisman & Iivari, 2007:42).

2.4.3 Rational culture

The rational culture emphasises individual achievement (Iivari, 2006:659; Huisman & Iivari, 2002b:93, Huisman & Iivari, 2007:37; Cameron *et al.*, 2006:42-43; Dastmalchian *et al.*, 2000:390). Focus areas of the rational cultures are the productivity and efficiency of the IS department, and the achievement of goals. The rational culture is very negative regarding the use and adoption of SDMs (Huisman & Iivari, 2002b:99). In a later study conducted by the two researchers (Huisman & Iivari, 2007:47), it was found that the rational culture is hostile towards the adoption of SDMs. Accordingly, the use and adoption of SDMs were found to be very negatively affected by a rational culture.

2.4.4 Hierarchical culture

A hierarchical culture emphasises the maintenance of security, order and routine in the workplace (Iivari, 2006:659; Huisman & Iivari, 2002b:93, Huisman & Iivari, 2007:37; Cameron *et al.*, 2006:37-38; Dastmalchian *et al.*, 2000:390). Hierarchical cultures follow rules and regulations to emphasise control, stability and efficiency. Due to the strong focus on rules and regulations for control and stability, this culture has a very strong positive association with the use and acceptance of SDMs in the adoption process (Huisman & Iivari, 2002b:99; Huisman & Iivari, 2007:47).

2.5 Organisational structure

2.5.1 Specialisation

Specialisation refers to the different specialists in an organisation and their fields of specialisation (Kwon & Zmud, 1987:235). Organisations might enhance technical specialities to facilitate the diffusion and use of innovations (Rai & Howards, 1994:135). Such enhancement promotes a positive atmosphere for the adoption and use of new innovations in the organisation (Kwon & Zmud, 1987:235). Although specialisation can increase that social and political conflict which leads to a negative association with the adoption, the overall conclusion is that specialisation encourages the adoption and use of innovations.

2.5.2 Centralisation

Centralisation refers to the degree to which an organisation emphasises its decision-making activities (Kwon & Zmud, 1987:235). In addition, centralisation is a drawback in terms of perspective and autonomy in the initiation and adoption of innovations. In contrast, in those situations where the right conditions prevail, centralisation can positively affect the adoption and use of innovation. The overall influence of centralisation on the adoption and use of innovations is negative, due to the fact that it only has a positive effect in specific situations, rather than in general (Kwon & Zmud, 1987:235).

2.5.3 Formalisation

Formalisation promotes functional differentiation, and is believed to create clear work definitions and procedures, but less autonomy (Kwon & Zmud, 1987:236). Although formalisation has negative associations in terms of the initiation of innovations, it has been found positively to influence the adoption and use of innovations (Kwon & Zmud,

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1987:235). If an innovation has been initiated, formalisation will help with the adoption of the SDM and its subsequent use.

2.6 Individual factors

Individual factors are those factors that influence the adoption and use of SDMs, in terms of the individual's level in an organisation or in the information department (Huisman & Iivari, 2002b:89). In section 2.6 those individual factors that influence the adoption and use of SDMs are discussed.

2.6.1 Job tenure

The legitimacy of an institution is generally related to job tenure (Kwon & Zmud, 1987:234). A positive relationship towards adoption can be expected, due to the increased levels of functional and political knowledge. Therefore, it is important to include consideration of those advantages that an individual receives from the organisation in regards to job tenure. Job tenure is, accordingly, viewed as having a positive influence on the adoption and use of SDMs.

2.6.2 Cosmopolitanism

Cosmopolitanism refers to receptivity to change (Kwon & Zmud, 1987:234). An increase in the number of outside contacts and the ability to adopt a broader perspective on professionalism and adoption leads to an increased adoption at the individual level. Also the cosmopolitanism of an individual refers to a point of view that extends beyond the immediate surroundings (Raghavan & Chand, 1989:83). Those individuals who may be considered as cosmopolitan are those who, due to their being supportive of the adoption of innovations, must be considered. Cosmopolitanism has a positive effect on the adoption and use of SDMs.

2.6.3 Education

The educational background of individuals, which enables them to understand change, usually supports the adoption and use of innovations (Kwon & Zmud, 1987:234). The possibility of implementing innovations in an organisation is influenced by the knowledge that individuals possess regarding such innovations (Rai & Howards, 1994:135). A good understanding of innovations can lead to a positive relationship with respect to the adoption of innovations (Rai & Howards, 1994:143). In addition, Grant and Ngwenyama (2003:31) found that educational levels facilitate the use of SDMs. In contrast, Huisman and Iivari (2002a:140,147) found that no relationship existed between the education levels possessed by individuals and the deployment of innovations. Despite such a finding, the education background of individuals will be acknowledged in this study, due to the views of Kwon and Zmud (1987:234) and Rai and Howards (1994:143), which stipulate that an increased level of education might be conducive to the adoption of SDMs. In addition, Grant and Ngwenyama (2003:31) found that the education level of individuals facilitates the use of methodologies.

2.6.4 Autonomy

An individual's control over their assigned task and their ability to execute the task on their own is known as their autonomy (Fitzgerald *et al.,* 2002:131; Bonner, 2008:71; Kwon & Zmud, 1987:238). The more that an individual trusts themselves to complete a task on their own, the more motivated and satisfied the individual tends to be (Bonner, 2008:71; Kwon & Zmud, 1987:238). A positive relationship has been found to exist between satisfaction and adoption concerning autonomy (Grant & Ngwenyama, 2003:31; Kwon & Zmud, 1987:238-239). Furthermore, a positive relationship between the compatibility of an SDM and autonomy has been found to lead to the use of SDMs (Bonner, 2008:71). If an individual feels that an SDM is compatible with their freedom, they are more likely to use the SDM. Autonomy can, therefore, be seen to have a positive effect on SDM use (Fitzgerald *et al.,* 2002:131; Bonner, 2008:71). Adopters rarely have complete autonomy over the adoption of SDMs in the workplace, as the management tends to make use of the SDM mandatory (Grant & Ngwenyama, 2003:31; Huisman & Iivari, 2002a:141). Even if a manager enforces an innovation and makes it mandatory, the individual's attitude to such an innovation plays an important role in its use, and can increase the costs and degree of resistance associated with the innovation (Ramiller, 1994:5). Therefore, due consideration should be given to keeping individuals motivated, as the boosting of individual autonomy should facilitate the adoption and use of SDMs.

2.6.5 Responsibility

Those individuals, who are in positions of power, such as in management, tend to possess a high degree of responsibility and self-worth (Fitzgerald *et al.,* 2002:131; Kwon & Zmud, 1987:238–239). The possession of such a high degree of individual responsibility allows the user to make decisions on his own and motivates the individual to accept change. The self-worth of an individual can also be described in terms of self-identity (Fitzgerald *et al.,* 2002:131; Kwon & Zmud, 1987:238-239), the possession of which might help the individual to feel more confident and motivated in the workplace. (Fitzgerald *et al.,* 2002:131). Therefore, giving responsibility to users facilitates their adoption and use of SDMs and promotes individual self-identification, which has a positive influence on the initiation of SDMs.

2.6.6 Experience

The experience of a systems developer can be defined as the prior technical knowledge that the individual possesses (Fitzgerald *et al.,* 2002:82; Chan & Thong, 2009:809). The experience of systems developers in an organisation influences whether the decision to adopt an SDM is positive or not (Fitzgerald *et al.,* 2002:82; Huisman & Iivari, 2003a:58-59). This is due to the fact that the organisation opines that experienced developers have enough knowledge and skill to be able to incorporate the SDM successfully (Fitzgerald *et al.,* 2002:82; Kautz *et al.,* 2004:15; Grant & Ngwenyama, 2003:31; Huisman & Iivari, 2003a:58-59) when it feels that there are sufficient experienced staff

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members in the IS department (Huisman & Iivari, 2003a:58-59). As a result, inexperienced developers are more likely to use SDMs to overcome their lack of experience (Fitzgerald *et al.,* 2002:82; Kautz *et al.,* 2004:15; Grant & Ngwenyama, 2003:31; Huisman & Iivari, 2002a:59-60). In accordance with the research, the systems developers' experience plays a significant positive role in the adoption and use of SDMs.

2.7 Environmental factors

The business environment in which an organisation finds itself can be classified in terms of two domains: that which sees the environment as the origin of information, and that which sees the environment as a stock of resources that can be accumulated, so that its influences are outside the control of the organisations (Kwon & Zmud, 1987:238). According to Kwon and Zmud (1987:238), environmental studies related to organisations are minimal. In the following section of this study, environmental factors that influence the adoption and use of SDMs by organisations will be discussed.

2.7.1 Heterogeneity

Heterogeneity refers to the number of competitors or similar environmental entities with which an organisation has to compete to gain an advantage in the environment (Kwon & Zmud, 1987:240). A positive relationship has been found between the initiation of innovations and the degree of heterogeneity in the environment. Accordingly, environmental contingency improves the likelihood of the adoption of an innovation, rather than inhibiting it (Kwon & Zmud, 1987:240). Heterogeneity, consequently, has a positive effect on the adoption of an SDM.

2.7.2 Uncertainty

Uncertainty refers to the degree of instability and turbulence in the environment to which an organisation is subject (Kwon & Zmud, 1987:240). The existence of a positive relationship between uncertainty and the adoption of an innovation has been found to be significant, due to the fact that an organisation feels that it needs to grow in order to survive. Furthermore, Huisman and Iivari (2002a:139) found that a negative relationship exists between the degree of uncertainty that is experienced in an environment and the adoption of an SDM. However, uncertainty is believed to stimulate the adoption of SDMs geared towards survival and growth (Huisman & Iivari, 2002a:141). Due to the lack of research that has previously been undertaken in the field, uncertainty will be considered in this study as an environmental factor which positively affects the adoption of an SDM.

2.7.3 Competition

The competition in an environment is related to the population present in the environment, as well as to the capacity of the environment to harbour competition (Kwon & Zmud, 1987:240). Such a factor is believed to increase the likelihood that an organisation will adopt an innovation (Kwon & Zmud, 1987:240). Therefore, competition is taken to play a positive role in SDM adoption.

2.7.4 Resources

Resources that are present in an environment are what keeps an organisation going. The extent to which the resources are spread evenly throughout the environment is called the concentration, or dispersion, of the resources (Kwon & Zmud, 1987:240). Resource concentration leads to an increase in the degree of learning in an organisation, which implies that it will be likely to try out new innovations to accumulate those resources that are available in the environment. A positive relationship has been found between the adoption of SDMs and resource concentration or dispersion (Kwon &

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Zmud, 1987:240-241). Consequently, the more resources that an organisation has available, the more likely an organisation is to adopt an SDM, Therefore, resources have been shown to have a positive effect on adoption.

2.7.5 Inter-organisational dependence

Inter-organisational dependence consists of the sharing of information and resources with another organisation (Kwon & Zmud, 1987:241). Such dependency fosters the adoption and initiation of innovation (Kwon & Zmud, 1987:240-241).

2.7.6 Survival

For an organisation to be able to survive, it must be innovative enough to ensure compatibility with its environment (Rai & Howards, 1994:135). Lack of innovation might, otherwise, lead to its customers switching to other suppliers (Rai & Howards, 1994:135). Due to the growing reliance of organisations on their IS departments, the instability of an environment does not have a major effect on the departments concerned. The need for an organisation to survive in a competitive marketplace means that it will be likely to be open to adopting innovations that will give it an edge over its competitors.

2.8 Summary

The findings of the literature study are summarised in Table 2.1, which indicates whether the factor concerned has a positive (+), a negative (–) or a neutral (neutral) influence on the adoption process. Chapter 3 will expand on the research design of the study.

Table 2.1.: Summary of findings of literature study

Innovation factors (SDM characteristics)	
1.	*Compatibility (+)*

2.	Relative advantage (+)
3.	Complexity (–)
4.	Demonstrability (not used)
5.	Trialability (+)
Organisational factors	
6.	Top management support (+)
7.	Information exchange among designers and users (+)
8.	Informal network structures (+)
9.	Task uncertainty (+)
10.	Venturesomeness (+)
11.	Financial strength (+)
12.	Size of the organisation (+)
13.	Planning, management and control (+)
14.	Training (+)
15.	Rotation of jobs or roles (+)
16.	Standardisation (+)

17.	Business areas (+)
18.	Maturity level (+)
19.	Voluntariness (+)
20.	Common view of managers and co-workers (+)
Organisational culture	
21.	Group culture (neutral)
22.	Developmental culture (+)
23.	Rational culture (–)
24.	Hierarchical culture (+)
Organisational structure	
25.	Specialisation (–)
26.	Centralisation (+)
27.	Formalisation (+)
Individual factors	
28.	Job tenure (+)
29.	Cosmopolitanism (+)

30.	Education (+)
31.	Autonomy (+)
32.	Responsibility (+)
33.	Experience (+)
Environmental factors	
34.	Heterogeneity (+)
35.	Uncertainty (+)
36.	Competition (+)
37.	Resources (+)
38.	Inter-organisational dependence (+)
39.	Survival (+)

Chapter 3: Research design

This study focuses on those factors that influence the adoption and use of SDMs in an organisation, as well as on which rules to enter into a fuzzy expert system to aid organisations in the decision-making process. Due to the fragmented nature of the research available in this specific field, an intensive literature study was undertaken to obtain the available rules. After the rules were identified, they were summarised as the foundation for the development model of the fuzzy expert system. In this chapter, the research design and method which were used in the execution of this study will be discussed.

The research design section will describe the philosophical paradigm that can be followed when doing research. The paradigms include those of interpretivism, critical research and positivism. After careful consideration of the latter, the paradigm was chosen for use in this study. Subsequently, the different types of research methods that support such a paradigm, including surveys, experiments and design and creation, are discussed. As the objective of the study is to develop a fuzzy expert system, the design and creation research method was chosen for use in the study. The rest of the section will cover the data collection method used, as well as the design and creation of the fuzzy expert system concerned.

3.1 Philosophical paradigms

The research paradigm is a set of shared assumptions, or a certain way of thinking about, the focus of the research (Oates, 2006:282). Furthermore, a paradigm is the belief and purpose that shapes the individual worldview (Njoman, 2001:17). In short, the research paradigm concerns itself with the communication of different shared visions and opinions, which will benefit both the research and creative knowledge acquisition (Oates, 2006:282). Different philosophical paradigms can be used to conduct research programmes, of which each has its own worldview and shared thinking, which reflects on different types of strategies that might be used to conduct research (Oates, 2006:282). The aim of the different philosophical paradigms is to identify and accept the most relevant research in the particular community in which the research projects are envisaged as being executed. The three paradigms of interpretivism, critical research and positivism, which were considered for this research, will be deliberated on in the following sections.

3.1.1 Interpretivism

A study conducted in the IS or computer science field that follows an interpretive research approach is concerned with the understanding of the social IS context (Oates, 2006:292; Njoman, 2001:19; Mingers, 2001:251), as well as with the relationship of the social context with the world environment in which it exists (Orlikowski & Baroudi, 1991:5). In other words, interpretivism is concerned with the social process by which ISs are developed, constructed and influenced in terms of their social setting (Oates 2006:292; Njoman, 2001:20).

An interpretive study neither seeks to prove a hypothesis nor to predict the understanding of phenomena, both of which are inherent to positivist research (Oates, 2006:292; Njoman, 2001:20; Orlikowski & Baroudi, 1991:5). Interpretivism merely seeks to identify, explore and explain the social settings and the factors of participation and independence of the social setting concerned (Oates, 2006:292). Furthermore, an interpretive study directly contrasts with descriptive studies (Orlikowski & Baroudi, 1991:5), due to the former's rejection of data relating to objects and factual accounts (Orlikowski & Baroudi, 1991:5). Instead, an interpretive study is directed towards the understanding of the social context by means of accessing the meaning that participants have in a specific social setting (Orlikowski & Baroudi, 1991:5; Mingers, 2001:251). Usually, interpretive studies investigate people and their perspective on the world around them (Oates, 2006:292). This research paradigm is used to foster an understanding of the unique context within which human beings interact with their world, as well as of how the perception of their world changes in keeping with different influences (Njoman, 2001:20). The shared worldview of interpretive paradigm possesses the following characteristics (Oates, 2006:292- 293; Klein & Myers, 1999:71-78):

- Multiple subjective realities: In terms of such realities, there is no single version of the truth, as different people, groups and cultures perceive the world around them in different ways, which are all regarded as the truth.
- Dynamic, socially constructed meaning: In terms of such meaning, the reality of an individual or group can only be accessed by social means, such as language, shared meaning and the shared understanding of reality, which differs over time and across groups.
- Research reflexivity: In terms of such reflexivity, researchers possess their own beliefs, values and actions, which will affect the research process. Researchers should be aware of the likelihood of such subjectivity, and be reflexive or self-reflective enough to acknowledge its potential effect on the research undertaken.
- Study of people in their natural social setting: In terms of such study, the research aims to study people in their natural world, rather than in terms of a simulated world. The adoption of the interpretivist approach means that the researchers involved risk imposing themselves on their natural world as outsiders in order to conduct the research concerned. The researcher should be aware of this aspect of the research process, and should try to conduct the research without imposing on the world of the subjects of his study.
- Qualitative data analysis: The analysis of qualitative data entails the researcher analysing the words that people use, including the metaphors that they use in their everyday conversations and the images that they construct.
- Multiple interpretations: The current research will find that there is no fixed explanation for the findings made in the study. Instead, there will be multiple

explanations for the study, with the researcher needing to discuss each of them and whichever explanation is most strongly supported by the evidence will be accepted.

3.1.2 Critical research

The critical research paradigm is a less well-known and less accepted paradigm, in comparison with the interpretive paradigm (Oates, 2006:296; Baroudi, 1991:6). The focus of this research is to identify power relationships, conflicts and contradictions occurring in the computer science and IS domain. Furthermore, the objective of the study is to empower individuals to eliminate the identified areas of concern, which are the source of alienation and domination (Oates, 2006:296; Baroudi, 1991:6; Orlikowski & Baroudi, 1991:6). The critical research protocol endeavours to evaluate the social realities that are under investigation and to attempt to transform them (Orlikowski & Baroudi, 1991:19).

That research which is executed within the critical paradigm assesses the social reality as it is created and recreated by individuals in their world, in a way that is similar to, and reflected on, in the interpretive paradigm (Oates, 2006:296; Baroudi, 1991:6). Critical research states that the reality of people is dominated by objects, and reflects on what individuals' experience, as well as on the ambit of the individuals' world. Interpretive research is criticised for not analysing the power and control element of the social settings of individuals (Orlikowski & Baroudi, 1991:19). The aim of the critical paradigm is to assess power relationships, conflict and contradictions, as well as to determine ways in which to eliminate such factors in the modern world (Oates, 2006:297; Baroudi, 1991:6). Furthermore, if a study is undertaken in terms of the critical paradigm, interpretation and understanding are insufficient (Orlikowski & Baroudi, 1991:19). The researcher should also identify and challenge positions of dominance in the world, in order to facilitate the making of assumptions regarding restrictions and unfair situations (Oates, 2006:297; Baroudi, 1991:6).

The following five themes are commonly found in critical research (Oates, 2006:297-298):

- Emancipation: The aim of critical research is to free individuals of the power that shapes organisations and society. The researcher does not just try to understand and explain the outcome of the study, but also endeavours to empower people to eliminate relationships of power and dominance.
- Critique of tradition: Critical researchers do not adhere to the status quo, but pose challenges and ask questions. The traditional managerial structure in an organisation consists of the manager as the leader and the employee as a mere tool in achieving the common goal. A critical research paradigm challenges such thinking, by arguing that the manager and employees share a common goal and that the power base of the relationship should be eliminated.
- Non-performative intent: The optimisation of productivity and profit that is attained by minimising the input so that the requirements of managerial efficiency and control are better met is rejected by the critical researcher.
- Critique of technology determinism: Technology, according to a critical researcher, has its own rules, to which the individuals and society concerned should adapt. Such rules enables those individuals who have invested in technology to gain power.
- Reflexivity: As with the interpretive paradigm, the critical paradigm questions the existence of objective, value-free knowledge, which is sought after in positivism. Research, in the case of the critical paradigm, is influenced by those individuals with power and a vested interest in the study. Critical researchers should state how the methods used and they themselves influenced the research. They need to keep in mind how the societal and organisational factors influenced them while they were conducting the study.

3.1.3 Positivism

The oldest of the three paradigms is positivism, which is also referred to as the scientific method of research, as it emphasises research into the natural science (Oates, 2006:283; Njoman, 2001:17-18). Such a paradigm is not suited to researching the social behaviour of people, nor to the interaction between the world and individuals, as occurs in the first two paradigms (Oates, 2006:283; Njoman, 2001:17-18). The scientific method has two basic assumptions, namely that the world is ordered and regular (not random), and that the world can be investigated objectively. In other words, a positivist paradigm describes nature, meaning that that research which is undertaken in respect of it is grounded on objective and factual accounts of that evidence which supports the study (Orlikowski & Baroudi, 1991:5).

To elaborate, such a paradigm is called positivist due to the scientific method used, which usually focuses on the conducting of experiments (Oates, 2006:286). However, in the computer science and IS world, experiments are not always feasible, so that the researcher has to resort to the use of other techniques for the collection of data (Oates, 2006:286). Those researchers who conduct research projects within the positivist paradigm assume that the world, as seen in terms of a specific project, is uniform (Oates, 2006:286; Njoman, 2001:17-18). The shared worldview of the positivist paradigm has the following characteristics (Oates, 2006:286; Lee & Baskerville, 2003:221):

- The world exists independently of humans: Aspects of the physical and social world can be studied, captured and measured, with the former being open to study without having to refer to the latter.
- Measures and modelling: By means of observations and measurements, the researcher produces a model of the working world.
- Objectivity: Researchers following the positivist paradigm should have a neutral presence in the world in which they are conducting the research, as well as be

objective about the research that they are conducting. The data that they collect should be independent of their own beliefs and values.

- Hypothesis testing: Empirical testing of the world is conducted in terms of theories and hypotheses, which are either confirmed or rejected.
- Quantitative data analysis: Such analysis requires the building of models for analysis in terms of mathematical and statistical precepts, which provide a logical and objective way of conducting research.
- Universal laws: Researchers strive to assert generalisations when working within a positivist paradigm. An objective of a positivist paradigm is to confirm the truth of universal laws and irrefutable facts, regardless of the researcher's presence.

The comparative evaluation of the three paradigms has enabled the positivist paradigm to be identified as the most suitable for use in the current study. The researcher's decision was influenced by the findings in the literature surveyed, as well as by the comparison of the three named paradigms. Most literature reviews, in contrast, reflect on surveys, hypothesis testing and empirical study methods, which are representative of the positivist paradigm. The domain of interpretive and critical research, which is focused on in terms of social research, was not found to be of relevance to this study. Therefore, the positivist paradigm was chosen, due to the fact that the objectives of the study are to produce an artefact, which will be instrumental in decision making regarding the adoption and use of SDMs.

3.2 Research method

Research methods are those approaches used to answer the questions raised by the researcher (Oates, 2006:35). One research question can usually be answered by using a single research method. The research method is usually employed to collect the empirical data or evidence in support of a study, as well as to draw conclusions for the research concerned (Oates, 2006:36). The different types of research methods associated with positivist research, consisting of surveys, experiments and design and creation, will be deliberated on in the following three paragraphs.

3.2.1 Surveys

The objective of a survey is to secure a common denominator in the data obtained from a large population of people, where the denominator will portray and standardise the results of the survey (Oates, 2006:93; Njoman, 2001:22; Pinsonneault & Kraemer, 1993:80; Palvia *et al.,* 2003:8). After the results have been standardised, the researcher needs to generalise them, in order to search for patterns in the data (Oates, 2006:93; Pinsonneault & Kraemer, 1993:80). Surveys can consist of various components, such as questionnaires, interviews, observations and documentation (Oates, 2006:286). The survey research method is mostly associated with the positivist paradigm, due to the search undertaken by the researcher for a pattern in the data (Oates, 2006:93). Surveys can also be used in critical and interpretive research (Oates, 2006:93; Palvia *et al.,* 2003:8). In the IS environment, surveys are widely accepted and used for conducting research.

3.2.2 Experiment

An experiment is a research method that investigates the cause and effect of a problem either to prove or to disprove a certain aspect of the problem by means of observation of the outcome of the experiment (Oates, 2006:127; Njoman, 2001:21; Pinsonneault & Kraemer, 1993:81). Such a research method forms the basis of positivist and scientific research paradigms (Oates, 2006:127; Pinsonneault & Kraemer, 1993:91). A researcher starts by formulating a hypothesis that needs to be tested. Subsequently, the researcher devises an experiment to test the hypothesis (Oates, 2006:127). The results obtained by means of observation and measurements are used either to prove or disprove the hypothesis (Oates, 2006:127; Pinsonneault & Kraemer, 1993:81). Such a process is usually repeated to prove that the same outcome is achieved, as well as to validate the results (Oates, 2006:127).

The following three factors need to be taken into account when conducting an experiment:

- Controls: Researchers need to identify the significant factors in an experiment, as the experiment might require the manipulation of conditions (Njoman, 2001:21; Pinsonneault & Kraemer, 1993:82; Palvia *et al.,* 2003:8).
- Identification of casual factors: Which factors are to be included in, or excluded from, the study requires defining prior to the experiment (Njoman, 2001:21; Pinsonneault & Kraemer, 1993:82; Palvia *et al.,* 2003:8).
- Observation and experiment: In order to be able to derive meaningful results from an experiment, the results must be observed closely (Njoman, 2001:21; Pinsonneault & Kraemer, 1993:82; Palvia *et al.,* 2003:8).

3.2.3 *Design and creation*

The designing and creating of a research method focuses on the development of ISs, which are referred to as artefacts (Iivari, 2007:42-43; Oates, 2006:108; Orlikowski & Iacono, 2001:121). The researcher endeavours to develop an IS knowledge system as an artefact, and to explore and exhibit the potential of the outcome of the study for the technological world (Iivari, 2007:51; Oates, 2006:109; Hevner *et al.*, 2004:82). Such artefacts should also contribute to the knowledge base, which is dependent on the role of the system in the IT environment (Iivari, 2007:45-46; Oates, 2006:109; Orlikowski & Iacono, 2001:122-123).

The different types of artefact that can be produced consist of the following:

- Constructs: Constructs are the vocabulary, such as that used in data flow diagrams, that is used in a specific IT domain to define problems and solutions (Oates, 2006:108; Hevner *et al.*, 2004:83).

- Models: Models are combinations of constructs that are used for problem solving and for developing systems, which are represented in the real world, such as use cases (Oates, 2006:108; Hevner *et al.*, 2004:83).
- Methods: Methods are the process stages and models that guide the development of software for solving problems in the IT environment of SDMs, such as information engineering (Oates, 2006:108; Hevner *et al.*, 2004:83-84).
- Instantiation: An instantiation is a fully operational computer-based system for implementing the model, method, ideas or theories that form the output of the research, and thus are the successful accomplishment of an operational system (Oates, 2006:108; Hevner *et al.*, 2004:84-85).

In the current study, the design and creation research method is used. Such a method was chosen due to the fact that the objective of the study is to develop a fuzzy expert system that facilitates the rules gleaned from the literature review. Furthermore, the extended objective of the study is to produce an artefact that will be instrumental in decision making regarding the adoption and implementation of an SDM. In addition, an instantiation will be produced, as the artefact to be developed will be a stand-alone, fully functioning computer-based IS, in the form of a fuzzy expert system, which is described later in the study

3.3 Data collection

The researcher endeavours, in this study, to formulate those rules that are required for building an expert system. The main focus of the study is to create an expert system, with the ability to use the said rules in decision making, as well as to decide whether or not to adopt and use an SDM in an organisation. The rules that form the knowledge base of the expert system will be reflected on later in the study.

To validate the study and to ensure its ability to reflect on real-life conditions, the rules concerned had to be collected from a reliable source. The source that was chosen consisted of those publications which had been produced by experts working in the specialised field of SDMs and which covered research conducted in real-life situations. The current publications relating to SDMs were found to have been produced in different expert areas. For this reason, a literature study was undertaken to summarise the contents of the existing literature, with the objective of compiling a relevant set of rules. Such rules will be used to develop a fuzzy expert system. The data collection method used for the study is a literature study, which is the basis on which the expert system will be developed.

3.4 Design and creation of the fuzzy expert system

As stated previously, the main focus of this study is to develop a fuzzy expert system which can facilitate decision making regarding the adoption of an SDM. The decision to develop a specific fuzzy expert system, rather than a conventional generalist system, is due to the fact that an organisation would have to be audited in order to gain information about it that would enable the making of an informed decision (Akoka & Comyn-Wattiau, 1996:362).

3.4.1 Expert systems

Expert systems, of which the goal is to solve complex problems in a narrow domain, are an area of artificial intelligence (Giarratano & Riley, 2005:2). They use extensive expert knowledge of the specific domain (Giarratano & Riley, 2005:5). Such use could be problematic, as it might compromise the knowledge base concerned (Giarratano & Riley, 2005:7). The problem domain is a specific problem area, whereas the knowledge domain consists of the expert's knowledge base, which is used to solve a specific problem. An expert system simulates the situation in order to solve the problem concerned. An expert system functions in terms of the knowledge base and the inference engine (Giarratano & Riley, 2005:6). The knowledge base consists of the rules that represent the knowledge of an expert in the specified domain. After the user inserts data into the expert system, the inference engine formulates conclusions, in terms of such rules. The inference engine represents the reasoning process that an expert might use to solve a systems problem (Giarratano & Riley, 2005:7).

3.4.2Fuzzy expert systems

As mentioned earlier, an expert system is a rule-based decision-making process, which is used by humans (Bizdoaca *et al.,* 2008:115). A fuzzy logic expert system is based on the same principles as those of a conventional expert system with advanced features (Duggal & Chhabra, 2002:180). The fuzzy logic expert system incorporates fuzzy logic with the rule-based decision-making capacity of a conventional expert system (Duggal & Chhabra, 2002:180). Fuzzy logic uses mathematical equations to solve real-world problems (Duggal & Chhabra, 2002:180).

Furthermore, the inexact nature of, or the uncertainty that exists in, the real world, is the reason why fuzzy logic is used in an expert system (Giarratano & Riley, 2005:261-262). Such a phenomenon is referred to as the fuzziness of those measures or rules that are used in an expert system (Badiru & Cheung, 2002:168). In mathematical terms, the fuzziness of a dataset can be described as the measure of the lack of distinction between the set and the complement of that set. The less of a distinction there is between the elements concerned, the fuzzier the measure becomes. In other words, it is the means of specifying how well an object satisfies a vague description or a set of uncertain rules that need to be satisfied (Giarratano & Riley, 2005:262, Russell & Norvig, 2003:526).

A fuzzy expert system uses the same basic functionalities as a conventional expert system, with the exception of the knowledge represented in the knowledge base (Duggal

& Chhabra, 2002:180). The rules that represent the knowledge in the knowledge base are used to examine the input criteria and to compare it with the desired criteria, as stipulated by the rules, after which the error between the input criteria and the desired target will be calculated, resulting in the solving of the membership functions. The area under the curve, between the error and membership functions, is calculated with the centre revolving around the overlapping areas of the functions, in order to produce values that are used as feedback for the system (see Figure 3.1). Such a process, which is called defuzzification, is used to calculate values and provides the feedback on certain rules of the expert system (Duggal & Chhabra, 2002:180).

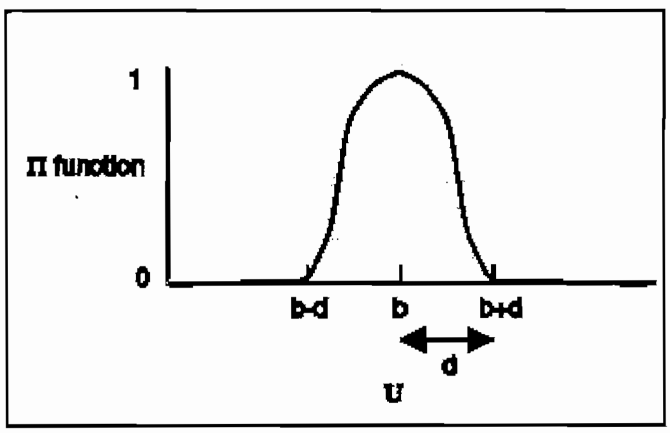


Figure 3.1: "Pi" graph (Orchard, 2004:28)

3.4.3 *Auditing process of the fuzzy expert systems*

The auditing of an organisation can be split up into the following steps, according to Akoka and Comyn-Wattiau (1996:362): the information acquisition decision; a design activity; an opinion decision or choice; and an action. The four advantages which are associated with the use of a fuzzy expert system in the execution of an audit are: a reduction in the amount of time required to specify a task; the improvement of the quality of decision making and control; the enhancement of the degree of expertise for recording the organisation's audit knowledge; and the improved educational possibilities for the audit employees. In accordance with the findings of the literature study, as well as for the above-mentioned reasons, as well as due to the fact that such fuzzy expert systems are only used by 9% of auditors, it was decided to use a fuzzy expert system for the purposes of this study.

Fuzzy expert systems generically consist of the following components (see Figure 3.2); (Giarratano & Riley, 2005:28; Badiru & Cheung, 2002:16-18):

- User interface: The user interface is the mechanism that allows the user to communicate with the fuzzy expert system.
- Explanation facility: The explanation facility explains the reasoning process of the fuzzy expert system.
- Inference engine: The inference engine makes inferences, by deciding which rules will satisfy the facts, or by prioritising those rules that are satisfied, executing them in order of prioritisation.
- Agenda: The agenda is a prioritised list of those facts that are satisfied in working memory.
- Knowledge acquisition facility: The knowledge acquisition facility is an automatic process, in which the system acquires information from users, rather than from experts coding the information in the system.
- Working memory: Working memory consists of a database that comprises facts that are used by the rules.
- Knowledge base: A knowledge base is a database made up of rules that use the facts.

The basic working of a fuzzy expert system is defined as follows (see Figure 3.2). The user uses the user interface to access the fuzzy expert system (Giarratano & Riley, 2005:28-29). The user interface consists of two categories: the knowledge acquisition facility, which receives user input, and the explanation facility, which provides the user with the results of the system. The inference engine uses the knowledge base, which consists of the rules, and the working memory, which consists of the facts. The inference engine tries to satisfy the rules, utilising the facts that have been gathered from the organisation. The outcome is the results that comply with the rules of the protocol that has been satisfied (Giarratano & Riley, 2005:28).

The rules, which formed the outcome of the extensive literature study, are the base of the knowledge engine of the fuzzy expert system. Furthermore, the information that has been gathered from the organisation will assimilate the working memory of the fuzzy expert system. The inference engine will use the knowledge base and the working memory in the decision-making process to determine whether the organisation is eligible for, and able to adopt, the SDM.

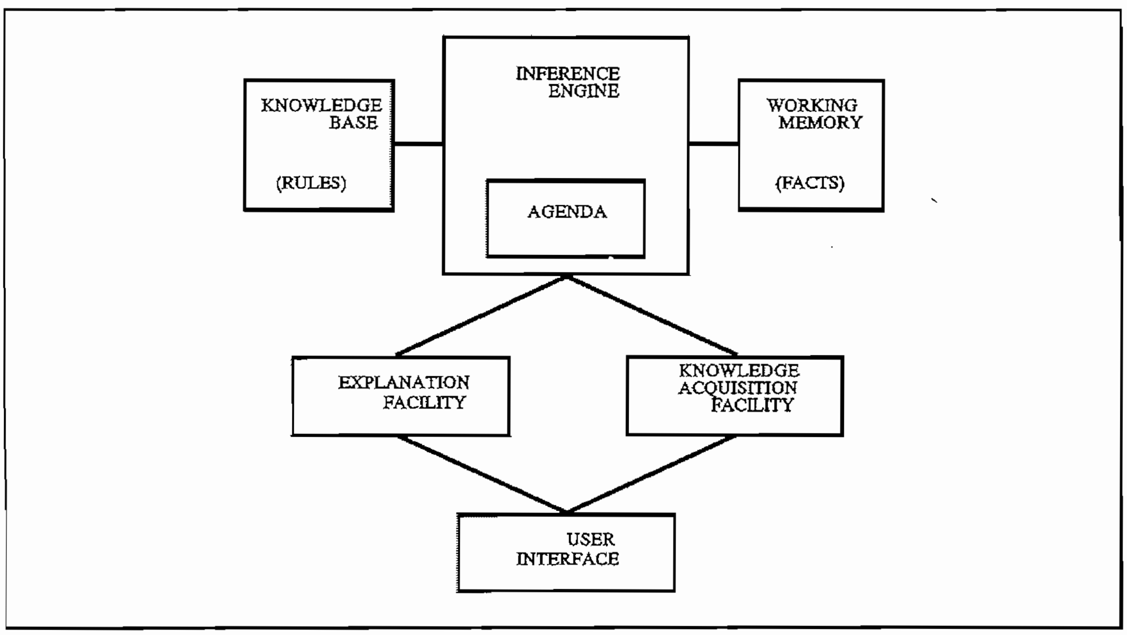


Figure 3.2: Structure of a fuzzy expert system (Giarratano & Riley, 2005:29)

The developing of the fuzzy expert system in this study followed two SDMs: the general development of, and the linear model for developing, an expert system (Giarratano &

Riley, 2005:359,374). The two methodologies were combined to formulate an SDM appropriate to the study. The development of the expert system will be discussed in full in the next chapter.

3.5 Summary

Figure 3.3 presents a summary of the contents of Chapter 3, which described the different philosophical paradigms applicable to the study. The positivist paradigm was identified, and therefore chosen, as the most appropriate and applicable for the study. The subsequent activity entailed the identification and evaluation of, as well as deliberation on, the different types of research methods that could support the positivism paradigm. The research method that was found to be most applicable for use in the study was that of design and creation, which was, therefore, used for concluding the research. The data collection method that was employed in the study directly resulted from the diverse and fragmented nature of the literature that had to be reviewed. Subsequent to the data collection, a detailed description with respect to the design and creation of the fuzzy expert system was deliberated on, resulting in recommendations being made as to the description and formulation of the fuzzy expert system. The next chapter will expand on the fuzzy expert system, and its development process.

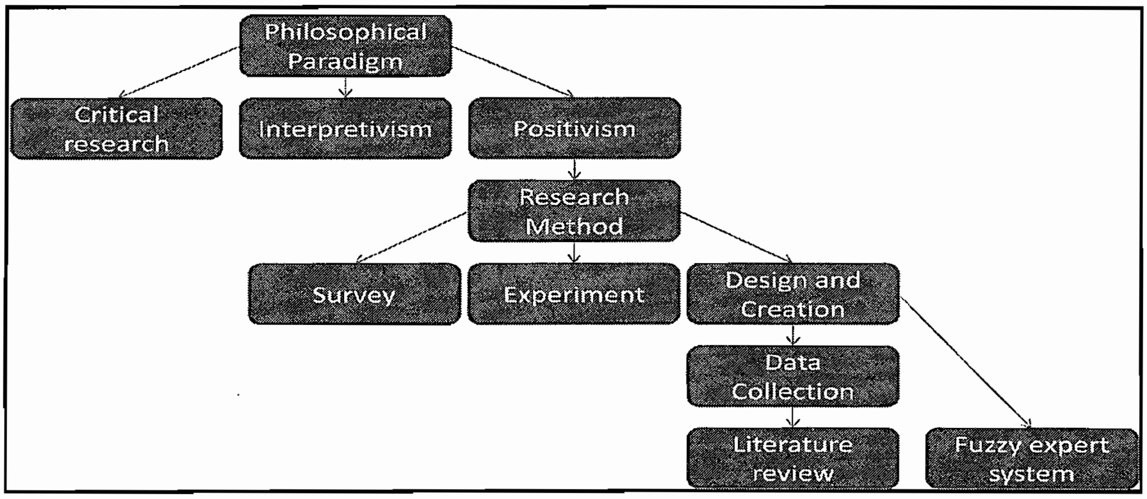


Figure 3.3.: Summary of contents of Chapter 3

Chapter 4: Fuzzy expert system

The main objective of the current study was to develop a fuzzy expert system that is capable of predicting whether or not an organisation is ready to adopt and use an SDM. The knowledge base of the fuzzy expert system was based on information gathered from the literature. Chapter 4 describes the developmental phases of the fuzzy expert system, as well as the working of the system.

4.1 Developmental methodologies

Combinations of the two different developmental methodologies were used to develop the fuzzy expert system. The SDMs were the general development of a fuzzy expert system (Giarratano & Riley, 2005:359), and the linear model for developing a fuzzy expert system (Giarratano & Riley, 2005:374), which will be described in the following section. After the theoretical background to the SDMs is described, their application will be discussed. The most outstanding features of the developmental methodologies were combined to create a new developmental methodology, which could capture the best features of each, and so allow for the selection of those features applicable to the study.

4.1.1 The general development of a fuzzy expert system

The general development of a fuzzy expert system (see Figure 4.1) consists of six phases: the feasibility study; the rapid prototype; the refinement of the system; the field testing; the commercial quality system; and maintenance and evolution, in that sequence (Giarratano & Riley, 2005:359).

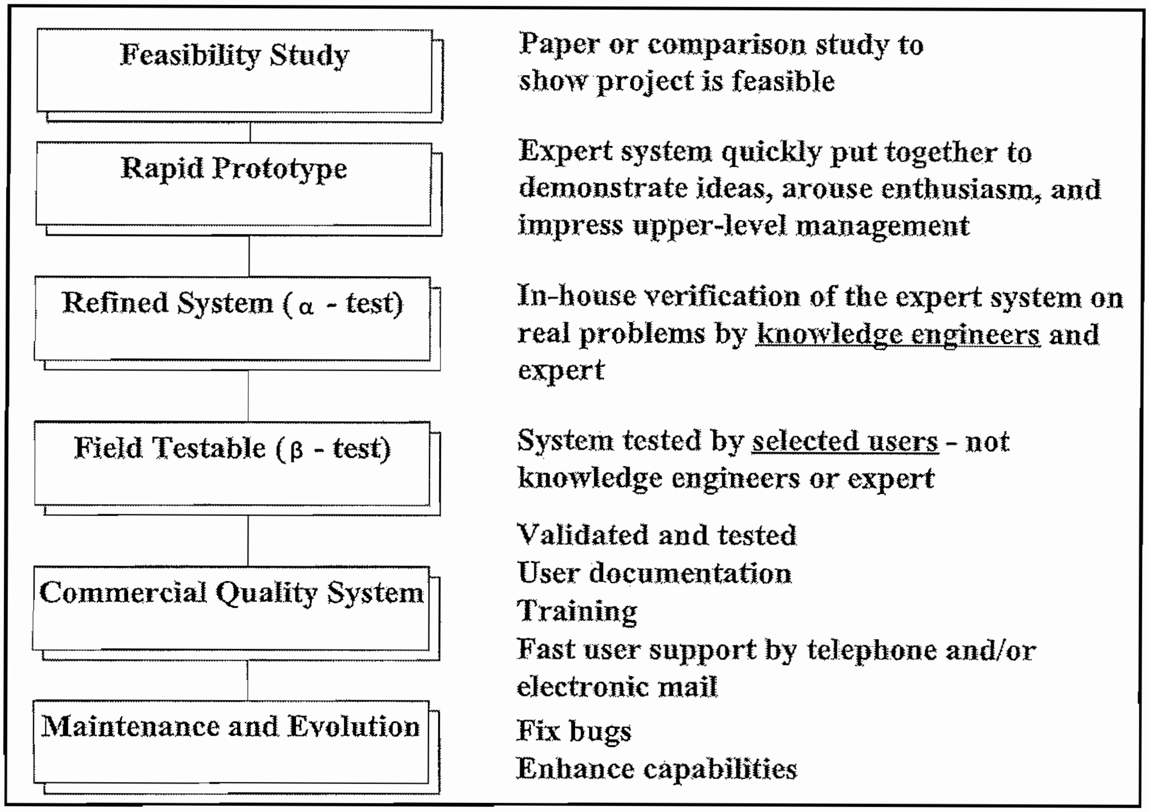


Figure 4.1: General development of a fuzzy expert system Giarratano & Riley, 2005:359)

The different phases of the methodology occur as follows (Giarratano & Riley 2005:358-362):

- ***Phase One: Feasibility study***

  The development and success of a fuzzy expert system depens on the source of knowledge concerned. If there is no knowledge available in the field of operation of the fuzzy expert system undergoing development, the system will not be successful. To prevent such an occurrence, a feasibility study is conducted to research the possibility of, as well as to establish the need for, developing a fuzzy expert system in a specific knowledge field. The output of this phase is a paper or comparison study, which indicates the feasibility of the study.

- ***Phase Two: Rapid prototype***

  Phase Two entails the development of a unit of the fuzzy expert system to demonstrate the concept behind the system. Developing a prototype can aid in determining whether the fuzzy expert system is likely to be a success. The prototype forms a platform, on which further development occurs. If the prototype succeeds, the complete fuzzy expert system is developed. If the prototype is not successful, the developmental methodology stops. The output associated with this phase is a quickly assembled fuzzy expert system, which demonstrates the concept concerned, arouses enthusiasm and impresses upper management.

- ***Phase Three: Refined system***

  During Phase Three, which is also known as the alpha testing phase, the fuzzy expert system is tested and refined. The test is conducted under experimental conditions. After the fuzzy expert system has been tested, the requisite refinements are reapplied and retested. Phase Three is executed until the fuzzy expert system is satisfactory. The output of this phase is a fuzzy expert system, which has been verified in-house by the relevant knowledge engineers and experts.

- ***Phase Four: Field testing***

  During Phase Four, which is also known as the beta testing phase, the fuzzy expert system is tested in real-life situations. If the system is unsuccessful, the necessary changes are then made, with the fuzzy expert system being retested until the system succeeds. The output of this phase is a fuzzy expert system, which has been tested by selected users other than the knowledge engineer and experts.

- ***Phase Five: Commercial quality systems***
  During Phase Five, the fuzzy expert system is, firstly, finalised, by means of verifying that the system is complete and fully functional. Secondly, the quality control checks are executed on the system. Finally, the system is commercialised. The output of this phase consists of the final fuzzy expert system, user documentation, user training and technical support.

- ***Phase Six: Maintenance and evolution***
  Phase Six consists of the monitoring of user feedback about the fuzzy expert system, which aids with the maintenance of the system and allows for the addition of any enhancements of the system that might be required. The output of the phase consists of patches for fixing bugs, or updates for enhancing capabilities.

4.1.2 The linear model for developing a fuzzy expert system

The linear model for developing a fuzzy expert system consists of six phases: planning; knowledge definition; knowledge design; code and checkout; knowledge verification; and system evaluation (see Figure 4.2). The model has the following milestones that must be reached by the end of each phase: the work plan; the knowledge baseline; the knowledge review; the preliminary data review; the knowledge system data review; the design baseline, the product baseline; the test audit review; and the final review (see Figure 4.2).

The developmental methodology combines the spiral, sequential and recursive process models. The different phases of the methodology are executed sequentially from planning to system evaluation, with each phase consisting of certain tasks that have to be executed. The phase will keep on executing until the tasks have all been completed. In general, the linear model for developing a fuzzy expert system only executes once. If it is necessary, all of the phases can start at the beginning, re-executing the methodology until the completion of the system. The developmental methodology was developed for the purpose of developing a large fuzzy expert system for commercial use. For smaller, research-type systems, such as that developed in the current research study, not all the phases and tasks need to be executed (Giarratano & Riley, 2005:375).

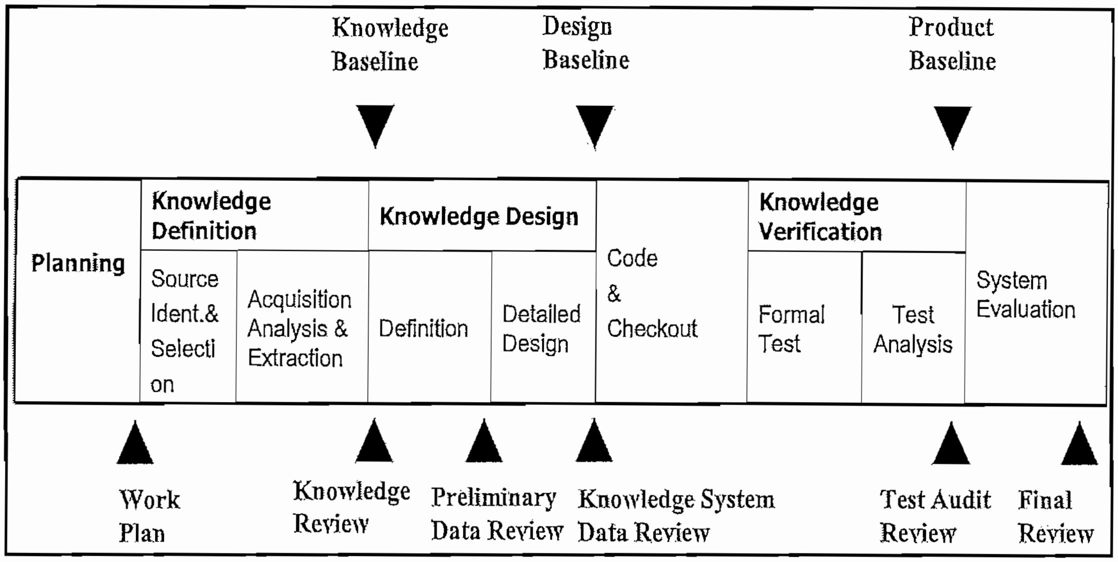


Figure 4.2: The linear model for developing a fuzzy expert system (Giarratano & Riley, 2005:374)

A discussion of the developmental methodology (Giarratano & Riley, 2005:375-380) follows:

- ***Phase One: Planning***

  Phase One of the methodology is the planning phase, which guides and evaluates the progress of the development of the fuzzy expert system. In addition, this phase ensures that a schedule is produced, with milestones to keep the development on track. The milestone for Phase One is a work plan, which facilitates the scheduling and evaluation of the development.

- ***Phase Two: Knowledge definition***

  Phase Two of the methodology consists of defining the knowledge requirements of the fuzzy expert system. The phase consists of the following two tasks: knowledge source identification, and knowledge acquisition, analysis and extraction:

  - *The source identification and selection task*

    The primary objectives of this task are to identify the source from which the knowledge will be obtained, as well as its importance, availability and selection.

  - *The knowledge acquisition, analysis and extraction task*

    The primary objectives of this task are to identify and classify the knowledge elements, as well as to identify the knowledge baseline.

  On completion of the two tasks, the milestones of knowledge baseline and review should be achieved, in order to verify that the knowledge is suitable for the next stage.

- ***Phase Three: Knowledge design***

  Phase Three produces a detailed design plan of the fuzzy expert system. The knowledge design that is produced facilitates the development of the system. Phase Three consists primarily of two tasks, knowledge definition and detailed design:

  - *Knowledge definition*

    The primary objectives of this task are to specify how the knowledge will be represented; to define the control structures in the fuzzy expert system; and to specify the structure of the internal facts, the preliminary user interface and the initial tests that need to be conducted.

  - *Detailed design*

    The primary objectives of the task are to specify the design structure and to define the implementation strategy, a detailed user interface, the reporting capabilities of the fuzzy expert system and a detailed test plan.

On completion of the phase, the milestones, consisting of the preliminary data review, the knowledge data review and the design baseline, should be reached. The reaching of such milestones ensures that the data have been correctly converted into knowledge, that the knowledge system truly represents the data, and that the design structure for the fuzzy expert system is complete.

- ***Phase Four: Code and checkout***

  The coding of the fuzzy expert system is implemented during this phase. The implementation of the code is followed by the testing of the system. Such testing includes the testing of the coding of the fuzzy expert system for programming errors. Such testing is done by implementing and testing the code, using the test data, drives and analysis. On completion of the testing, the fuzzy expert system should be error free. If the system passes the tests, the development of the system will move on to the next phase.

- ***Phase Five: Knowledge verification***

  The verification, correctness and consistency of the fuzzy expert system are determined during the knowledge verification phase, which primarily consists of the following two tasks, namely formal testing and test analysis:

  - *Formal testing*

    The primary objectives of formal testing are to irnplement the formal test procedure, and to document the test results.

  - *Test analysis*

    The primary objective of test analysis is to test for incorrect, incomplete and/or inconsistent answers.

  The testing done during the knowledge verification phase entails the production of the final product of the fuzzy expert system for the users. During this phase, the users use the system, and the feedback from the system is used for correcting it. The milestones accomplished as part of the phase include the test audit review and the product baseline. The attainment of such milestones facilitates the development of the fuzzy expert system, by resulting in the production of a document that elaborates on the audit review of, and produces a product baseline for, the fuzzy expert system.

- ***Phase Six: System evaluation***

  The purpose of this final phase in the creation of the SDM is to summarise the developmental process of the fuzzy expert system. The milestone for this phase includes the evaluation of results, the recommendations for the fuzzy expert system and the validation that the system is correct and complete.

4.1.3 Combined developmental methodology

The combinations of the previously mentioned developmental methodologies (see Figure 4.3) are discussed in this section. The general development of a fuzzy expert system and the linear model for developing fuzzy expert system methodologies are designed to facilitate the development of a large fuzzy expert system in large IS departments (Giarratano & Riley, 2005:359). Furthermore, the general development of a fuzzy expert system, and the linear model for developing fuzzy expert system methodologies, focuses on the commercial development and use of the fuzzy expert system. The fuzzy expert system developed in this study shows that a small system of this nature can be developed to facilitate the adoption and use of an SDM. It should be kept in mind that the system that was developed in this study was intended for research, rather than for commercial purposes.

The combined developmental methodology (see Figure 4.3) consists of the following *seven* phases, which were extracted from the previously mentioned developmental methodologies: the feasibility study; planning; knowledge definition; knowledge design; rapid prototyping; knowledge verification; and system evaluation, in that order. The methodology combines spiral, sequential and recursive methodologies. Each phase consists of primary tasks that the phase executes in order to attain the primary objectives. On completion of the phases of the methodology, the methodology can be re-executed from the first to the last phase, if necessary. The phases consist of the following:

- ***Phase One: Feasibility study***

  The purpose of Phase One is to determine the feasibility of a fuzzy expert system. Such a feasibility study indicates whether there is a demand for the fuzzy expert system in the specific knowledge area. Furthermore, the feasibility study, which is part of the general development of a fuzzy expert system methodology, aids in obtaining the objectives of the system. This phase forms the first phase of the combined methodology, ensuring that there is, indeed, a need for the fuzzy expert system developed in this study. As the linear model for developing a fuzzy expert system lacks such a phase, it was included in this study.

- ***Phase Two: Planning***

  Phase Two facilitates the formulation of the research proposal for the fuzzy expert system. The planning phase defines the objectives of the fuzzy expert system, the resources that are needed for the fuzzy expert system and the tasks that need to be undertaken. This phase constitutes part of the linear model for developing a fuzzy expert system, and was included in the combined developmental methodology to ensure that the fuzzy expert system was developed on time, with the appropriate milestones. The output of the phase is a work plan that indicates the schedule and the milestone in the development of the fuzzy expert system.

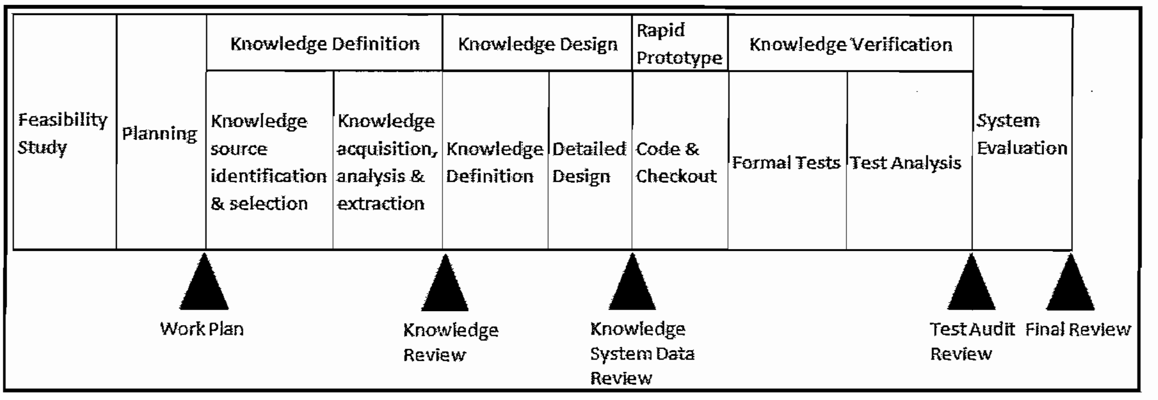


Figure 4.3: Combined developmental methodology

- ***Phase Three: Knowledge definition***

  The primary objective of Phase Three is to define the knowledge requirements. The phase consists of the following two tasks, namely the identification of the knowledge source and the selection and acquisition, analysis and extraction of knowledge, which are described below:

  – *Identification and selection of the knowledge source*

    The primary objective of this task is to identify the different types of sources of knowledge for the fuzzy expert system, as well as to select the appropriate sources. This task was included in the combined developmental methodology to ensure that there were enough sources gathered for the fuzzy expert system. The phase also facilitates in the validation of the different sources.

  – *Acquisition, analysis and extraction of knowledge*

    The primary objective of this task is to define and classify the knowledge element of the fuzzy expert system. This task was included in the combined developmental methodology to ensure that the knowledge gathered from the different sources was defined in terms of knowledge elements, and classified into the different knowledge categories.

  This phase was included in the combined SDM to ensure that the knowledge requirements were developed and followed. The output of this phase is the construction of the knowledge review, which ensures that the knowledge is suitable for the next phase.

- ***Phase Four: Knowledge design***

  Phase Four results in the production of a detailed design for the fuzzy expert system. The phase consists of two tasks, knowledge definition and detail design, which are described below:

  - *Knowledge design*

    The main objective of the task is to specify how the knowledge and the control structure of the fuzzy expert system will be represented in the fuzzy expert system. The task was imported, because the fuzzy expert system needed to be designed in advance, to ensure that all of the knowledge requirements were met.

  - *Detailed design*

    The main objective of this task is to design the control structure, a user interface and the reporting of the fuzzy expert system. This phase was included in the combined methodology in order to elaborate on the knowledge design. Performance of the task facilitates the technical design of the fuzzy expert system.

  This phase was included in the methodology to ensure that the design of the fuzzy expert system was complete prior to the coding of the fuzzy expert system. This phase facilitates the construction of a fuzzy expert system by producing a knowledge system data review.

- ***Phase Five: Rapid prototype***

  The main objective of this phase is to code the fuzzy expert system, which is done by developing a small portion of the fuzzy expert system, namely the prototype. After the prototype of the system has been developed, it is tested and updated until the prototype works. If the prototype passes the test, the next prototype is developed on top of the previous prototype, until the entire fuzzy expert system is developed. This phase, which was gleaned from the general

Chapter 4: Fuzzy expert system

development of a fuzzy expert system methodology, was combined with the code and checkout phase from the linear model in order to develop a fuzzy expert system. The reason for performing this action was due to the fuzzy expert system that was developed being only a small illustration of proof that a fuzzy expert system could, in fact, be developed for the study. Accordingly, prototyping was found to be an applicable developing method. The coding and checkout help to ensure that the fuzzy expert system has been tested and is functioning correctly.

- ***Phase Six: Knowledge verification***

  The main objective of Phase Six is to determine the correctness, completeness and consistency of the fuzzy expert system. The phase requires the performance of two tasks, namely formal testing and test analysis, as described below:

  - *Formal testing*

    The main objective of formal testing is to test the procedures of the fuzzy expert systems, as well as the correctness of the reports generated. The formal testing task is necessary to ensure that the coding of the fuzzy expert system is complete and correct.

  - *Test analysis*

    The main objectives of test analysis are to validate the results obtained so far. This task was included to ensure that the fuzzy expert system is tested on users, to ensure that the fuzzy expert system produces correct and complete results.

  Phase Six was included in the combined methodology to ensure that the fuzzy expert system was tested in full. Only the testing phase of the liner model for developing a fuzzy expert system was included in the combined methodology. The reason for such an inclusion was because the testing phase in the linear model for developing a fuzzy expert system already included all those testing phases which were required for the general development of a fuzzy expert system methodology. The output of this phase is the test audit review, which serves to verify that the fuzzy expert system is tested and working properly.

- ***Phase Seven: System evaluation***

  The purpose of Phase Seven, which is the final phase in the combined methodology, is to summarise the developmental process of the fuzzy expert system. The phase was included in the study to ensure that the objectives of the fuzzy expert system were reached. The output of this phase is the final review, which determines whether or not the objectives of the fuzzy expert system have been reached. In consideration of the time and scope of this study, only a technical testing of the system was undertaken.

4.2 The development of the fuzzy expert system

The development of the fuzzy expert system was aided by the combined methodology (see Figure 4.3), as has previously been mentioned. This section will describe how the fuzzy expert system was developed by means of implementing the combined methodology. The technical detail of the fuzzy expert system will be discussed in the next section of this dissertation. Each phase of the specific methodology will be described in regards to the fuzzy expert system, which was developed in this study.

- ***Phase One: Feasibility study***

  The feasibility study was conducted at the beginning of the study to introduce the study and to document the research proposal (see Chapter 1). The source of knowledge comprised the publications of experts in their fields of specialisation. Sufficient knowledge was found to be available for conducting the research study. The publications were gathered and analysed to extract that knowledge relevant to the research study (see Chapter 2).

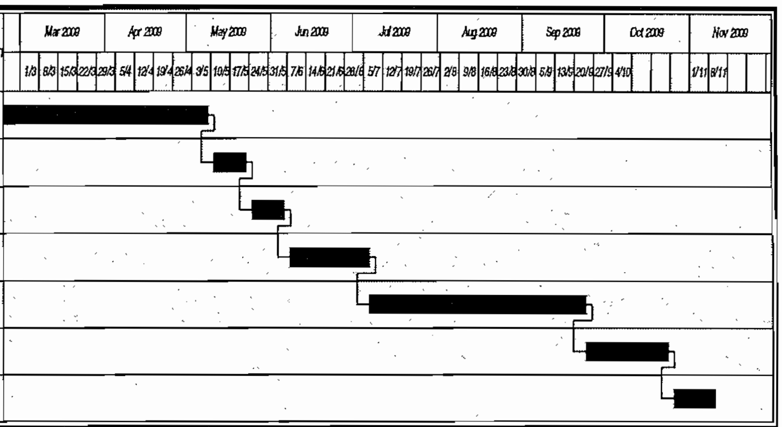
  The developmental tools, consisting of FuzzyCLIPS and Jess, which were required for the study, were then identified to ensure that software was available which could aid in the development of the fuzzy expert system. FuzzyCLIPS was chosen in preference to Jess. The procedural language required had to be identified in order to develop the user interface. After identifying the procedural language C#, it was used for the development of the user interface.

- ***Phase Two: Planning***

After the feasibility study was conducted, the planning phase began. The phase elaborated on the feasibility study by defining the aims and objectives of the study. Furthermore, the combined methodology was scheduled and planned (see Table 4.1).

Table 4.1: Planning of combined methodology

ID	Task Name	Start	Finish	Duration
1	Feasibility Study	23/02/2009	08/05/2009	55d
2	Planning	11/05/2009	22/05/2009	10d
3	Knowledge Definition	25/05/2009	05/06/2009	10d
4	Knowledge Design	08/06/2009	06/07/2009	21d
5	Rapid Prototype	07/07/2009	23/09/2009	57d
6	Knowledge Verification	24/09/2009	23/10/2009	22d
7	System Evaluation	26/10/2009	09/11/2009	11d



- ***Phase Three: Knowledge definition***

The knowledge definition phase defined the knowledge requirements. This phase was executed in the form of two tasks, namely the identification and selection of the knowledge source and the acquisition, analysis and extraction of knowledge.

 – *Identification and selection of the knowledge source*

To ensure the validity of the knowledge used in the fuzzy expert system, the online journal articles of experts in their fields of specialisation were used. The articles used presented data from real-life situations and were used for the gathering of knowledge relevant to the study. The articles were accessed through several different databases and search engines, including EBSCO Host, Science Direct, ISI Web of Knowledge, Scopus and Google Scholar. The keywords used in the databases and search engines to search for relevant publications included: "system development methodologies", "adoption", "use", "diffusion", "innovation", "developmental methods", "influences", "individual factors", "organisational factors", and "environmental factors". Once the results of such searches had been analysed, knowledge relevant to the study was gleaned from the relevant articles (see Chapter 2).

– *Acquisition, analysis and extraction of knowledge*

The articles that were chosen for the gathering of knowledge relating to the fuzzy expert system were analysed to search for relevant elements. The relevant knowledge was extracted from the articles, with the knowledge elements being documented in the literature review (see Chapter 2). The knowledge elements were categorised in the literature review in terms of the following categories: innovation (SDM); organisational factors; individual factors; environmental factors; and adopting units. The conceptual framework used in this study for the categorisation of knowledge elements is shown in Figure 4.4.

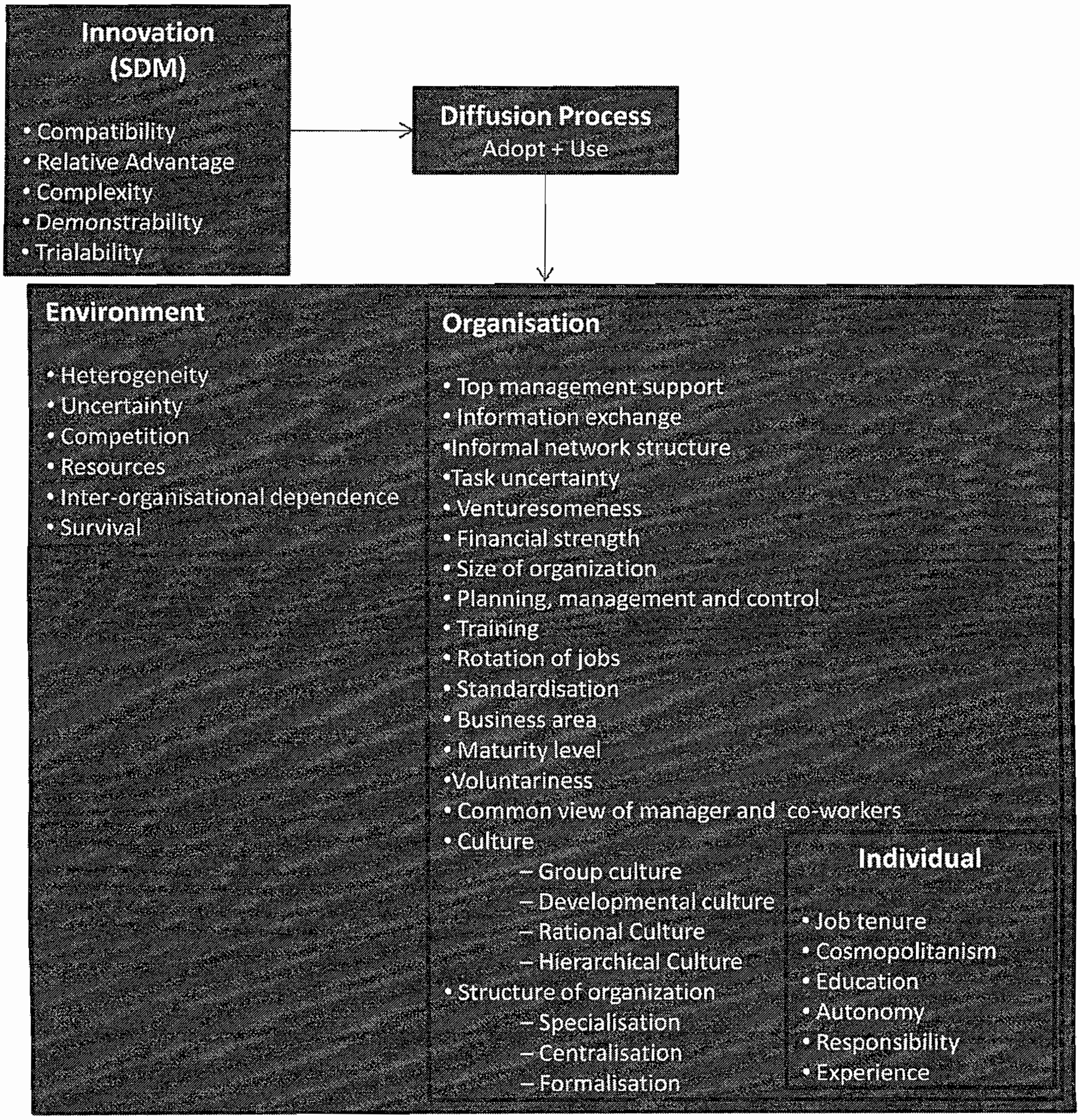


Figure 4.4: Conceptual framework

- ***Phase Four: Knowledge design***

The main objective of Phase Four is to produce the detailed design of the fuzzy expert system. The two primary tasks in this phase are those of knowledge definition and detailed design.

  - *Knowledge definition*

The knowledge representation of each knowledge element was determined as follows. It was decided that each of the knowledge elements would form a fact for the fuzzy expert system. Furthermore, each fact would have a deftemplate, which would transform the fact into a fuzzy rule for the fuzzy expert system. The deftemplate calculates the value of the knowledge element on a scale of 1 to 10. In addition, each knowledge element would have three defrules to represent the scale. The defrules were "not supported", "fairly supported", and "strongly supported". The defrules and deftemplates will be discussed in full, with examples, in the next section of this dissertation.

The control structures of the fuzzy expert system consisted of a deffunction for each knowledge element. After calculating the impact of the specific fuzzy rule on the total score of the system, the deffunction added the score to the appropriate category's total score. Each category was assigned its own defrule, which calculated the impact of that category on the total score of the system. The total score of the system also had its own defrule assigned, which calculated the total score of the fuzzy expert system. Furthermore, a defrule, defuzzification, was incorporated to govern all of the deftemplates, rules and deffunctions of the fuzzy expert system. The defuzzification rule controlled the entire fuzzy expert system. The defuzzification and deffunction will be discussed in full, with examples, in the next section.

A procedural programming language was used to develop the user interface as part of the control structure. The procedural language controlled the user input for each knowledge element and displayed the results of the fuzzy expert system. In terms of such functioning, after the user has entered the input in the system, the user interface gives control to the fuzzy expert portion of the program. The fuzzy expert then calculates the results and gives the control back to the user interface. The user interface can then display the results that the fuzzy expert system has calculated. The user interface will be discussed in full, with examples, in the next section.

– *Detailed design*

During the detailed design, the knowledge representation, control structures, user interface and reporting of results were designed. These aspects will be explained in full, with examples, in the next section.

- ***Phase Five: Rapid prototype***

During Phase Five, the fuzzy expert system was developed by means of the construction of a series of prototypes and the testing of the prototypes. Each prototype was constructed on the basis of the previous prototype, expanding the previous version of the fuzzy expert system. The first few prototypes were used for constructing the fuzzy expert system. The development of the user interface followed on the construction of the system. The subsequent prototypes focused on communicating with the fuzzy expert system portion of the system and on receiving user input. After the user interface was enabled to receive user input, the development focused on representing those results which were calculated by the fuzzy expert portion of the system. After the construction of each prototype, testing was done to ensure that the system worked properly. The testing undertaken during this phase was only to ensure that the coding of the fuzzy expert system worked correctly.

- ***Phase Six: Knowledge verification***

During Phase Six, the correctness, completeness and consistency of the fuzzy expert system was tested. The phase requires the performance of the following two tasks: formal testing and test analysis, which are described below:

– *Formal testing*

In order to test the fuzzy expert system formally, artificial values were input into the system. The results of the artificial values were known and verified, with the results that the system produced. Following such a procedure ensured that the entire system was tested to verify that the output of the system was correct. If the test indicated the existence of problems in the system, the rapid prototyping phase was re-executed to correct such problems. Once the problems were corrected, the knowledge verification phase started again. Such testing, which is called alpha testing, was undertaken by the researcher.

– *Test analysis*

The test analysis task tested that the fuzzy expert system did not produce incorrect, incomplete and/or inconsistent answers. This testing, which is called beta testing, was undertaken by various users of the fuzzy expert system other than the researcher. Such users included the students and lecturers concerned. If the test indicated that there were problems in the system, the formal testing task was re-executed. If the formal testing task found the same problems again, the rapid prototype phase was re-executed to correct the problems, with the knowledge verification phase being re-executed from the start.

- ***Phase Seven: System evaluation***

The summary of the development of the fuzzy expert system is documented in Chapter 5, which describes the aims and objectives of the study, as well as which of the objectives were attained in the study. Furthermore, the chapter describes the results of the study, further research that can be conducted and the limitations of the study.

4.3 Description of the fuzzy expert system

The fuzzy expert system was developed in two different programming languages, namely FuzzyCLIPS and C#. The fuzzy expert system part of the system was developed in FuzzyCLIPS, whereas the user interface was developed in the procedural language C#. The fuzzy expert system portion of the system acts like a template, in that it is a fully working system, without the input added for executing the system. After the user interface receives the user input from the user, the user interface copies the fuzzy expert system template, adding the input at the end of the system. Such an action is taken for each new entry into the system. The user interface then executes the FuzzyCLIPS complier, with the changed fuzzy expert system. After the fuzzy expert system has completed executing the action, all of the results are written into a file, which is used by the user interface to display the results. After discussing the fuzzy expert system, the user interface part of the system will be explored next.

4.3.1 Discussion of the fuzzy expert system

FuzzyCLIPS, which is an extended version of CLIPS, is an expert development tool, which was developed in the programming language C++. The modifications that were made to FuzzyCLIPS enabled the programming language to handle those fuzzy reasoning concepts which CLIPS could not. FuzzyCLIPS enables knowledge experts to express their rules using their own fuzzy terms. Furthermore, FuzzyCLIPS allows the knowledge expert to use sets of normal rules, numeric comparisons, and logic controls, as well as to define uncertainty in terms of rules and facts (Orchard, 2004:1). In conclusion, FuzzyCLIPS was used to develop the fuzzy expert system in this study, because the previously mentioned capabilities were needed for the development of the system. Following is a description of how the fuzzy expert system was developed in FuzzyCLIPS.

The development of the fuzzy expert system started with the gathering of those facts which were needed to develop the knowledge base. The facts, which were gathered during the literature review, were categorised according to their influence domain, namely in terms of organisational, individual, environmental and innovative (SDM) factors. The fuzzy expert system was divided into facts with, and facts without, regression values. The former were those facts that were extracted from descriptions of empirical studies, which provided the regression values. The influence of the factor concerned on the regression values was used in this case. The latter were those facts that were extracted from descriptions of non-empirical studies, for which the regression values were unavailable. Figure 4.5 depicts those factors with regression values in the appropriate categories.

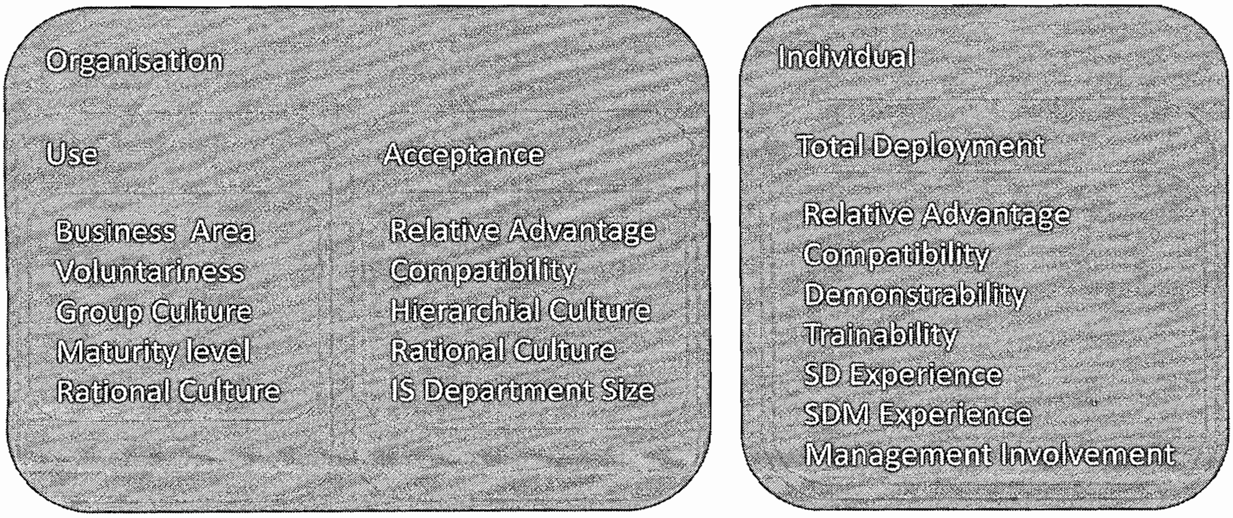


Figure 4.5: Factors with regression

The facts for which the regression values were not given were assigned values on the basis of the influence that each specific fact had on the adoption and use of the SDM. A value of 1 was assigned to a fact that was found to have a positive influence on the adoption and use of the SDM; a value of 0 was assigned to a fact that was found to have no influence on the adoption and use of the SDM; and a value of –1 was assigned to a fact that was found to have a negative effect on the adoption and use of the SDM.

All of the facts that were extracted from the literature were added to the division for facts without regression values, to ensure accurate assessment. Only those facts with regression values were added to the division for facts with regressive values. In other words, some of the facts were duplicated, though they retained the specified value that was associated with their particular division. The only difference for the two divisions lay in the values which were used to represent the impact that the factor had on the adoption and use of the SDM. Accordingly, all of the facts were programmed in the same way.

After the facts had been gathered for the knowledge base, they were transformed into fuzzy rules to form the knowledge base of the fuzzy expert system. A deftemplate, which is a construct that is used to convert a fact into a fuzzy rule, was used for each factor. A fuzzy rule is used for both reasoning about and defining a threshold of uncertainty for the fuzzy rule. The deftemplate for the fuzzy rule regarding top management support, which was categorised as an organisational factor, is given as an example of the concept of a deftemplate.

```
(deftemplate O_F_Top_Management_Support
        1 10 Effect
 (
  (Not_Supported    (pi 1 2))
```

```
  (Fairly_Supported  (pi 1.5 5.5))
  (Strongly_Supported  (pi 1 9))
 )
)
```

Firstly, the name of the deftemplate is declared in order to identify it: "O_F_Top_Management_Support". Secondly, the range of values which can be assigned to the deftemplate is declared "(1 10 Effect)". Accordingly, each deftemplate can be assigned a value between 1 and 10. The value represents the score that an organisation has obtained for the specific fuzzy rule. The value is the user input to the system. The last part of the deftemplate consists of the declaration of the fuzziness, which can be understood as the reasoning and the threshold of uncertainty for a fuzzy rule. FuzzyCLIPS uses mathematical graphs to determine the fuzziness of a value. The graph that was used in this study was the "pi" graph, which is depicted in Figure 4.6. The declaration of the graph "(pi 1 2)" can be rephrased as "(pi d b)" to better illustrate the figure concerned. The range of the graph can be described as b + d and b – d, as seen in Figure 4.6, meaning that the range for the graph "(pi 1 2)" can be calculated as 2 + 1 and 2 – 1, which is the range between 1 and 3. In other words, if the score of the specific fuzzy rule falls between the values of 1 and 3 "(pi 1 2)", the deftemplate launches the defrule "Not_Supported". If the score falls between the values of 4 and 7 "(pi 1.5 5.5)" the defrule "Fairly_Supported" will be launched. Finally, if the score falls between the values of 8 and 10 "(pi 1 9)", the "Strongly_Supported" defrule will be launched. The defrules are discussed in the next section.

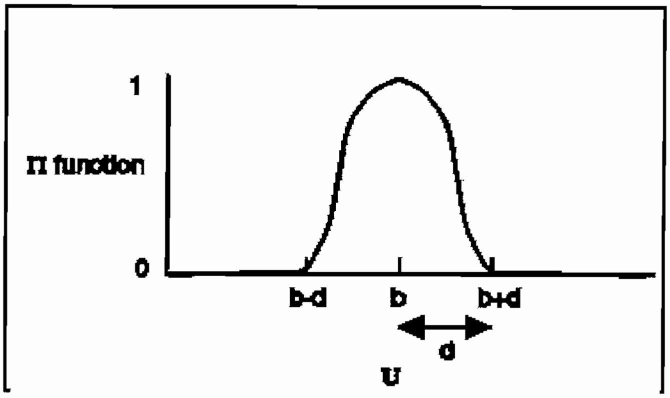


Figure 4.6: "Pi" graph (Orchard, 2004:28.)

As mentioned earlier, each fuzzy rule has three defrules to represent the scale of 1 to 10. The deftemplate launches the appropriate rule needed to represent the fuzzy rule, as previously mentioned. Following is an example of the three defrules, based on the same fuzzy rule, namely top management support.

```
(defrule O_F_Top_Management_Support_Not
        (O_F_Top_Management_Support Not_Supported)
=> (printout outputfile  "Top_Management_Support FOR ORGANISATION Not
supported" crlf)
)
(defrule O_F_Top_Management_Support_Fairly
        (O_F_Top_Management_Support Fairly_Supported)
=> (printout outputfile  "Top_Management_Support FOR ORGANISATION fairly
supported" crlf)
)
(defrule O_F_Top_Management_Support_Strongly
        (O_F_Top_Management_Support Strongly_Supported)
```

=> (printout outputfile "Top_Management_Support FOR ORGANISATION Strongly supported" crlf)

)

Each of the defrules starts by declaring the name of the defrule concerned, in order to identify it:

"(defrule O_F_Top_Management_Support_Not",

"(defrule O_F_Top_Management_Support_Fairly",

"(defrule O_F_Top_Management_Support_Strongly".

After the defrule has been assigned a name, the condition for launching the defrule is declared:

"(O_F_Top_Management_Support Not_Supported)"

"(O_F_Top_Management_Support Fairly_Supported)"

"(O_F_Top_Management_Support Strongly_Supported)"

Such a procedure means that, if the deftemplate "O_F_Top_Management_Support" inserts the "Not_Supported" defrule in the system, the "O_F_Top_Management_Support_Not" defrule is launched. Such an action applies to all of the defrules. After the defrule has been launched, the defrule will write the result of the rule in the output file "=> (printout output file "Top_Management_Support FOR ORGANISATION Not supported" crlf)".

The next portion of the fuzzy expert system consists of the deffunction. The deffunction was used to calculate the impact on the total score that a specific fuzzy rule had, as well as to calculate the final score of the category into which the specific fuzzy rule fell. Following is the deffunction for top management support. The first part of the deffunction declares a name identifying the deffunction: "(deffunction O_F_Calculate_Top_Management_Support (?temp1)". In the deffunction's header, a parameter is declared, which will be used for the calculations. The parameter that the deffunction receives is the value that the user assigned to the specific fuzzy rule. The impact that the fuzzy rule has on the total score is then calculated and stored in terms of a global variable "bind ?*O_F_Top_Management_Support_Var* (* ?temp1 1))". After this, the total value for the category of fuzzy rule is calculated: "(bind ?*O_F_Total_Var* (+ ?*O_F_Total_Var* ?*O_F_Top_Management_Support_Var*))".

```
(deffunction O_F_Calculate_Top_Management_Support (?temp1)

(bind ?*O_F_Top_Management_Support_Var* (* ?temp1 1 ))
(bind ?*O_F_Total_Var* ( + ?*O_F_Total_Var*
?*O_F_Top_Management_Support_Var*))

(printout outputfile  "1.Top_Management_Support FOR ORGANISATION value is : "
?*O_F_Top_Management_Support_Var* crlf)
(assert(O_F_final ?*O_F_Total_Var*))
(assert(O_F_Ffinal O_F_final))
)
```

Next, the impact of the fuzzy rule on the total score is written into the output file: "(printout output file "1.Top_Management_Support FOR ORGANISATION value is"?*O_F_Top_Management_Support_Var* crlf)". Lastly, the deffunction inserts two facts into the fuzzy expert system. The first fact calculates the total score of the category of the specific fuzzy rule "(assert(O_F_final ?*O_F_Total_Var*))". The deffunction then inserts a fact to calculate the final score which the organisation will receive from the fuzzy expert system "(insert(O_F_Ffinal O_F_final))".

The next part of the fuzzy expert system consists of eight defrules for calculating the total scores for the fuzzy expert system. One defrule calculated the total score of all of the fuzzy rules which did not have the regression values stated. Three of the defrules calculated the totals for each category of those fuzzy rules that did not have the regression values stated. The remaining defrules calculated the totals for each category where the factors had the regression values given.

Following is the defrule for calculating the total score for the category of organisational factors. The first part of the defrule declares the name of the defrule identified: "(defrule O_F_TestFinal_1". After the declaration of the defrule, the condition under which the defrule will be launched is declared: "(O_F_Ffinal O_F_final)". Following this action, the defrule adds the total for the category to the final score, which value it assigns to a global variable: "(bind ?*F_F_Total_Var* (+ ?*F_F_Total_Var* ?*O_F_Total_Var*))". After this action, the defrule will insert a fact into the system in order to launch the defrule to calculate the final score: " (bind ?t ?*O_F_Total_Var*)". The decision as to whether or not to adopt and use an SDM will be discussed in the next section.

```
(defrule O_F_TestFinal_1
        (declare (salience -2))
        (O_F_Ffinal O_F_final)
=>

(bind ?*F_F_Total_Var* (+ ?*F_F_Total_Var* ?*O_F_Total_Var*))
(bind ?t ?*O_F_Total_Var* )

(assert(F_F_final ?*F_F_Total_Var*))
(assert(F_F_Ffinal F_F_final))
```

```
(if (< ?t 56)
then
 (printout outputfile  "" crlf)
 (printout outputfile  "" crlf)
 (printout outputfile  "FINAL ASSESSMENT FOR ORGANISATION FACTORS " crlf)
 (printout outputfile  "------------------------------------- " crlf)
 (printout outputfile  "" crlf)
 (printout outputfile  "FACTORS FOR ORGANISATION SHOW DO NOT ADOPT: " ?t
crlf)
)
(if (and ( >= ?t 56) (< ?t 112))
 then
 (printout outputfile  "" crlf)
 (printout outputfile  "" crlf)
 (printout outputfile  "FINAL ASSESSMENT FOR ORGANISATION FACTORS " crlf)
 (printout outputfile  "------------------------------------- " crlf)
 (printout outputfile  "" crlf)
 (printout outputfile  "FACTORS FOR ORGANISATIONAL SHOW Good Change to
ADOPT: " ?t crlf)
)
(if (>= ?t 112)
 then
 (printout outputfile  "" crlf)
```

```
(printout outputfile "" crlf)
(printout outputfile "FINAL ASSESSMENT FOR ORGANISATION FACTORS " crlf)
(printout outputfile "-------------------------------------- " crlf)
(printout outputfile "" crlf)
(printout outputfile "FACTORS FOR ORGANISATIONAL SHOW Strong Change to
ADOPT: " ?t crlf)
)
)
```

Next, the defrule tests the value and writes the output to the output file, which is done by means of the "if" statement. The "if" statement verifies the final score and writes the appropriate output into the output file.

Finally, the defrule that controls the entire expert system will be discussed. Firstly, the defrule is assigned a name to identify the defrule: "(defrule defuzzification-1". After performing this action, the condition for the launching of the defrule is set. The defrule will launch when all of the deftemplates have launched. After this, the defrule will write the values the user assigned to each fuzzy rule into the output file: "(bind ?t18 (maximum-defuzzify ?f18))

(printout outputfile "defuzzy O_F_Top_Management_Support: " ?t18 crlf)". Following this the defrule executes all of the deffunction

"(O_F_Calculate_Top_Management_Support ?t18)". The purpose of this defrule is to control the entire fuzzy expert system. The discussion of the defuzzification defrule requires that the defuzzification defrule be inserted into the text. Although the defuzzification defrule takes up a large amount of space, it is important that the entire defuzzification defrule be provided to strengthen the description. Following is the defrule "defuzzification-1", as programmed in the fuzzy expert system.

```
(defrule defuzzification-1
  (declare (salience -1))



?f1 <- (A_O_Relative_Advantage ?)
?f2 <- (A_O_Compatibility ?)
?f3 <- (A_O_IS_Department_Size ?)
?f4 <- (A_O_Hierarchical_Culture ?)
?f5 <- (A_O_Rational_Culture ?)

?f6 <- (U_O_Business_Area ?)
?f7 <- (U_O_Voluntariness ?)
?f8 <- (U_O_Maturity ?)
?f9 <- (U_O_Group_Culture ?)
?f10 <- (U_O_Rational_Culture ?)

?f11 <- (I_Relative_Advantage ?)
?f12 <- (I_Compatibility ?)
?f13 <- (I_Demonstrability ?)
?f14 <- (I_Trainability ?)
?f15 <- (I_SD_Experience ?)
?f16 <- (I_SDM_Experience ?)
?f17 <- (I_Management_Involvement ?)
```

```
?f18 <- (O_F_Top_Management_Support ?)
?f19 <- (O_F_Information_Exchange ?)
?f20 <- (O_F_Specialisation ?)
?f21 <- (O_F_Centralisation ?)
?f22 <- (O_F_Formalisation ?)
?f23 <- (O_F_Informal_Network ?)
?f24 <- (O_F_Task_Uncertainty ?)
?f25 <- (O_F_Venturesomeness ?)
?f26 <- (O_F_Financial_Strength ?)
?f27 <- (O_F_Size_Of_Organisation ?)
?f28 <- (O_F_Planning_Management_Control ?)
?f29 <- (O_F_Training ?)
?f30 <- (O_F_Rotation_Of_Jobs ?)
?f31 <- (O_F_Standardisation ?)
?f32 <- (O_F_Business_Area ?)
?f33 <- (O_F_Maturity ?)
?f34 <- (O_F_Voluntariness ?)
?f35 <- (O_F_Common_View ?)

?f36 <- (O_M_Group_Culture ?)
?f37 <- (O_M_Developmental_Culture ?)
?f38 <- (O_M_Rational_Culture ?)
?f39 <- (O_M_Hierarchical_Culture ?)
```

```
?f40 <- (I_F_Job_Tenure ?)
?f41 <- (I_F_Cosmopolitanism ?)
?f42 <- (I_F_Education ?)
?f43 <- (I_F_Autonomy ?)
?f44 <- (I_F_Responsibility ?)
?f45 <- (I_F_Experience ?)

?f46 <- (E_F_Heterogeneity ?)
?f47 <- (E_F_Uncertainty ?)
?f48 <- (E_F_Competition ?)
?f49 <- (E_F_Resources ?)
?f50 <- (E_F_Inter_Organisational_Dependence ?)
?f51 <- (E_F_Survival ?)

?f52 <- (F_In_Compatibility ?)
?f53 <- (F_In_Relative_Advantage ?)
?f54 <- (F_In_Complexity ?)
?f55 <- (F_In_Demonstrability ?)
?f56 <- (F_In_Trailability ?)

=>

(printout outputfile  "" crlf)
```

```
(printout outputfile  "" crlf)
(printout outputfile  "VALUES FROM ASSESSING THE ORGANISATION ACCEPTANCE" crlf)
(printout outputfile  "----------------------------------------------" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "" crlf)

(bind ?t1 (maximum-defuzzify ?f1))
(printout outputfile  "defuzzy A_O_Relative_Advantage: "  ?t1 crlf)

(bind ?t2 (maximum-defuzzify ?f2))
(printout outputfile  "defuzzy A_O_Compatibility: " ?t2 crlf)

(bind ?t3 (maximum-defuzzify ?f3))
(printout outputfile  "defuzzy A_O_IS_Department_Size: " ?t3 crlf)

(bind ?t4 (maximum-defuzzify ?f4))
(printout outputfile  "defuzzy A_O_Hierarchical_Culture: " ?t4 crlf)

(bind ?t5 (maximum-defuzzify ?f5))
(printout outputfile  "defuzzy A_O_Rational_Culture: " ?t5 crlf)

(printout outputfile  "" crlf)
(printout outputfile  "" crlf)
```

```
(printout outputfile "VALUES FROM ASSESSING THE ORGANISATION USAGE" crlf)
(printout outputfile "-------------------------------------------" crlf)
(printout outputfile "" crlf)
(printout outputfile "" crlf)



(bind ?t6 (maximum-defuzzify ?f6))
(printout outputfile "defuzzy U_O_Business_Area: " ?t6 crlf)

(bind ?t7 (maximum-defuzzify ?f7))
(printout outputfile "defuzzy U_O_Voluntariness: " ?t7 crlf)

(bind ?t8 (maximum-defuzzify ?f8))
(printout outputfile "defuzzy U_O_Maturity: " ?t8 crlf)

(bind ?t9 (maximum-defuzzify ?f9))
(printout outputfile "defuzzy U_O_Group_Culture: "  ?t9 crlf)

(bind ?t10 (maximum-defuzzify ?f10))
(printout outputfile "defuzzy U_O_Rational_Culture: " ?t10 crlf)



(printout outputfile "" crlf)
(printout outputfile "" crlf)
```

```
(printout outputfile "VALUES FROM ASSESSING THE INDIVIDUAL TOTAL DEPLOYMENT" crlf)
(printout outputfile "------------------------------------------" crlf)
(printout outputfile "" crlf)
(printout outputfile "" crlf)


(bind ?t11 (maximum-defuzzify ?f11))
(printout outputfile "defuzzy I_Relative_Advantage: " ?t11 crlf)

(bind ?t12 (maximum-defuzzify ?f12))
(printout outputfile "defuzzy I_Compatibility: " ?t12 crlf)

(bind ?t13 (maximum-defuzzify ?f13))
(printout outputfile "defuzzy I_Demonstrability: " ?t13 crlf)

(bind ?t14 (maximum-defuzzify ?f14))
(printout outputfile "defuzzy I_Trainability: " ?t14 crlf)

(bind ?t15 (maximum-defuzzify ?f15))
(printout outputfile "defuzzy I_SD_Experience: " ?t15 crlf)

(bind ?t16 (maximum-defuzzify ?f16))
(printout outputfile "defuzzy I_SDM_Experience: " ?t16 crlf)
```

```
(bind ?t17 (maximum-defuzzify ?f17))
(printout outputfile  "defuzzy I_Management_Involvement: "  ?t17 crlf)


(printout outputfile  "" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "VALUES FROM ASSESSING THE ORGANISATION FACTORS"
crlf)
(printout outputfile  "--------------------------------------------" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "" crlf)



(bind ?t18 (maximum-defuzzify ?f18))
(printout outputfile  "defuzzy O_F_Top_Management_Support: "  ?t18 crlf)


(bind ?t19 (maximum-defuzzify ?f19))
(printout outputfile  "defuzzy O_F_Information_Exchange: "  ?t19 crlf)


(bind ?t20 (maximum-defuzzify ?f20))
(printout outputfile  "defuzzy O_F_Specialisation: "  ?t20 crlf)


(bind ?t21 (maximum-defuzzify ?f21))
(printout outputfile  "defuzzy O_F_Centralisation: "  ?t21 crlf)
```

```
(bind ?t22 (maximum-defuzzify ?f22))
(printout outputfile  "defuzzy O_F_Formalisation: "  ?t22 crlf)

(bind ?t23 (maximum-defuzzify ?f23))
(printout outputfile  "defuzzy O_F_Informal_Network: "  ?t23 crlf)

(bind ?t24 (maximum-defuzzify ?f24))
(printout outputfile  "defuzzy O_F_Task_Uncertainty: "  ?t24 crlf)

(bind ?t25 (maximum-defuzzify ?f25))
(printout outputfile  "defuzzy O_F_Venturesomeness: "  ?t25 crlf)

(bind ?t26 (maximum-defuzzify ?f26))
(printout outputfile  "defuzzy O_F_Financially_Strong: "  ?t26 crlf)

(bind ?t27 (maximum-defuzzify ?f27))
(printout outputfile  "defuzzy O_F_Size_Of_Organisation: "  ?t27 crlf)

(bind ?t28 (maximum-defuzzify ?f28))
(printout outputfile  "defuzzy O_F_Planning_Management_Control: "  ?t28 crlf)

(bind ?t29 (maximum-defuzzify ?f29))
(printout outputfile  "defuzzy O_F_Training: "  ?t29 crlf)
```

```
(bind ?t30 (maximum-defuzzify ?f30))
(printout outputfile  "defuzzy O_F_Rotation_Of_Jobs: "  ?t30 crlf)

(bind ?t31 (maximum-defuzzify ?f31))
(printout outputfile  "defuzzy O_F_Standardisation: "  ?t31 crlf)

(bind ?t32 (maximum-defuzzify ?f32))
(printout outputfile  "defuzzy O_F_Business_Area: "  ?t32 crlf)

(bind ?t33 (maximum-defuzzify ?f33))
(printout outputfile  "defuzzy O_F_Maturity: "  ?t33 crlf)

(bind ?t34 (maximum-defuzzify ?f34))
(printout outputfile  "defuzzy O_F_Voluntariness: "  ?t34 crlf)

(bind ?t35 (maximum-defuzzify ?f35))
(printout outputfile  "defuzzy O_F_Common_View: "  ?t35 crlf)

(printout outputfile  "" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "VALUES FROM ASSESSING THE MATURITY FACTORS" crlf)
(printout outputfile  "-----------------------------------------" crlf)
(printout outputfile  "" crlf)
```

```
(printout outputfile  "" crlf)



(bind ?t36 (maximum-defuzzify ?f36))
(printout outputfile  "defuzzy O_M_Group_Culture: "  ?t36 crlf)

(bind ?t37 (maximum-defuzzify ?f37))
(printout outputfile  "defuzzy O_M_Developmental_Culture: "  ?t37 crlf)

(bind ?t38 (maximum-defuzzify ?f38))
(printout outputfile  "defuzzy O_M_Rational_Culture: "  ?t38 crlf)

(bind ?t39 (maximum-defuzzify ?f39))
(printout outputfile  "defuzzy O_M_Hierarchical_Culture: "  ?t39 crlf)

(printout outputfile  "" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "VALUES FROM ASSESSING THE INDIVIDUAL FACTORS" crlf)
(printout outputfile  "-------------------------------------------" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "" crlf)

(bind ?t40 (maximum-defuzzify ?f40))
(printout outputfile  "defuzzy I_F_Job_Tenure: "  ?t40 crlf)
```

```
(bind ?t41 (maximum-defuzzify ?f41))
(printout outputfile  "defuzzy I_F_Cosmopolitanism: "  ?t41 crlf)

(bind ?t42 (maximum-defuzzify ?f42))
(printout outputfile  "defuzzy I_F_Education: "  ?t42 crlf)

(bind ?t43 (maximum-defuzzify ?f43))
(printout outputfile  "defuzzy I_F_Autonomy: "  ?t43 crlf)

(bind ?t44 (maximum-defuzzify ?f44))
(printout outputfile  "defuzzy I_F_Responsibility: "  ?t44 crlf)

(bind ?t45 (maximum-defuzzify ?f45))
(printout outputfile  "defuzzy I_F_Experience: "  ?t45 crlf)


(printout outputfile  "" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "VALUES FROM ASSESSING THE ENVIROMENT FACTORS" crlf)
(printout outputfile  "----------------------------------------" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "" crlf)
```

```
(bind ?t46 (maximum-defuzzify ?f46))
(printout outputfile  "defuzzy E_F_Heterogeneity: "  ?t46 crlf)

(bind ?t47 (maximum-defuzzify ?f47))
(printout outputfile  "defuzzy E_F_Uncertainty: "  ?t47 crlf)

(bind ?t48 (maximum-defuzzify ?f48))
(printout outputfile  "defuzzy E_F_Competition: "  ?t48 crlf)

(bind ?t49 (maximum-defuzzify ?f49))
(printout outputfile  "defuzzy E_F_Resources: "  ?t49 crlf)

(bind ?t50 (maximum-defuzzify ?f50))
(printout outputfile  "defuzzy E_F_Inter_Organisational_Dependence: "  ?t50 crlf)

(bind ?t51 (maximum-defuzzify ?f51))
(printout outputfile  "defuzzy E_F_Survival: "  ?t51 crlf)



(printout outputfile  "" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "VALUES FROM ASSESSING THE INNOVATION (SDM)" crlf)
(printout outputfile  "---------------------------------------" crlf)
(printout outputfile  "" crlf)
```

```
(printout outputfile  "" crlf)



(bind ?t52 (maximum-defuzzify ?f52))
(printout outputfile  "defuzzy F_In_Compatibility: "  ?t52 crlf)

(bind ?t53 (maximum-defuzzify ?f53))
(printout outputfile  "defuzzy F_In_Relative_Advantage: "  ?t53 crlf)

(bind ?t54 (maximum-defuzzify ?f54))
(printout outputfile  "defuzzy F_In_Complexity: "  ?t54 crlf)

(bind ?t55 (maximum-defuzzify ?f55))
(printout outputfile  "defuzzy F_In_Demonstrability: "  ?t55 crlf)

(bind ?t56 (maximum-defuzzify ?f56))
(printout outputfile  "defuzzy F_In_Trailability: "  ?t56 crlf)

(retract ?f1 ?f2 ?f3 ?f4 ?f5 ?f6 ?f7 ?f8 ?f9 ?f10 ?f11 ?f12 ?f13 ?f14 ?f15 ?f16 ?f17)
(retract ?f18 ?f19 ?f20 ?f21 ?f22 ?f23 ?f24 ?f25 ?f26 ?f27 ?f28 ?f29 ?f30 ?f31 ?f32 ?f33
?f34)
(retract ?f35 ?f36 ?f37 ?f38 ?f39 ?f40 ?f41 ?f42 ?f43 ?f45 ?f46 ?f47 ?f48 ?f49 ?f50 ?f51
?f52 ?f53 ?f54 ?f55 ?f56)
```

```
(printout outputfile  "" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "VALUES AFTER ANALYSING ORGANISATION" crlf)
(printout outputfile  "--------------------------------------" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "" crlf)

(A_O_Calculate_Relative_Advantage ?t1)
(A_O_Calculate_Compatibility ?t2)
(A_O_Calculate_IS_Department_Size ?t3)
(A_O_Calculate_Hierarchical_Culture ?t4)
(A_O_Calculate_Rational_Culture ?t5)

(U_O_Calculate_Business_Area ?t6)
(U_O_Calculate_Voluntariness ?t7)
(U_O_Calculate_Maturity ?t8)
(U_O_Calculate_Group_Culture ?t9)
(U_O_Calculate_Rational_Culture ?t10)

(I_Calculate_Relative_Advantage ?t11)
(I_Calculate_Compatibility ?t12)
```

```
(I_Calculate_Demonstrability ?t13)
(I_Calculate_Trainability ?t14)
(I_Calculate_SD_Experience ?t15)
(I_Calculate_SDM_Experience ?t16)
(I_Calculate_Management_Involvement ?t17)

(printout outputfile  "" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "VALUES AFTER ANALYSING ORGANISATION FACTORS" crlf)
(printout outputfile  "-------------------------------------" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "" crlf)

(O_F_Calculate_Top_Management_Support ?t18)
(O_F_Calculate_Information_Exchange ?t19)
(O_F_Calculate_Specialisation ?t20)
(O_F_Calculate_Centralisation ?t21)
(O_F_Calculate_Formalisation ?t22)
(O_F_Calculate_Informal_Network ?t23)
(O_F_Calculate_Task_Uncertainty ?t24)
(O_F_Calculate_Venturesomeness ?t25)
(O_F_Calculate_Financial_Strength ?t26)
(O_F_Calculate_Size_Of_Organisation ?t27)
(O_F_Calculate_Planning_Management_Control ?t28)
```

(O_F_Calculate_Training ?t29)

(O_F_Calculate_Rotation_Of_Jobs ?t30)

(O_F_Calculate_Standardisation ?t31)

(O_F_Calculate_Business_Area ?t32)

(O_F_Calculate_Maturity ?t33)

(O_F_Calculate_Voluntariness ?t34)

(O_F_Calculate_Common_View ?t35)

(O_M_Calculate_Group_Culture ?t36)

(O_M_Calculate_Developmental_Culture ?t37)

(O_M_Calculate_Rational_Culture ?t38)

(O_M_Calculate_Hierarchical_Culture ?t39)

(I_F_Calculate_Job_Tenure ?t40)

(I_F_Calculate_Cosmopolitanism ?t41)

(I_F_Calculate_Education ?t42)

(I_F_Calculate_Autonomy ?t43)

(I_F_Calculate_Responsibility ?t44)

(I_F_Calculate_Experience ?t45)

(E_F_Calculate_Heterogeneity ?t46)

(E_F_Calculate_Uncertainty ?t47)

(E_F_Calculate_Competition ?t48)

```
(E_F_Calculate_Resources ?t49)
(E_F_Calculate_Inter_Organisational_Dependence ?t50)
(E_F_Calculate_Survival ?t51)

(printout outputfile  "" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "VALUES AFTER ANALYSING ORGANISATION FACTORS" crlf)
(printout outputfile  "-----------------------------------------" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "" crlf)

(F_In_Calculate_Compatibility ?t52)
(F_In_Calculate_Relative_Advantage ?t53)
(F_In_Calculate_Complexity ?t54)
(F_In_Calculate_Demonstrability ?t55)
(F_In_Calculate_Trailability ?t56)

(printout outputfile  "" crlf)
(printout outputfile  "" crlf)
(printout outputfile  "FINAL ASSESSMENT" crlf)
(printout outputfile  "-----------------------------------------" crlf)
```

4.3.2 Discussion of the user interface

As previously mentioned, the procedural language used to develop the user interface for the fuzzy expert system was C#. The user interface of the system was developed to receive input from the user, to insert the values into the system and to display the results of the fuzzy expert portion of the system. This section will describe how the user interface works.

The user interface was split into three parts, which can be seen in Figure 4.7, which is the main menu of the user interface. The first part of the system can be accessed by means of the "Submit new Company" button. This part of the program allows the user to insert values into the system by manually assigning values to each factor of the system. The second part of the system, "Display Company Results", displays the results of the fuzzy expert system. Finally, the "Company Audit" user can insert values into the system by answering question about the organisation, resulting in the system automatically inserting the values derived from the questions. The remaining part of the section will describe the three parts of the system.

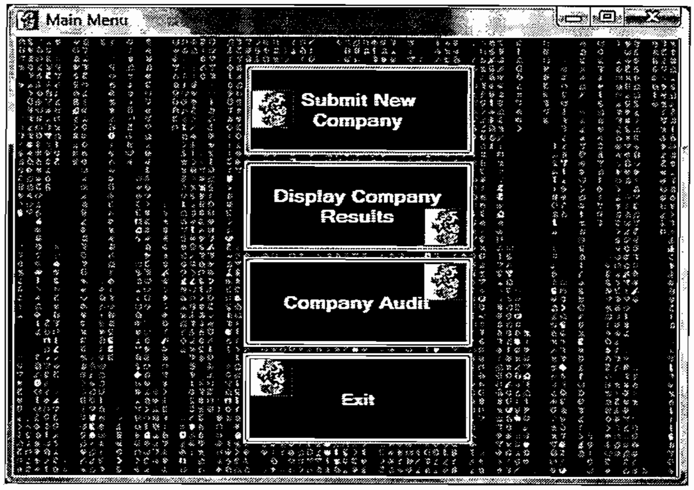


Figure 4.7: Main menu

4.3.2.1 Submit new company

The "submit new company" form is depicted in Figure 4.8. The form consists of two tabs: "Regression" and "Factors". The "Regression" tab allows the user to insert values for the factors with regression values and the "Factors" screen allows the user to insert values for the factors without regression values. In the middle of the form is a textbox into which the name of the company is inserted. The "Submit" button allows the user to submit the results that have been specified for the company whose name has been entered into the textbox. Such an Action copies the fuzzy expert template for the specified company and adds the results at the end of the file. This executes the modified file with results in the FuzzyCLIPS compiler. After the fuzzy expert system has executed the action, the results will be written into an output file. The "Load" button allows the user to reload the information relating to a previously entered company by typing the previous company's name in the textbox and clicking on the "Load" button. The system will then search for the previously entered company and execute the modified file for it. After the fuzzy expert system has finished the execution, the results will be rewritten into an output file.

In order to submit a value for a factor in the system, a user must click on the factor in the listbox on the left. After selecting the desired factor, the user must set the value in the spinbox. The spinbox will allow the user to assign any value from 1 to 10. After the user has specified the value for the factor, the user must click on the "=>" button to add the factor to the right listbox. The factor will then appear in the listbox on the right with the value assigned, and be erased from the listbox on the left.

In order to eliminate a factor from the right listbox, the user needs only to click on both the desired factor and the "<=" button to eliminate the factor. The factor will then disappear from the listbox on the right and appear in the listbox on the left. If all of the factors have been selected and assigned a value, the "Submit" button can be clicked for the relevant results to be submitted and executed.

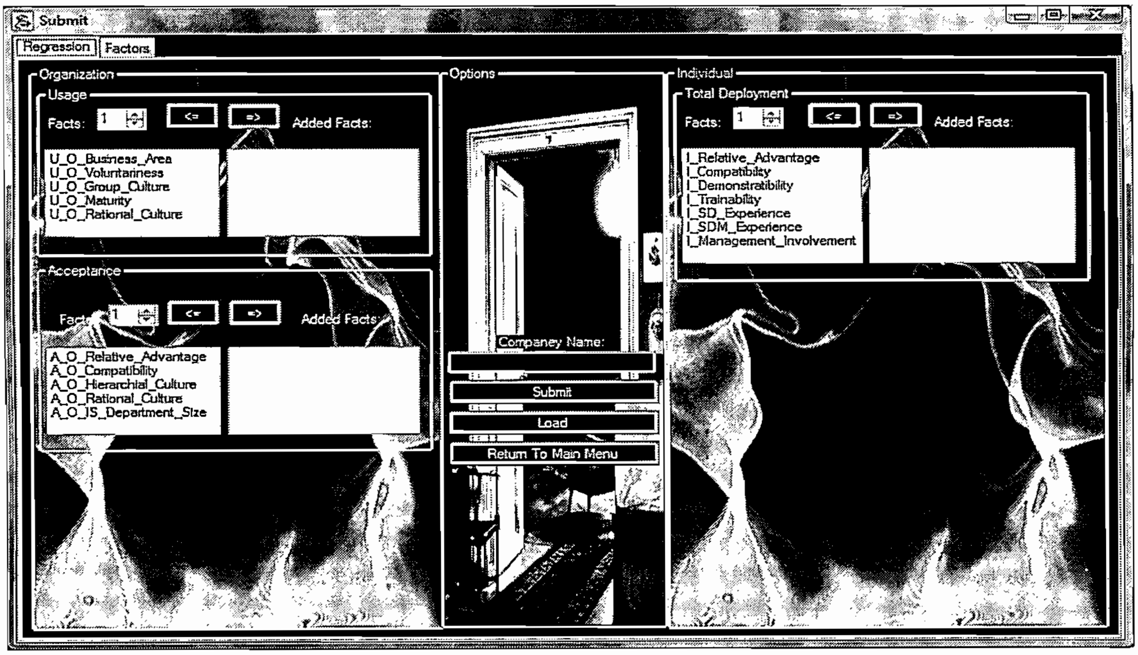


Figure 4.8: Submit screen (regression tab)

4.3.2.2 Display company results

The main forms for displaying the results are depicted in Figure 4.9. The textbox allows the user to enter the name of the company for which the results are needed. The user can then click on the "Load Results" button. The system will search for the relevant values if the user has already submitted values for the company concerned. If the values have already been submitted for the company, the system will extract the results from the output file. The checkboxes "Submit results" and "Audit results" allow the user to specify which method of input was used, so that the system will display the correct values. After the "Load Results" button has been clicked, the richtextbox will be filled with the contents of the output file, which can be seen as a summary of the results of the fuzzy expert system. The summary of the results displayed in the richtextbox include: the rules that fire during the execution of the fuzzy expert portion of the system; the values that the user assigned to each rule; and the results for each rule and category. If the user wants to see a more detailed report, the user can use the tabs of the form: "Rules Results", "User Input Results" and "Final Results".

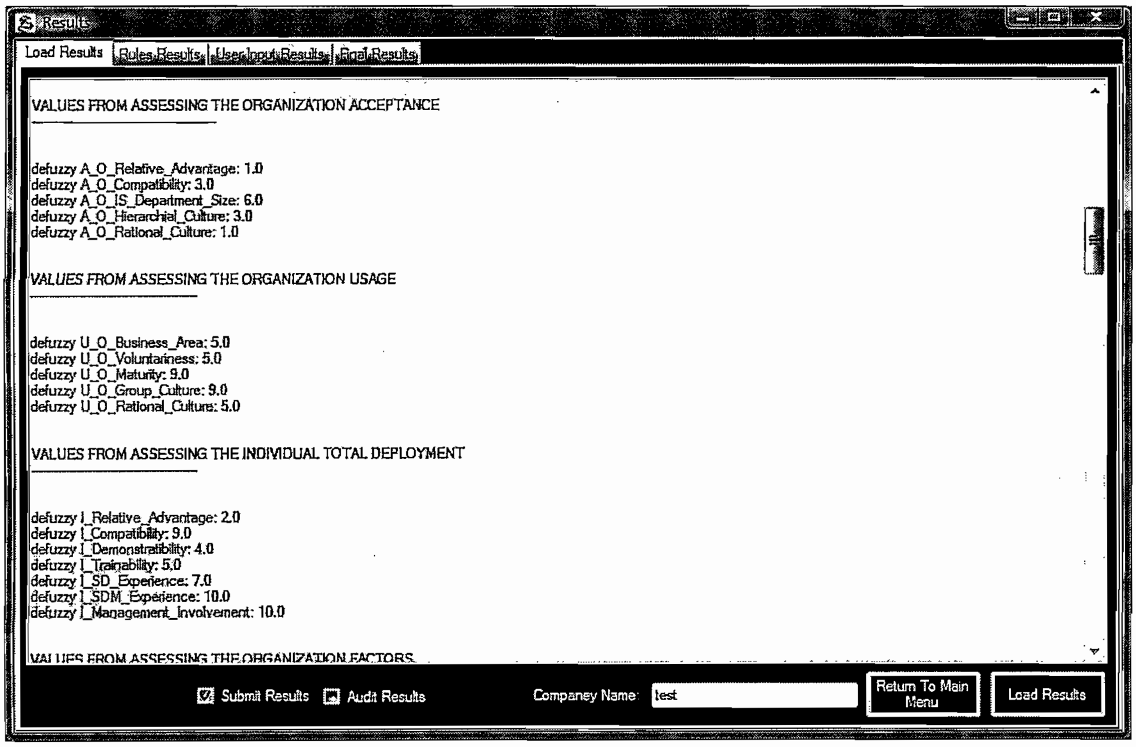


Figure 4.9: Results (load results tab)

The form for the "Rules Results" tab (see Figure 4.10) summarises the defrules launched while the fuzzy expert system was being executed. In the listbox on the left is the name of the defrule and in the listbox on the right is the result of every defrule launched. If a user clicks on a rule, the system will automatically highlight the result for that specific rule.

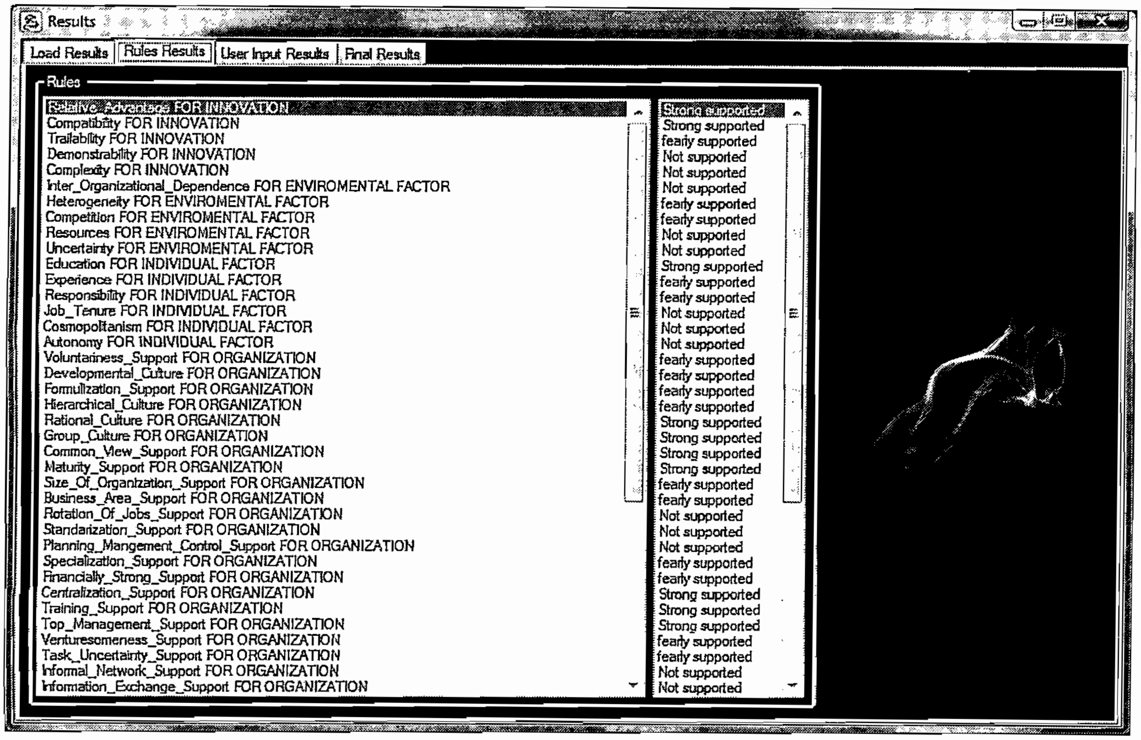


Figure 4.10: Results (rule results tab)

On the form for the "User Input Results" tab (see Figure 4.11), the user can view those values that were assigned to the various factors. The form displays the factors with regression values on the left and the factors without regression values in the middle and on the right. The factors are shown in their categories, with the total score for each category also being shown.

Finally the "Final Results" tab summarises all of the results. The form for the "Final Results" tab is depicted in Figure 4.12. The left-hand side of the form depicts the results for the factors with regression values. At the bottom left-hand side of the form is a summary of each category for those factors with regression values. The right-hand side of the form summarises the factors without regression values. The bottom right-hand side of the form displays the final results for such factors.

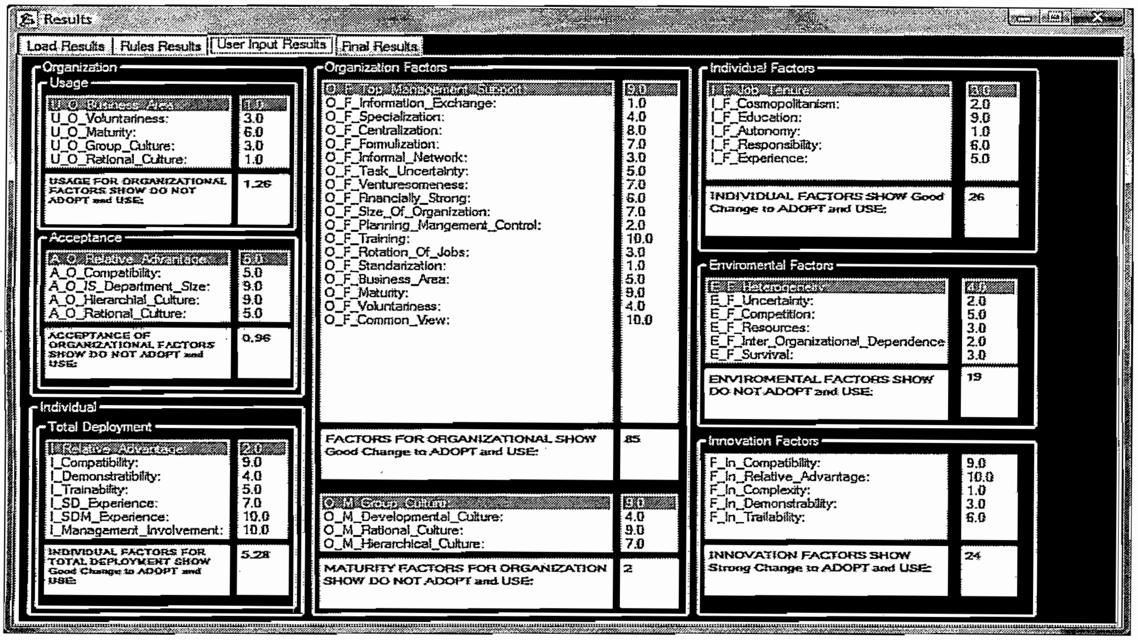


Figure 4.11: Results (user input results tab)

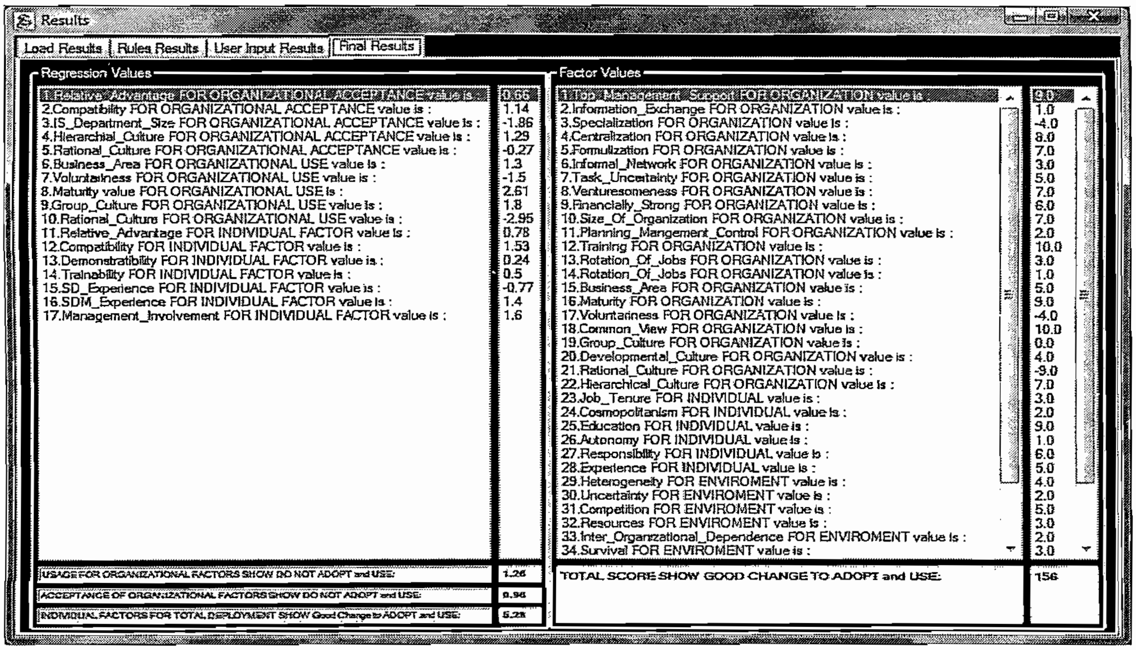


Figure 4.12: Results (final results tab)

The total scores which were mentioned in the previous discussion were calculated as is now described. Table 4.2 depicts the calculations for the factors with regression in the category 'organisational use'. The column factor indicates the name of the factor. The column use indicates the regression value assigned to the specific factor. Lastly, the user input column indicates the score from 1 to 10 which the user can assign the specified factor. Only the boundaries of the three ranges, namely those of "not supported", "fairly supported" and "strong supported" are shown in Table 4.2. The regression value is multiplied by the use score value to calculate the impact that the factor will have on the adoption and use of the SDM. The intervals for "not supported", "fairly supported" and "strongly supported" are depicted with the "pi" chart value for the fuzzy expert system. A heuristic approach was used to determine the boundaries of the ranges.

Table 4.2: Calculation of total values for organisational use with regression values

With regression values							
Organisation							
Factor	**Use**	**User input**					
		1	3	4	7	8	10
Business area	0.26	0.26	0.78	1.04	1.82	2.08	2.6
Voluntariness	-0.3	-0.3	-0.9	-1.2	-2.1	-2.4	-3
Maturity	0.29	0.29	0.87	1.16	2.03	2.32	2.9
Group culture	0.2	0.2	0.6	0.8	1.4	1.6	2
Rational culture	-0.59	-0.59	-1.77	-2.36	-4.13	-4.72	-5.9
TOTAL	-0.14	-0.14	-0.42	-0.56	-0.98	-1.12	-1.4

TOTAL	< -0.56	Not supported	TOTAL < -0.56	(pi 1 2)
TOTAL	> = -0.56	Fairly supported	-0.56 < = TOTAL < -1.12	(pi 1.5 5.5)
TOTAL	< -1.12	Fairly supported		
TOTAL	> = -1.12	Strongly supported	-1.12 < = TOTAL < = -1.4	(pi 1 9)
TOTAL	< = -1.4	Strongly supported		

Table 4.3 depicts the calculations for the factors with regression in the category "organisational acceptance". The calculations were done in the same way as described for those given in Table 4.2.

Table 4.3: Calculation of total values for organisational acceptance with regression values

With regression values							
Organisation							
Factor	**Acceptance**	**User input**					
		1	3	4	7	8	10
Hierarchical culture	0.43	0.43	1.29	1.72	3.01	3.44	4.3
Relative advantage	0.66	0.66	1.98	2.64	4.62	5.28	6.6
Compatibility	0.38	0.38	1.14	1.52	2.66	3.04	3.8
IS department size	-0.31	-0.31	-0.93	-1.24	-2.17	-2.48	-3.1
Rational culture	-0.27	-0.27	-0.81	-1.08	-1.89	-2.16	-2.7
TOTAL	0.89	0.89	2.67	3.56	6.23	7.12	8.9

TOTAL	< 3.56	Not supported	TOTAL < 3.56	(pi 1 2)
TOTAL	>= 3.56	Fairly supported		
TOTAL	< 7.12	Fairly supported	3.56 <= TOTAL < 7.12	(pi 1.5 5.5)
TOTAL	>= 7.12	Strongly supported		
TOTAL	< = 8.9	Strongly supported	7.12 <= TOTAL < = 8.9	(pi 1 9)

Table 4.4: Calculation of total values for individual total deployment with regression values

With regression values							
Individual							
Factor	**Total deployment**	**User input**					
		1	3	4	7	8	10
Relative advantage	0.39	0.39	1.17	1.56	2.73	3.12	3.9
Compatibility	0.17	0.17	0.51	0.68	1.19	1.36	1.7
Demonstrability	0.06	0.06	0.18	0.24	0.42	0.48	0.6
Trainability	0.1	0.1	0.3	0.4	0.7	0.8	1

SD experience	-0.11	-0.11	-0.33	-0.44	-0.77	-0.88	-1.1
SDM experience	0.14	0.14	0.42	0.56	0.98	1.12	1.4
Management involvement	0.16	0.16	0.48	0.64	1.12	1.28	1.6
TOTAL	0.91	0.91	2.73	3.64	6.37	7.28	9.1

TOTAL	< 3.64	Not supported	TOTAL < 3.64	(pi 1 2)
TOTAL	> = 3.64	Fairly supported		
TOTAL	< 7.28	Fairly supported	3.64 < = TOTAL < 7.28	(pi 1.5 5.5)
TOTAL	> = 7.28	Strongly supported		
TOTAL	< = 9.1	Strongly supported	7.28 < = TOTAL < = 9.1	(pi 1 9)

Table 4.4 depicts the calculations for the factors with regression values in the category 'individual total deployment'. The calculations were done in the same way as was described for those shown in tables 4.2 and 4.5.

Table 4.5: Calculation of total values for factors without regression values

Without regression values	**Influence**	**User input**					
		1	3	4	7	8	10
Innovation (SDM)	**2**	2	6	8	14	16	20
Compatibility	1	1	3	4	7	8	10
Relative advantage	1	1	3	4	7	8	10
Complexity	-1	-1	-3	-4	-7	-8	-10
Demonstrability	0	0	0	0	0	0	0
Trialability	1	1	3	4	7	8	10
Organisational factors	**14**	14	42	56	98	112	140
Top management support	1	1	3	4	7	8	10
Information exchange among designers and users	1	1	3	4	7	8	10
Informal network structures	1	1	3	4	7	8	10
Task uncertainty	1	1	3	4	7	8	10

Venturesomeness	1	1	3	4	7	8	10
Financially strong	1	1	3	4	7	8	10
Size of organisation	1	1	3	4	7	8	10
Planning, management and control	1	1	3	4	7	8	10
Training	1	1	3	4	7	8	10
Rotation of jobs or roles	1	1	3	4	7	8	10
Standardisation	1	1	3	4	7	8	10
Business areas	1	1	3	4	7	8	10
Maturity level	1	1	3	4	7	8	10
Voluntariness	-1	-1	-3	-4	-7	-8	-10
Common view of managers and co-workers	1	1	3	4	7	8	10
Specialisation	-1	-1	-3	-4	-7	-8	-10
Centralisation	1	1	3	4	7	8	10
Formalisation	1	1	3	4	7	8	10
Cultural maturity of the organisation	**1**	1	3	4	7	8	10
Group culture	0	0	0	0	0	0	0
Developmental culture	1	1	3	4	7	8	10
Rational culture	-1	-1	-3	-4	-7	-8	-10
Hierarchical culture	1	1	3	4	7	8	10
Individual factors	**6**	6	18	24	42	48	60
Job tenure	1	1	3	4	7	8	10
Cosmopolitanism	1	1	3	4	7	8	10
Education	1	1	3	4	7	8	10
Autonomy	1	1	3	4	7	8	10
Responsibility	1	1	3	4	7	8	10
Experience	1	1	3	4	7	8	10
Environmental factors	**6**	6	18	24	42	48	60
Heterogeneity	1	1	3	4	7	8	10
Uncertainty	1	1	3	4	7	8	10
Competition	1	1	3	4	7	8	10
Resources	1	1	3	4	7	8	10
Inter-organisational dependence	1	1	3	4	7	8	10
Survival	1	1	3	4	7	8	10
TOTAL	**29**	**29**	87	116	203	232	290

Chapter 4: Fuzzy expert system

TOTAL	< 116	Not supported	TOTAL < 116	(pi 1 2)
TOTAL	> = 116	Fairly supported		
TOTAL	< 232	Fairly supported	116 < = TOTAL < 232	(pi 1.5 5.5)
TOTAL	> = 232	Strongly supported		
TOTAL	< = 290	Strongly supported	232 < = TOTAL < = 290	(pi 1 9)

Table 4.6 depicts the values calculated for the factors without regression values. The values were calculated in the same way as with the previously mentioned method, with the exception that the influence of the factors was either 1, 0 or –1. Another difference is that all of the categories calculated are shown in the table.

4.3.2.3 Company audit

The final part of the user interface allows users to submit values in response to questions about the organisation (see the form in Figure 4.13). The user answers the questions on a scale of 1 to 10 by dragging the scroll bar to the right of a question. If the question requires a more detailed response, a listbox enumerating the different options is given, from which the user can choose the appropriate answer. After the user has answered the questions concerned, the company name must be entered in the textbox. The "Submit" button can then be clicked. The submit button calculates the values for each question, following the same process as in the case of the previously mentioned "Submit" button. If there is only one question for the fact, the score for the specific fact is the value of that question. In contrast, if there is more than one question for the fact, then the average of the questions is calculated to arrive at the score value for the fact. Finally, if a fact is represented by a listbox, each element in the listbox has a score value of its own. Figure 4.13 presents the first tab of 9 as an example, as the other tabs are all similar in appearance and function.

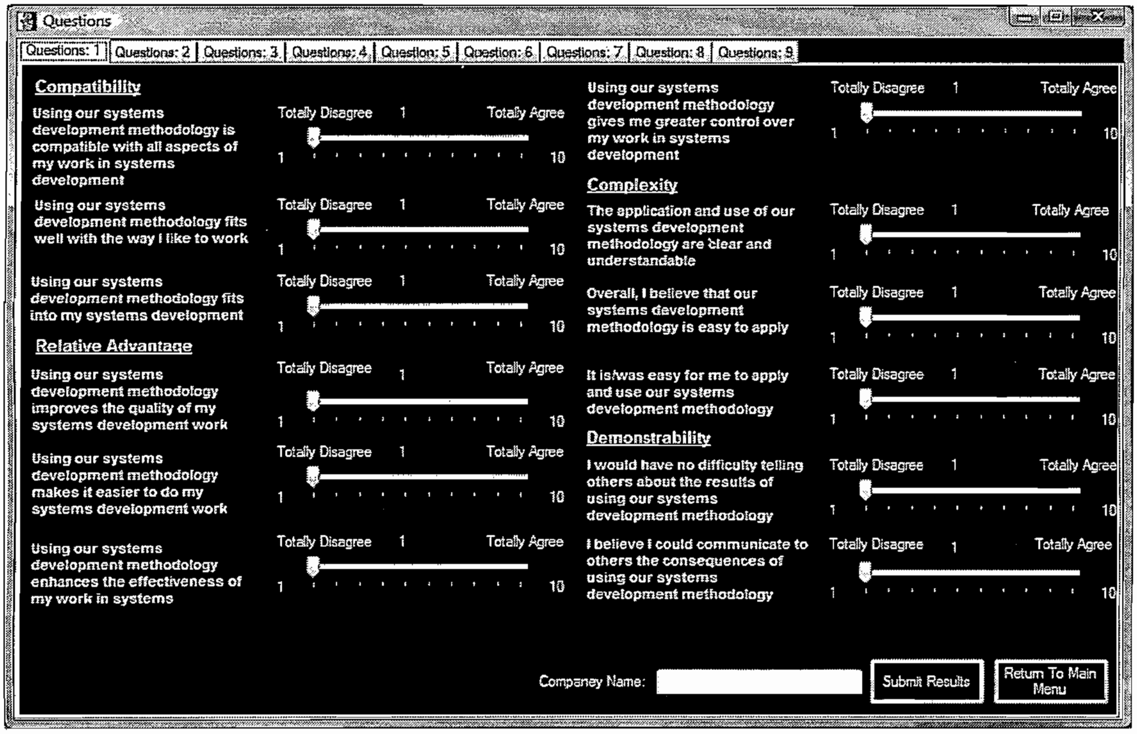


Figure 4.13: Questions (Questions: 1 tab)

4.4 Summary

The aim of this study was to develop a fuzzy expert system to facilitate the adoption and use of SDMs. Chapter 4 describes in detail how this objective was reached for the study. The fuzzy expert system was developed by combining two SDMs, namely the general development of, and the linear model for developing, a fuzzy expert system. A fuzzy expert system was developed in FuzzyCLIPS, with a user interface that was developed in C#. The fuzzy expert system portion of the system performs all of the computations, whereas the user interface allows the user to submit values to, and to view the results of, the system.

Chapter 5: Conclusion

The main objective of this study was to develop a fuzzy expert system that could facilitate an organisation with the adoption and use of an SDM. Relevant information, which was gleaned from online scientific journals, was reviewed and converted into rules to form the knowledge base of the fuzzy expert system. This chapter provides an overview of the objectives, results, contributions and limitations of the study, concluding with proposals for future research.

5.1 Aim and objectives

The aim of the study was to develop a fuzzy expert system, which would be able to advise an organisation on the adoption and use of an SDM suited to its needs.

The objectives of the research study were:

- to conduct a literature study to establish rules for the adoption and use of an SDM in an organisation;
- to convert the above-mentioned rules into a knowledge base on which the fuzzy expert system can base its decisions; and
- to develop and test the fuzzy expert system.

The first research objective was reached by analysing relevant online scientific journal articles, which were widely scattered among the different expert systems. For this reason, an extensive literature review was conducted in order to access all key information to do with the adoption and use of SDMs. The factors with bearing on such adoption and use, which were gleaned from the literature, were converted into rules to form the knowledge base of the fuzzy expert system, in order to achieve the second research objective. The rules were formulated by adding each factor to the fuzzy expert system. Finally, the fuzzy expert system was developed, to reach the third research objective. This was done by using a combination of FuzzyCLIPS and C# programming languages. The fuzzy expert system portion of the system was programmed in FuzzyCLIPS and the user interface was programmed in C#. Following this was the testing of the fuzzy expert system to ensure that the system worked properly. By doing this the last research objective was reached.

5.2 Results

The current study resulted in a literature review that produced the rules for the fuzzy expert system, in terms of which the system itself could be developed.

5.2.1 Literature review results

The literature review produced the rules that were needed for developing the fuzzy expert system. The rules comprised those factors that influence the adoption and use of an SDM. The factors were categorised according to the type of influence that each factor has on an organisation, in terms of innovation (SDM), organisation, individuals and the environment. Each of the categories, together with the relevant facts, was used in the fuzzy expert system to illustrate the effect that the category and factors had on the adoption and use of an SDM by an organisation. Table 5.1 below provides an overview of the literature study and its results.

Table 5.1: Summary of rules

Innovation factors (SDM characteristics)	
1.	***Compatibility*** is the degree to which an innovation is consistent with the values, experiences and needs of an organisation. Compatibility was found to have a positive effect on the adoption and use of an SDM.
2.	***Relative advantage*** is the perceived benefit that an innovation can provide for an organisation. Relative advantage was found to have a positive effect on the adoption and use of an SDM.
3.	***Complexity*** refers to the degree of difficulty involved in understanding and using an innovation. Complexity was found to have a negative effect on the adoption and use of an SDM.
4.	***Demonstrability*** refers to the visibility of the results of an innovation. Demonstrability was not used as a factor in this study.
5.	***Trialability*** is the degree to which a methodology can undergo experimentation on a trial basis. Trialability was found to have a positive effect on the adoption and use of an SDM.
Organisational factors	
6.	***Top management support*** consists of the support provided by top management for the adoption and use of an SDM. Top management support was found to have a positive effect on the adoption and use of an SDM.

7.	*Information exchange among designers and users* includes consideration of the purpose, objectives, and impact of the system, aimed at helping both designers and users to reach a mutual understanding about the IS concerned. Information exchange among designers and users was found to have a positive effect on the adoption and use of an SDM.
8.	*Informal network structures* are viewed as the communication of innovations and information transfer, in which individuals communicate the idea of adoption among the adopters. Informal network structures were found to have a positive effect on the adoption and use of an SDM.
9.	*Task uncertainty* relates to the routine and programmable nature of the tasks that an organisation has to execute to complete its day-to-day functions as well as to conduct its decision-making activities. Task uncertainty was found to have a positive effect on the adoption and use of an SDM.
10.	*Venturesomeness* is the capacity of an organisation to foster the trying out of new and different things. Venturesomeness was found to have a positive effect on the adoption and use of an SDM.
11.	*Financial strength* refers to the possession of extensive resources by an organisation. Financial strength was found to have a positive effect on the adoption and use of an SDM.
12.	*Size of the organisation* refers to the amount of resources and the number of people in the organisation. The size of the organisation was found to have a positive effect on the adoption and use of an SDM.

13.	*Planning, management and control* relate to the planning, management and control of a project. Planning, management and control were found to have a positive effect on the adoption and use of an SDM.
14.	*Training* is the formal procedure by which an organisation standardises the learning of its employees to ensure that the goals and objectives of the organisation are reached. Training was found to have a positive effect on the adoption and use of an SDM.
15.	*Rotation of jobs or roles* refers to the degree to which an organisation rotates job or roles in an information department. The rotation of roles was found to have a positive effect on the adoption and use of an SDM.
16.	*Standardisation* refers to the standardisation of the development process. Standardisation was found to have a positive effect on the adoption and use of an SDM.
17.	*Business areas* are the areas of endeavour in which a business participates, which have a significant influence on the IS structures used in an organisation. Business areas were found to have a positive effect on the adoption and use of an SDM.
18.	*Maturity level* refers to "the extent to which a specific process is explicitly defined, managed, measured, controlled, and effective" The maturity level was found to have a positive effect on the adoption and use of an SDM.
19.	*Voluntariness* is the extent of voluntary use and acceptance of an innovation, which indicates the free will to use it. Voluntariness was found to have a positive effect on the adoption and use of an SDM.

20.	*Common view of managers and co-workers* is the view that is held in common by both managers and workers, which is also called perceptual congruence. The common view of managers and co-workers was found to have a positive effect on the adoption and use of an SDM.
Organisational culture	
21.	*Group culture* is primarily focused on human relations and flexibility. The group culture was found not to have a significant effect on the adoption and use of an SDM.
22.	*Developmental culture* focuses on what might happen in the future. The developmental culture was found to have a positive effect on the adoption and use of an SDM.
23.	*Rational culture* emphasises individual achievement. The rational culture was found to have a negative effect on the adoption and use of an SDM.
24.	*Hierarchical culture* emphasises the maintenance of security, order and routine in the workplace. The hierarchical culture was found to no significant effect on the adoption and use of an SDM.
Organisational structure	
25.	*Specialisation* refers to the different specialists in an organisation and their fields of specialisation. Specialisation was found to have a negative effect on the adoption and use of an SDM.

26.	*Centralisation* refers to the degree to which an organisation emphasises its decision-making activities. Centralisation was found to have a positive effect on the adoption and use of an SDM.
27.	*Formalisation* promotes functional differentiation, and is believed to create clear work definitions and procedures, but less autonomy. Formalisation was found to have a positive effect on the adoption and use of an SDM.
	Individual factors
28.	*Job tenure* refers to the length of time that an employee occupies a certain post at an organisation. Job tenure was found to have a positive effect on the adoption and use of an SDM.
29.	*Cosmopolitanism* refers to receptivity to change. Cosmopolitanism was found to have a positive effect on the adoption and use of an SDM.
30.	*Education* relates to the schooling and training of individuals, which enables them to understand change, so that they are more likely to support the adoption and use of innovations. Education was found to have a positive effect on the adoption and use of an SDM.
31.	*Autonomy* concerns an individual's control over their assigned task and their ability to execute the task on their own. Autonomy was found to have a positive effect on the adoption and use of an SDM.
32.	*Responsibility* refers to the ability to take ownership of one's own actions. Responsibility was found to have a positive effect on the adoption and use of an SDM.

33.	*Experience* is defined as the prior technical knowledge that an individual possesses. Experience was found to have a positive effect on the adoption and use of an SDM.
	Environmental factors
34.	*Heterogeneity* refers to the number of competitors or similar environmental entities with which an organisation has to compete to gain an advantage in the environment. Heterogeneity was found to have a positive effect on the adoption and use of an SDM.
35.	*Uncertainty* refers to the degree of instability and turbulence in the environment to which an organisation is subject. Uncertainty was found to have a positive effect on the adoption and use of an SDM.
36.	*Competition* is related to the population present in the environment, as well as to the capacity of the environment to harbour competition. Competition was found to have a positive effect on the adoption and use of an SDM.
37.	*Resources* in an environment are what keeps an organisation going. Resources were found to have a positive effect on the adoption and use of an SDM.
38.	*Inter-organisational dependence* consists of the sharing of information and resources among organisations. Inter-organisational dependence was found to have a positive effect on the adoption and use of an SDM.
39.	*Survival* demands of an organisation that it is innovative enough to ensure its compatibility with the environment. Survival was found to have a positive effect on the adoption and use of SDMs.

5.2.2 *Fuzzy expert system results*

The completion of the fuzzy expert was a result on its own. Its development was undertaken in accordance with the combined methodology depicted in Figure 5.1. The developmental methodology resulted from the combination of two other methodologies, namely the general development of a fuzzy expert methodology and the linear model for developing such a system. The development phases consisted of the following: the feasibility study; planning; knowledge definition; knowledge design; rapid prototyping; knowledge verification; and system evaluation.

The system was able to receive input from users and to calculate whether or not an organisation was ready to adopt and use an SDM. The results that the system calculated showed the influence that a factor had on the adoption and use of an SDM.

Furthermore, the system also indicated the influence that a category had on the adoption and use of an SDM. In addition, the system was divided into factors that had regression values and factors without such values. The systems calculated the influence of each of the divisions on the adoption and use of an SDM separately, and were able to produce results for both such divisions.

The successful development of the fuzzy expert system was the most important result of the study. A fully working version of the fuzzy expert system is included in the study (see Appendix A).

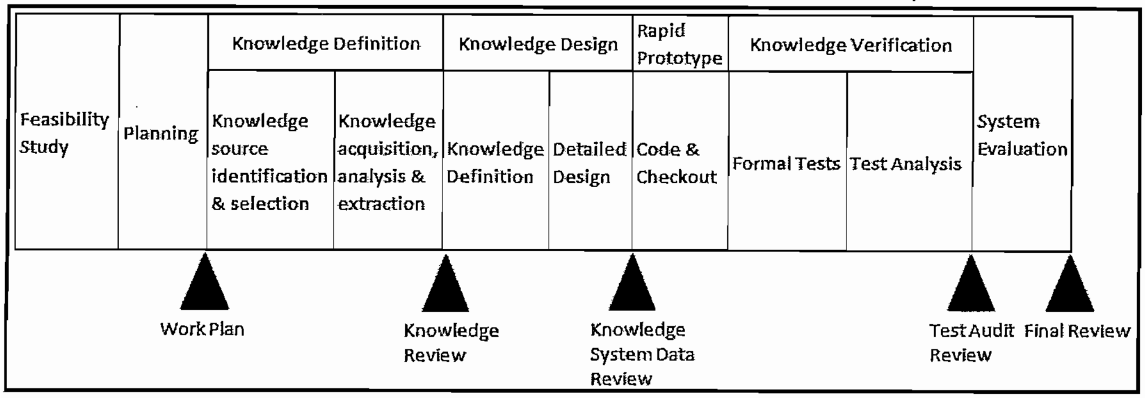


Figure 5.1: Combined developmental methodology

5.3 Contributions

This study has made a valuable contribution in the IS area, especially regarding the adoption and use of SDMs. The study produced a literature review that grouped most of the factors that influence such adoption and use. The literature review also provided an overview of the influence that each factor has on the adoption and use.

The study also developed a management tool, in the form of a fuzzy expert system, which can be used to facilitate the adoption and use of an SDM. The fuzzy expert system allows users to audit an organisation, to manually submit values for an organisation and to produce insightful reporting regarding the results. During company audits, users need to fill in comprehensible questions about the organisations concerned. Once such answers have been fed into the fuzzy expert system, the system has the capacity to calculate, and report on, the scores that the organisations have received.

The manual submission for an organisation allows users to assign values directly to factors. Such values can then be used to determine in which areas the organisation needs to improve in order to be able successfully to adopt and use an SDM.

The reports which are produced by the fuzzy expert indicate whether an organisation should adopt and use an SDM. Furthermore, such reports allow the user to see in which areas the organisation needs to improve before it can successfully adopt and use an SDM.

5.4 Limitations

The current study was largely based on information gleaned from online scientific journals. The lack of relevant empirical research in the IS field was found to be marked. Due to the inadequacy of empirical data for each factor, the knowledge base is still incomplete. Furthermore it is premature to evaluate the system in term of its value for real organisations, but this could be the focus of future research.

5.5 Future research

More empirical studies are required into those factors that influence the decision to adopt and use SDMs. Furthermore, research can be conducted to extend the fuzzy expert system by means of the following:

- Addition of rules: A more extensive search can be conducted into other factors that influence the decision to adopt and use an SDM. Such research could take the form of questionnaires and surveys.

- Elaboration of the audit process: Researchers could investigate more reliable tools for measuring the audit process.
- Selection of an SDM: The capacity of the fuzzy expert system could be extended to enable it to select the appropriate SDM for an organisation that is ready to adopt and use one.

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Appendix A