



A Green approach towards systems development methodologies

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ABSTRACT

The aim of this study was to determine a Green approach towards systems development methodologies and to investigate influences that affect the adoption of Green Information Technologies and Green Information Systems in South Africa. A literature review was done in order to determine which empirical is required to achieve the research objectives.

The positivistic paradigm was found to be the most suited paradigm for this study. A survey was used as the research method and conducted in South Africa. The data was collected using a questionnaire, after determining that it was the most suited data collection method. The questionnaire was validated using structural equation modelling in order to determine if the data that was collected is valid. The valid data was then evaluated using different statistical methods, such as correlations, t-test, ANOVA tests and Cross-Tabs.

The study revealed that the different characteristics of organisations can influence different aspects, such factors that inhibit or motivate the adoption of Green IT and Green IS. Interestingly, characteristics of individuals had no impact. It was also revealed that organisational culture and national culture had an impact on factors that motivate the adoption of Green IT initiatives.

Keywords: Green Information Technology; Green Information Systems; Green System Development; Sustainable System Development; Adoption; Diffusion; Organisational Culture; National Culture

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Global warming and climate change are currently of the most critical concerns and important issues worldwide (Wang, 2010; Chung, 2008; Fernando & Atsuko, 2009; Watson *et al.*, 2010). Our planet is in danger, is frequently a topic in research and enjoys worldwide media interest (Wang, 2010; Hansen, 2011; Goodland, 1995; Dedrick, 2010). Even though it has been debated that global warming is a natural process (Robinson *et al.*, 2007), it has been established that human activities are the main cause of global warming, especially through the release of greenhouse gas emissions, which increases the temperature of the earth (Rahmstorf & Ganopolski, 1999; Stott *et al.*, 2008; Wong *et al.*, 2001; Johnston, 2008). It is critical for our planet that environmental sustainability is achieved (Hoesch-Klohe *et al.*, 2010; Huang, 2008). Environmental sustainability is used as an umbrella term for taking environmental issues, such as greenhouse gas emissions, energy usage, air quality and waste generated into consideration.

Many organisations and industry sectors are aware that this is an urgent situation and that it is critical that they improve their environmental impact (Molla, 2009a; Hewlett *et al.*, 2009; Jenkin *et al.*, 2011; Hart, 1997; Henriques & Sadorsky, 1999; Erek, 2011; Melville, 2010). Governments are also implementing new regulations and legislation, which forces organisations to lower their environmental impact (Jenkin *et al.*, 2011; Dedrick, 2010; Erek, 2011). In South Africa, however, there is currently very little legislation or enforcement of international standards with which organisations need to comply in terms of being Green. The King 3rd report, auditing organisations's sustainability, is currently only mandatory for organisations that are registered on the Johannesburg Stock Exchange (Petzer *et al.*, 2011).

Organisations that want to improve their environmental impact should see it as a source of opportunity, innovation and even as a competitive advantage (Porter & Kramer, 2006; Porter & Van der Linde, 1995; Erek, 2011). Reducing their environmental impact can also reduce the costs of an organisation by managing resources more effectively and helping to attract and keep skilled employees (Harmon *et al.*, 2010; Sinnett, 2010; Fernandez *et*

al., 2003; Argarwal *et al.*, 2012). There are also additional advantages, such as a better reputation with different stakeholders (Jenkin *et al.*, 2011; Erek, 2011).



Figure 1.1: Flow of Chapter 1

The layout of Chapter 1 is depicted in Fig. 1.1. The chapter starts with an introduction to Green IT and Green IS, explaining briefly what these two terms refers to, as well as why they are important topics to investigate. The next section explains different possible influences on the adoption of Green IT/IS. This is followed by the problem statement, which gives an oversight of why the research is necessary. In the next section, the different research objectives, which are required in order to solve the problem identified in the problem statement, are stated. The reasons why this study is significant will be mentioned in the next section and then a summary will be given of the remaining chapters of this study.

1.2 Introduction of Green Information Technology and Green Information Systems

The growing concern for the environment has led to the investigation of the environmental impact of IT (Dedrick, 2010). It is estimated that the Information Technology (IT) industry is currently responsible for 2% off all global greenhouse emissions (Gartner, 2007) and due to the growing demand in computing power and storage, this figure will keep rising (Velte *et al.*, 2008; EPA, 2007; Erek *et al.*, 2011). IT equipment also increases the power usage of organisations significantly (Elliot & Binney, 2008; Hedwig *et al.*, 2009; Murugesan, 2008; Erek, 2011). Power consumption is very important in a South African context, since our electricity is mainly generated from fossil fuels, which have an extremely large carbon footprint (Elliot & Binney, 2008; Sioshansi, 2009). Higher power consumption also leads to higher costs to an organisation (Capra & Merlo, 2009; Dedrick, 2010). The availability of power could also be a threat to organisations that use too much (Chung, 2008; Molla, 2008).

The IT industry has many areas that contribute to greenhouse gas emissions and these areas need to be improved. IT organisations no longer have the choice whether they want

to take the environment into account and they should focus on how they are going to become Green in an efficient manner (Erek, 2011; Dedrick, 2010). Some of the direct IT areas that can be improved include aspects, such as energy usage, electronic waste generation and preventing pollution and additional infrastructure used by IT (Hilty, 2007; Molla & Ahmad, 2011; Chen *et al.*, 2009; Molla, 2009a). In terms of electronic waste, the majority of research is on the life cycle of hardware. All IT equipment should have the smallest possible impact on the environment and this can be done with techniques, such as storage virtualisation, better power management and recycling of IT products (Molla, 2009 ; Murugesan, 2008 ; Boudreau *et al.*, 2008 ; Harmon *et al.*, 2010).

In the current literature the usage of different terms, such as "ecologically sustainable", "environmentally friendly", "environmentally sustainable" and "Green" are all used to describe IT, which is used without a negative impact on the environment (Ijab *et al.*, 2010). For the purpose of this paper the term Green will be used to describe a process or object, which has the smallest possible negative effect on the environment. Green IT is the usage of IT with the smallest possible negative impact on the environment. IS researchers have not focused on Green IT until recently (Molla *et al.*, 2011; Erek, 2011). Researchers have now realised the importance of taking the environmental impact of IT equipment into account (Elliot, 2007; Elliot & Binney, 2008; Melville, 2010). Researchers also feel that additional research is needed in terms of the environmental impact of IT (Elliot & Binney, 2008; Elliot, 2007; Dedrick, 2010). There are many different Green IT techniques that effectively reduce the negative effects of IT equipment and service during its entire life cycle (Elliot & Binney, 2008; Harmon *et al.*, 2010; Köhler & Erdmann, 2004; Dedrick, 2010; Dedrick, 2010).

The role of IS in improving environmental sustainability should be better understood (Watson *et al.*, 2010). IS can be successfully used to lower negative environmental effects and it is very important to improve the sustainability of the planet (Melville, 2010; Elliot, 2007; Erek *et al.*, 2009; Chen *et al.*, 2008; Olson, 2008; Nigel, 2010; Premerean *et al.*, 2010; Watson *et al.*, 2008b; Hilty *et al.*, 2006). Only one article could be found that critiques the fact that technology has the potential to improve sustainability (Fuchs, 2008).

An IS that is used by an organisation to enable or to help it to lower its entire footprint is called a Green IS (Jenkin *et al.*, 2011). IT is the basis used for developing and using IS(s) (Friedman, 1994). Therefore the techniques used for Green IT can be implemented in

Green IS(s) to ensure that the IT products that are used to lower the organisation's carbon footprint have the smallest possible impact on the environment.

1.3 Introduction of influences of the adoption of Green IT and Green IS

Even though several studies have been done regarding the adoption of IT and IS(s) (Png *et al.*, 2001; Grover *et al.*, 1997; Khanzanchi *et al.*, 2007), the factors that motivate and inhibit Green IT and Green IS are still not clear (Molla, 2009a; Molla, 2008). The research regarding these factors is also very limited (Chen *et al.*, 2008; Chen *et al.*, 2010; Molla, 2008; Petzer *et al.*, 2011). Studies on technology adoption are usually focused on the different characteristics of an organisation, such as sector, size and resources (Molla & Ahmad, 2011; Orlikowski, 1993; Thong, 1999). Research has not determined if the theories for adoption of Green IT and IS(s) are the same as for normal IT and IS. The increasing focus on sustainability and other ethical influences could result in the motivational factors of Green IT being very different from that of other IT (Olson, 2008). The largest motivator of IT is usually economic gain, whereas for Green IT, it could be due to several other motivations, such as the ever-increasing consciousness of the dire condition of our planet (Molla, 2009a; Lindenberg & Steg, 2007; Chen *et al.*, 2009).

It has also been established that culture has a definite influence on the adoption and diffusion of IT systems development processes (Iivari & Huisman, 2007; Argarwal *et al.*, 2012; Chow & Coa, 2008). Culture has different levels, namely a gender, generation, social class, organisational and a national level. Of these levels, much literary material suggests that the national and organisational levels have the most profound effect on different aspects IT and IS(s) (Iivari & Huisman, 2007; Chow & Coa, 2008; Iivari & Iivari, 2011). It is, however, currently unclear if culture will have the same impact on the acceptance of Green IT and IS(s).

1.4 Problem statement

Research on lowering an organisation's environmental impact is currently mostly done on the IT sector and not as much on the IS sector. In the IS sector, there is very little research being done, specifically regarding greener systems development. The latest IS research focuses on how IS can be used for transformation towards a more sustainable way of doing things within organisations (Ijab, 2011; Gabriel, 2008) and the reduction of

resource consumption (Watson *et al.*, 2010). The study of Melville (2010) suggests using the transformative influence of IS to help change the perception of the importance of improving environmental and economic performance of organisations. Ijab *et al.* (2010) also did a comprehensive literature review in order to clarify the difference between Green IT and Green IS and to provide a better conceptualisation of Green IS, which IS researchers can use as a theoretical basis.

The environmental sustainability of IT should also be addressed from a systems development process perspective (Begtsson, 2010; Huang, 2008). Systems development is that creation of an IS that impacts directly on how the system functions and the type of infrastructure used (Begtsson, 2010). The design of most ISs are not designed and developed in an environmental friendly manner (Ijab *et al.*, 2010). The importance of using an systems development methodologies (SDM) to develop ISs is widely known (Hardy *et al.*, 1995; Iivari *et al.*, 2000) and it can be successfully used for better control and effectiveness of the systems development process (Fitzgerald *et al.*, 2002; Huisman & Iivari, 2006). A Green SDM is therefore required for an effective and well-controlled Green systems development process.

In order to develop Green SDMs, current Green SMDs should be thoroughly studied, so that possible activities, tasks or areas that can be improved in terms of their environmental impact are identified (Sheenoy & Eerata, 2011; Begtsson, 2010). The system development process should be modified so that the entire process incorporates environmental sustainability (Begtsson, 2010; Huang, 2008). A Green IS and normal IS should be designed to be Green from the start of development (Ijab *et al.*, 2010). This will ensure that each stage of the development process will be greener, as well as continuously working towards the goal of a greener end product (Naumann *et al.*, 2011).

After investigating the current research done in the IT and IS sectors, it became apparent that there is a need to research Green software development and specifically Green SDMs. A common concern with an SDM is that its effectiveness needs to be improved (Roberts *et al.*, 1998) and that it needs to be adapted based on new situations or requirements (Fitzgerald, 1998; Russo *et al.*, 1995; Standing, 2002; Fitzgerald *et al.*, 2002) and in this case it should be more effective in terms of being Green. SDMs should not only be adapted so that the end product is greener, but also that the entire development process will be greener. In order to do this different Green IT techniques

and initiatives should be identified, which will help to eliminate the negative effect of all IT used for the development of the system, as well as the IT implement in the system. The effectiveness of different Green initiatives should also be determined, so that only the effective initiatives are incorporated into the SDM. In this way Green ISs include Green IT, as well as Green systems development, since both these terms are necessary for a Green IS.

In South Africa research on determining possible reasons for the adoption of Green IT and IS is very limited and only one study could be found on this matter (Petzer *et al.*, 2011). Green ISs are not currently being prioritised in South Africa and Green IT adoption is addressed poorly. In order to improve this situation, factors that could possibly motivate or inhibit the adoption of Green IT and Green IS should also be investigated in this study (Molla & Ahmad, 2011).

1.5 Research Objectives

The **first objective** is to develop a Green approach towards systems development methodologies so that the development process, as well as the end product is greener. In order to achieve this objective, the following secondary objectives must be achieved:

- 1.1. Investigate different techniques or initiatives that can be used to reduce the negative impact of IT;
- 1.2. Determine the effectiveness of Green IT techniques or initiatives;
- 1.3. Evaluate different SDMs and determine if any existing systems development methodologies incorporate Green objectives into the systems development methodology;
- 1.4. Determine how current SDMs can be adapted to a have greener development process and a greener end product; and
- 1.5. Determine how a Green SDM should be classified.

The **second objective** is to determine the possible influences that could affect the adoption of Green IT and Green systems development. In order to achieve this objective, the following secondary objectives must be achieved:

- 2.1. Determine the factors that motivate or inhibit organisations from adopting Green IT initiatives;

- 2.2. Determine the impact that organisations' characteristics have on the adoption of Green IT initiatives and the incorporation of Green IT techniques into systems development;
- 2.3. Determine the impact of an individual's characteristics in an organisation on the adoption of Green IT initiatives and the incorporation of Green IT techniques into systems development;
- 2.4. Determine the impact that organisational culture has on the adoption of Green IT initiatives and the incorporation of Green IT techniques into systems development; and
- 2.5. Determine the impact that national culture has on the adoption of Green IT and the incorporation of Green IT techniques into systems development.

1.6 Research Paradigms and Methods

This study was conducted in the positivistic paradigm, which is used most frequently in IS research (Chen & Hirschheim, 2004; Arnott & Pervan, 2005). A literature study was first conducted in order to establish different Green IT techniques and considerations. This section was also used to create a framework for determining if current Green SDMs are thorough. The literature study was further used to determine how to classify SDMs and to investigate how Green SDMs can be classified. The literature study was also conducted to determine different possible influences on the adoption of Green IT and ISs.

Once the literature study was done, a survey was conducted by creating and distributing a questionnaire based on the knowledge gained from the literature study. The survey was conducted in South Africa between 1 May 2012 and 31 August 2012. The purpose of the survey was to confirm the different findings in the literature section, as well as to establish possible relationships between identified factors. The questionnaires were distributed to 54 different organisations and 134 completed questionnaires were returned. Once the data was gathered it was analysed in SPSS, using different statistical methods. Lastly, the empirical results were interpreted so that the knowledge obtained from the study could be presented.

1.7 Significance of the Study

Dedrick (2010) suggests that IS researchers focus decisions regarding the entire system, such as selection of hardware, system architecture and in-sourcing versus outsourcing. This research attempts to do this. This research also satisfies several of the different research areas proposed by Elliot (2007), Melville (2010) and Ijab *et al.* (2010), due to the fact that system development will determine the environmental impact of the IS. Lastly, Petzer *et al.* (2011) suggest the the role of culture with regard to Green values should be investigated, which the study also attempts to do.

This study aims to make the following theoretical contributions:

- Create an SDM, which is thorough and more effective than current Green SDMs.
- Contribute theoretically by determining with empirical data the future predictions for Green IT initiatives in South Africa, determining which Green IT techniques are perceived to be effective in the industry and if organisations are currently adapting their SDM for a Green development process.
- Even though there are published articles regarding Green system development, they are not based on any empirical data. The comprehensiveness of these Green SDMs is not known and it will therefore be determined in this study.
- The research also attempts to determine possible factors that influence the adoption of Green IT and Green IS in South Africa.

This study aims to make the following practical contributions:

- The first is that the adaption of the systems development process, will allow IS professionals to develop systems in a manner that is environmentally friendly. This study also gives professionals guidelines on the type of Green IT initiatives that are available so that they can implement them in their organisations.
- The second contribution is that by identifying factors that influence the adoption of Green initiatives, it allows professionals to focus on these factors in order to help them adopt Green IT and ISs.

1.8 Summary of following chapters

The rest of the dissertation will consist of the following chapters:

Chapter 2: Green IT and IS

This chapter focuses on partially achieving the first objective of developing a Green approach towards system development methodologies. This is done by investigating the sub-objectives of determining the different techniques or initiatives that can be used to reduce the negative impact of IT and to evaluate the different SDMs and to determine if any existing SDM(s) incorporate Green IT techniques. Green IT and Green IS(s) are clearly defined in this chapter. This chapter also reports important factors, which should be taken into account when developing information systems in a greener way. These factors will be used to determine which SDM will be most suited to be adapted for a Green system development process and end-product. Tools and techniques that can be used specifically for the IT and IS industry and which can be incorporated into a system development methodology will be investigated.

Chapter 3: Adoption of Green IT and IS

The aim of this chapter is to partially achieve the second main objective, namely to determine the possible influences that could affect the adoption of Green IT and Green system development. This is done by investigating different sub-objectives such as determining the factors that motivate or inhibit organisations from adopting Green IT. It is also important to investigate the impact of organisational culture and national culture on the adoption of Green IT/IS.

Possible Green IT and IS(s) motivational and inhibiting factors are identified. The influence of culture on the adoption of Green IT and IS(s) is investigated, both on a national and organisational level. Different frameworks for measuring organisational and national culture will also be discussed, as well as how they will be implemented during this specific study.

Chapter 4: Research Methodology and Results

This explains the research methodology that was used to conduct the study. The different possible philosophical paradigms, research strategies, data collection techniques and data analysis techniques that were used when researching IS(s) are explained. The chosen paradigm will be explained which is important for understanding the basic underlying beliefs and assumptions used for this study. The chosen research method, together with the data collection will also be explained.

The chapter then presents the empirical data of the study and supplements the findings found from literature in chapters three and four so that all the research objectives are properly addressed.

Chapter 5: Interpretations of the Results, Limitations, Contributions and Future research.

This chapter gives a short overview of the demographics of the organisations and individuals that participated in the survey. The different empirical results that were presented in chapter four are interpreted and discussed in terms of the aims and objectives of this study. Additional results that were not part of the initial research objectives are also discussed. All the limitations and the theoretical and practical contributions of this particular study are discussed and the chapter is concluded with recommendations for future research.

1.9 Summary

This chapter provided a brief introduction to the study. The problem statement was presented along with different research objectives that are required to solve this problem. The research approach that is used for this study is also discussed. Lastly, the remaining chapters of this study are also summarised and outlined. The next section will investigate Green IT and Green IS, which will form the theoretical basis for this study. This chapter will also focus on partially achieving the first main objective.

CHAPTER 2

GREEN IT AND IS

2.1 Introduction

The purpose of this chapter is to help achieve the first objective of developing a Green approach towards systems development methodologies. It focuses specifically on the sub-objectives of determining the different techniques or initiatives that can be used to reduce the negative impact of IT and to evaluate the different SDMs and to determine if any existing SDMs incorporate Green IT techniques. Lastly it focuses on determining how a Green SDM can be classified.

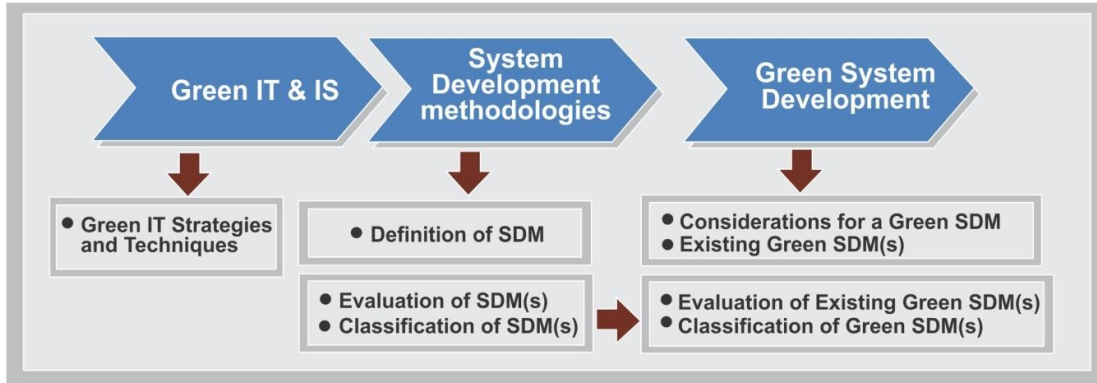


Figure 2.1: Flow of Chapter 2

The structure of the chapter is depicted in Figure 2.1. The first section of the chapter explains the terms Green IT and Green IS, as well as the difference between these terms. A clear definition for both these terms is also given. This section then also attempts to achieve the research objective, which requires determining the different techniques and strategies that can be used to reduce the negative impact of IT.

The next section focuses on SDMs. The definition of an SDM is often unclear, therefore this term is explained and a clear definition of the term is given. The next part of this section is very important and investigates the different methods and frameworks for evaluating and classifying SDMs. The last section incorporates the first two sections of this chapter in order to achieve the research objective of evaluating the different SDMs and to determine if any existing SDMs incorporate Green IT techniques.

The first part of this section summarises the different techniques and strategies determined in the first section of the chapter and groups them into ten considerations. The next part of the chapter will then investigate the different existing Green SDMs and investigates the techniques that they incorporate. The evaluation of Green SDMs is done next. This is done by using the differing evaluation methods determined in the second section of the chapter, as well as the ten Green IT considerations explained in the first part of this chapter. Lastly, the classification framework, which is explained in the second section is applied and used to determine how Green SDMs should be classified in the hierarchy of SDMs.

2.2 Green IT and Green IS(s)

In the introduction section of this study it is mentioned that the IT industry is currently responsible for 2% of all global greenhouse emissions. This might not appear to be such a large percentage, but it is almost the same carbon footprint as the entire aviation industry. The negative impact that IT has on the environment is truly significant and will increase if it is not handled correctly, since the world is becoming ever more dependent on this industry (Molla, 2009a). There are several areas of IT that contribute directly to an organisation's negative impact on the environment and these areas need to be improved (Fernando & Atsuko, 2009; Hilty, 2007). Organisations need to become aware of these areas and implement strategies or techniques to reduce their negative impacts. The term 'Green IT' is usually used when referring to techniques or strategies used to reduce the negative impact of IT on the environment. It is a very broad concept and its scope is not clear (Erek, 2011; Molla, 2009a). Currently there is no universally accepted definition for the term (Erek, 2011). Table 2.1 is a summary of Green IT definitions found in previous literature. This table will be used to establish if there are similarities or universal components in the different definitions.

Table 2.1 **Different definitions of Green IT**

Author	Green IT definition
(Elliot, 2007)	Green IT is "The design, production, operation and disposal of ICT and ICT-enabled products and services in a manner that is not harmful and may be positively beneficial to the environment during the course of its whole-of-life"
(Wang, 2008)	Green computing is "Supporting personal computing and business-critical computing needs in a sustainable manner in terms of minimizing strains and impact on resources and environment"
(Murugesan, 2008)	Environmentally sustainable IT is "The study and practice of designing, manufacturing, using and disposing of computers, servers and associated subsystems efficiently and effectively with minimal or no impact on the environment"
(Harmon & Auseklis, 2009)	Green computing is "The practice of maximising the efficient use of computing resources to minimise the environmental impact. This includes the goals of controlling and reducing a product's environmental footprint by minimising the use of hazardous materials, energy, water, and other scarce resources, as well as minimising waste from manufacturing and throughout the supply chain. Green computing goals extend to the product's use over its life cycle, and the recycling, re-use, and biodegradability of obsolete products"
(Chen <i>et al.</i> , 2009)	"Green IS and IT refer to IS and IT products (e.g., software that manages an organization's overall emissions) and practices (e.g., disposal of IT equipment in an environmentally friendly way) that aims to achieve pollution prevention, product stewardship, or sustainable development"

Author	Green IT definition
(Molla, 2009a)	“Green IT is an organisation’s ability to systematically apply environmental sustainability criteria (such as pollution prevention, product stewardship, use of clean technologies) to the design, production, sourcing, use and disposal of the IT technical infrastructure, as well as within the human and managerial components of the IT infrastructure”
(Hedwig <i>et al.</i> , 2009)	“Green IT denotes all activities and efforts incorporating ecologically friendly technologies and processes into the entire lifecycle of information and communication technology”
(Molla, 2009b)	“Green IT is a systematic application of ecological-sustainability criteria (such as pollution prevention, product stewardship, use of clean technologies) to the design, production, sourcing, use and disposal of the IT technical infrastructure, as well as within the human and managerial components of the IT infrastructure in order to reduce IT, business process and supply chain related emissions, waste and water use; improve energy efficiency and generate Green economic rent.”
(Erek <i>et al.</i> , 2011)	“Green IT is the systematic application of practices that enable the minimisation of the environmental impact of IT, maximise efficiency and allow for company-wide emission reductions based on technology innovations.”

After comparing the different definitions it is apparent that there are certain components that are repeated in the different definitions. The first component is the reduction of the negative impact of IT on the environment, as can be summarised as follows (Wang, 2008; Elliot, 2007; Murugesan, 2008; Harmon & Auseklis, 2009; Molla, 2009a; Chen *et al.*, 2009; Hedwig *et al.*, 2009):

The use of IT, throughout the entire life cycle (design, production, operation and disposal), should be done in such way that it has the smallest possible negative effect on the environment.

There is also a second component that is apparent from the above definitions (Elliot, 2007; Molla, 2009b; Chen *et al.*, 2009; Ereik *et al.*, 2011):

IT should be used in such a way that it not only eliminates or reduces the negative effects of IT on the environment, but also reduces the entire organisation's negative impact on the environment.

The first component is part of all the Green IT definitions listed in Table 2.1. The second component relates to the explanation of Green IS in many different articles (Harmon & Auseklis, 2009; Watson *et al.*, 2008; Molla, 2009b; Dedrick, 2010; Dunton & Sewchurran, 2011; Marrone *et al.*, 2011). Therefore these two components need to be divided into two terms, namely

- Green IT, which consists of the first component
- Green ISs, which consist of the second component.

For the purpose of this dissertation Green IT will be used to refer to the first component and Green IS to the second. Green IS(s) is a new term, sometimes also called "IT for Green" or "the second wave of Green IT" and it is not defined clearly (Harmon & Auseklis, 2009; Gartner Inc., 2009; Ijab *et al.*, 2010). There is a clear distinction between Green IT and Green IS(s) (Watson *et al.*, 2008; Molla, 2009b).

There are severable significant differences between Green IT and Green IS(s):

- Green IT tries to improve problems caused by IT, whereas Green IS tries to use IS to improve environmental issues. Green IS incorporates environmentally friendly practices into IS.
- Green IT is used to reduce the 2% of greenhouse emissions, Green IT could be used to help reduce the 98% of all the other industries (Dedrick, 2010).
- Green IT is the predecessor of Green IS and included in it (Dunton & Sewchurran, 2011; Marrone *et al.*, 2011; Watson *et al.*, 2010). Green IS evolved out of Green IT.
- In 2008 Green IT was recognised by many CIOs as the most important strategic technology. A transition occurred in 2010 where the CIOs' emphases shifted to Green IS(s) (Gartner Inc., 2007; Gartner Inc., 2009).

- Green IT is usually reactive to specific problems caused by the IT they use; Green IS(s) is a proactive approach that is used to redesign or optimise current processes of the organisation (Van Osch *et al.*, 2010).

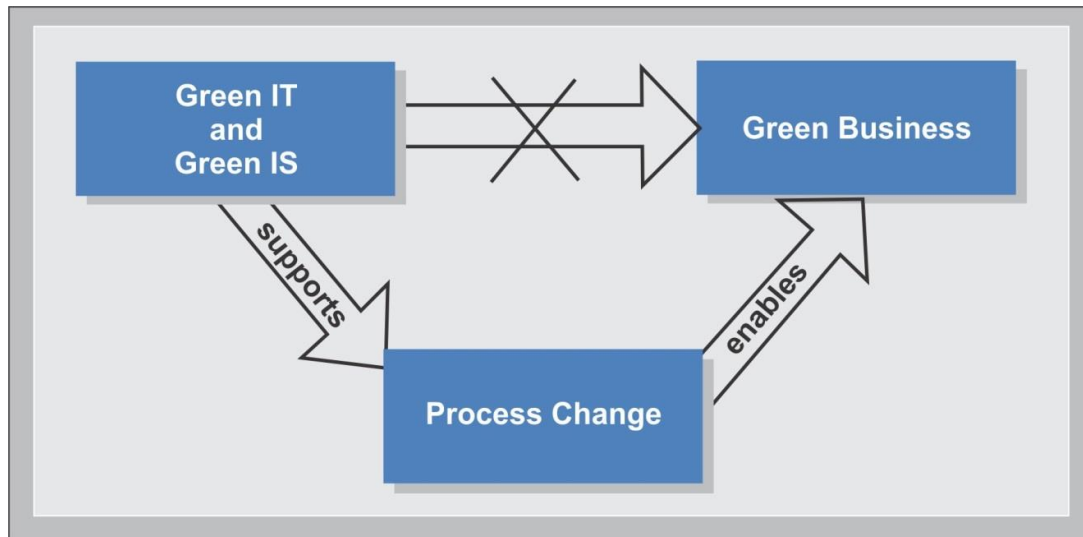


Figure 2.2: The role of Green IT and Green IS(s) in making an organisation greener (Loos *et al.*, 2011)

Figure 2.2 is an illustration of the role of Green IT and Green IS(s) (Loos *et al.*, 2011).

Figure 2.2 illustrates that Green IT and Green IS can support process change, which enables a greener business. Based on the differences of Green IT and Green IS(s), Figure 2.2 should be changed as represented in Figure 2.3. Green IT serves as a platform and is used within Green IS and is not directly used for business change. Green IS is directly responsible for supporting process change for a Green business.

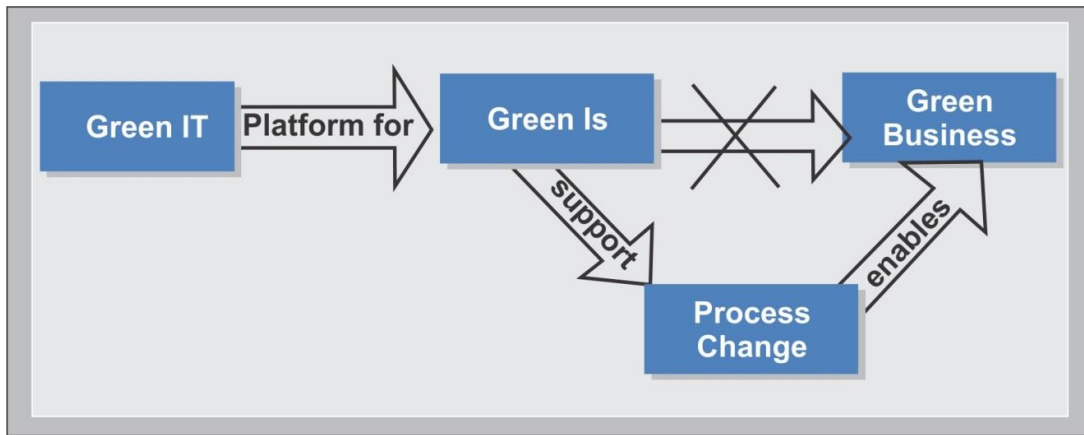


Figure 2.3: The role of Green IT and Green IS(s) in making an organisation greener

Based on the differences of Green IT and IS(s) it is clear that Green IT has one major limitation, namely that it is not a holistic approach and more emphases should be put on Green IS(s) (Erek, 2011; Hilty, 2007). Most of the Green IT approaches only try to improve specific problem areas of IT and do not see the possibilities, which IT can have on an organisation (Hilty, 2007). Therefore it will merely be considered as a platform for Green IS(s). This platform enables a Green IS to extend the scope of Green IT so that an entire organisation's environmental impact can be lowered, while ensuring that this positive change will not be balanced out by the negative effect of the IT used for the IS (Loos *et al.*, 2011; Watson *et al.*, 2010).

The most important usage of Green IS(s) is to decrease the negative environmental impact of entire organisations. The Green IS should be used to change organisational processes, so that the entire organisation can become greener. It is not a new concept that IT can be used by organisations in order to gain competitive advantage (Kettinger *et al.*, 1994). Green IS(s) do not only have a positive impact on the environment but can also have a positive effect on the organisation by improving productivity, reducing cost and increasing profit (Watson *et al.*, 2010; Loos *et al.*, 2011; Erek *et al.*, 2011; Molla, 2009a; Harmon *et al.*, 2010; Argarwal *et al.*, 2012).

There are many areas that have specific Green ISs, which can be implemented in an organisation. Environmental management systems use Green ISs in order to monitor, evaluate, improve and report the environmental impact of an organisation (Watson *et al.*,

2008; Melville, 2010). Green ISs can be used to increase the efficiency of energy consumption and therefore reduce the amount of energy consumed (Watson *et al.*, 2010; Atkinson & Castro, 2008; Hilty, 2007). There are also buildings that incorporate Green ISs in order to adapt to different changes in the environment (Atkinson & Castro, 2008; Fernando & Atsuko, 2009). These buildings are managed by a Green IS that uses remote sensors to monitor and analyse resource usage. This IS can also be used to adjust features of the building, such as the temperature. Different Green ISs are used to increase the efficiency of transportation (Watson *et al.*, 2008; Atkinson & Castro, 2008; Huang, 2008; Hilty, 2007). These systems can be used to manage a transportation fleet and dynamically choose the routes in order to decrease traffic congestion, reduce travel time, as well as to reduce fuel usage. Airlines also use an IS to schedule the least number of flights and to utilise seats as effectively as possible, which ensures that no fuel is unnecessarily wasted. The possibilities for the use of Green ISs are endless and the extensiveness of their use will be determined by the organisation that implements them.

2.2.1 Green IT Strategies and Techniques

In order to achieve one of the sub-objectives of this study, namely to investigate different techniques or initiatives that can be used to reduce the negative impact of IT, this section will identify the different Green IT techniques that are currently available in literature. These techniques will also be used later in the study to achieve another sub-objective, namely to determine how current SDMs can be adapted to have a greener development process and a Green end product.

Green IT strategies and techniques should consider the entire life cycle of IT equipment, since each stage can possibly have a negative effect on the environment. The stages that IT equipment consists of are: design, manufacturing, operation and disposal (Elliot & Binney, 2008; Köhler & Erdmann, 2004; Harmon *et al.*, 2010). Table 2.2 is a summary of different techniques that can be used during the different stages of IT equipment's and services' life cycle:

Table 2.2 Techniques used in different stages of IT equipment's and services' life cycle

Stage of life cycle	Techniques
Design	1. Use Green goals so that products are designed with the environment in mind (Harmon & Auseklis, 2009) 2. Design IT equipment or services so that the usage and the disposal thereof, will have the smallest negative impact on the environment. (Harmon & Auseklis, 2009; Elliot & Binney, 2008; Murugesan, 2008; Abenius, 2009; Harmon <i>et al.</i>, 2010)
Manufacturing	Use low-energy manufacturing practices (Elliot & Binney, 2008)
Operation	1. For printing and paper: a) Print double-sided paper (Molla, 2009a). b) Give employees a personal pin to start a print job and share one large printer (Erek, 2011) b) Use recycled paper (Velte <i>et al.</i>, 2008) b) Go paperless (Send faxes electronically or scan documents) (Velte <i>et al.</i>, 2008) 2. Data centres can be turned into Green Data centres, by buying new energy-efficient equipment or refurbishing old equipment (Molla, 2009a; Harmon & Auseklis, 2009; Ruth, 2009; Murugesan, 2008; Scott, 2011). 3. For physical infrastructure: a) Cooling concepts (Erek, 2011; Harmon & Auseklis, 2009; Velte <i>et al.</i>, 2008) i. Airside/waterside economiser (Molla, 2009a) (Velte <i>et al.</i>, 2008) ii. Hot aisle/cool aisle data centre layout (Molla, 2009a; Velte <i>et al.</i>, 2008) b) Energy management/efficiency (Murugesan, 2008) i. High efficiency stand-by power systems (Molla, 2009a; Erek, 2011) ii. Upgrades to more efficient transformers and UPS (Molla, 2009a) iii. DC-powered IT equipment (Molla, 2009a) iv. The usage of energy-efficient lights (Molla, 2009a) v. Grid computing (Erek, 2011) c) Use renewable energy sources (Molla, 2009a; Watson <i>et al.</i>, 2008; Murugesan, 2008; Velte <i>et al.</i>, 2008) 4. For Technical Infrastructure: a. Virtualisation Concepts: (Erek, 2011; Harmon & Auseklis, 2009; Molla, 2009a; Ruth, 2009; Velte <i>et al.</i>, 2008) i. Server consolidation and virtualisation (Molla, 2009a; Murugesan, 2008; AIIA, 2009) ii. virtualisation/Thin Clients (Erek, 2011; Watson <i>et al.</i>, 2008; Molla, 2009a; Ruth, 2009; Murugesan, 2008; AIIA, 2009; Velte <i>et al.</i>, 2008)

Stage of life cycle	Techniques
	b. Rightsizing IT equipment (Molla, 2009a) c. Storage tiering (Molla, 2009a) d. Data de-duplication (Molla, 2009a) e. Cloud computing (Erek, 2011; Harmon & Auseklis, 2009; Ruth, 2009; Scott, 2011) f. Power and workload management (Erek, 2011; AIIA, 2009; Harmon & Auseklis, 2009; Molla, 2009a) i. Power and workload management software (Harmon & Auseklis, 2009) ii. Shift from desktops to laptops (Harmon & Auseklis, 2009) iii. Compliance to standards and laws (Erek, 2011) v. Power-efficient monitors (Ruth, 2009) vi. Use black screens instead of screen savers (AIIA, 2009; Velte <i>et al.</i>, 2008) v. Monitoring of power consumption of IT Equipment (Capra <i>et al.</i>, 2012; Velte <i>et al.</i>, 2008) vii. Use Green drives (Velte <i>et al.</i>, 2008) viii. Use colours that are not very bright for interfaces (Velte <i>et al.</i>, 2008)
Disposal	1. It should be disposed of in an environmentally friendly manner (Molla, 2009a; Murugesan, 2008) 2. Recycle IT equipment (Molla, 2009a; Ruth, 2009; Murugesan, 2008; Velte <i>et al.</i>, 2008). 3. Choose vendors with a take-back option. 4. Re-use Equipment (Velte <i>et al.</i>, 2008)

The design, manufacturing, operation and disposal of IT equipment all have different considerations that need to be taken into account and each of the stages has many ways in which to possibly improve the environmental impact of the IT equipment. When IT equipment and services are *designed*, the impact that they will have on the environment should be taken into consideration. If the equipment or service is not designed in an environmentally friendly manner, all the other stages of the life cycle will also have a larger negative effect on the environment. IT equipment should be designed so that it is easy to recycle (Harmon & Auseklis, 2009). During this stage it must be ensured that as little as possible toxic material will be used for the manufacturing of the IT equipment. These materials will be a problem in the disposal stage (Elliot & Binney, 2008; Harmon *et al.*, 2010).

The *manufacturing processes* should use as little electricity as possible (Elliot & Binney, 2008). The *operation stage* is very important and is the stage, which can be made greener the easiest. A policy should be determined for the operations of IT, including how IT infrastructure can be used to help with the greenness of the organisation. The IT equipment should be operated with consideration to the environment. The policy should include IT power management, staff computer usage and Green data centres. The policy should also be enforced to ensure that it is used (Molla, 2009a). IT equipment consumes a very large amount of electricity and therefore during the operation stage power management is essential (Elliot & Binney, 2008). During the operation stage it must be ensured that the energy usage of IT equipment and its cooling is kept to a minimum, that the IT equipment is energy efficient and that the overall negative effect of IT equipment on the environment is kept to a minimum. IT equipment and infrastructure that use energy, should to be turned off when not in use (Molla, 2009a).

A policy should also be determined for the *disposal* of IT equipment. The policy should state if IT equipment is to be re-used, refurbished, recycled or disposed of (Molla, 2009a). Electronic waste should be minimised and disposed of in the correct manner (Harmon & Auseklis, 2009).

The life cycle of IT equipment and services is very important, but it is not the only area that can contribute to greener IT. The following are additional areas, which can be made greener by means of specific techniques as summarised in Table 2.3.

Table 2.3: Additional Green IT techniques

Area	Techniques
Processes	1. Green process engineering (Harmon & Auseklis, 2009; Loos <i>et al.</i>, 2011) 2. Notations methods (Hoesch-Klohe <i>et al.</i>, 2010)
Communication	Teleworking and video conferencing (Loos <i>et al.</i> , 2011; Erek, 2011; Watson <i>et al.</i> , 2008; Fernando & Atsuko, 2009; Ruth, 2009; AIIA, 2009; Fuchs, 2008; Ijab <i>et al.</i> , 2010; Velte <i>et al.</i> , 2008)
Procurement/ Sourcing	1. Check for Eco-labels (Erek, 2011; Capra & Merlo, 2009; Ruth, 2009; Murugesan, 2008) 2. Check for certification (Erek, 2011) 3. Perform a TFCO-Analysis (Erek, 2011) 4. Consider Green track record of vendors (Molla, 2009a)

Area	Techniques
Metrics	1. Incorporate different metrics into processes so that the environmental impact of those processes could be monitored (Smith & Williams, 2002; Kipp & Jiang, 2011; Harmon & Auseklis, 2009; Murugesan, 2008; Ruth, 2009; Williams & Lewis, 2008; Rivoire <i>et al.</i>, 2007) : a. Measure data centre efficiency b. IT resource usage c. Organisational metrics d. Job durations e. Project performance reporting f. Use for effective decision making g. Monitor carbon emissions
Green software	1. Software applications should be programmed in such a manner that the consume less resources and have computational efficiency (Ruth, 2009; Steigerwald <i>et al.</i>, 2007; Hannig & T, 2002) 2. Use Multithreading (Steigerwald <i>et al.</i>, 2007) 3. Develop software that will allow a longer life cycle for hardware (Albertao <i>et al.</i>, 2010) 4. Use energy-efficient operating systems (Capra <i>et al.</i>, 2010)

An organisation should focus on the different *processes* within the organisation. Notational methods can also be used to represent processes in terms of resource usage and overall environmental impact. This will help to determine which processes within the organisation have the largest environmental impact and to ensure that the organisation focuses on the biggest problem areas. The existing processes can be reengineered and adapted to become greener and when new processes are designed they should take the environment into account.

Green *communication* techniques, such as teleworking and video conferencing, can be used to eliminate or minimise the transportation needs of an organisation. This means that less transportation is needed, and therefore the organisation will lower its greenhouse gas emissions. A *procurement/sourcing* policy must be determined to establish precise rules for buying IT equipment and services. Organisations need to buy environmentally friendly IT equipment and acquire services from vendors with a Green track record. This policy should include how they are going to analyse the Green track record of IT equipment and services vendors and determine the weights to environmental consideration, so that this can be used to evaluate vendors and sourcing decisions (Loos *et al.*, 2011; Velte *et al.*, 2008). A vendor should also preferably have a *take-back* option, which means that when the equipment is no longer in use it can be returned to the vendor and therefore the responsibility of disposing it is transferred to the vendor (Molla, 2009a).

Metrics can be used to monitor IT equipment to ensure that it is used as effectively as possible and to determine the impact of the equipment on the environment, for example the resource consumption. Software developers often make the mistake of thinking that software does not have an impact on the environment. This is not true. *Environmentally friendly software techniques* are used to ensure that software is as Green as possible. When software is developed with computational efficiency in mind, it will help to extend the life cycle of hardware because it does not require more powerful hardware. These techniques also ensure that software uses as little resources as possible and therefore saves electricity. Software developers should also use an operating system that uses the least amount of resources possible.

2.3 Systems development methodologies

This section consists of three parts. The first section will explain the definition of a SDM, so that there is no ambiguity regarding the term. The second part will investigate different ways of evaluating an SDM and the last part will focus on classification models of SDMs. The reason why these three parts need to be investigated is because they will be applied in a Green context in the next section of this chapter, in order for different research objectives to be achieved.

The definition of an SDM will be derived in the first part of the section, in order to remove any ambiguities regarding the meaning of this term. This part will also include the different components that are encompassed under this term.

2.3.1 Definition of a systems development methodology

It is difficult to define a systems development methodology. There are many different definitions, but not one that is universally accepted (Iivari *et al.*, 2000). The different definitions have led to problems in terms of research, since it is unclear what the author's research is truly about (Ramsin & Paige, 2010). The main idea is clear, that systems development methodologies are used to enhance the systems development process. This process consists of steps and instructions that developers can follow in order to produce a better quality product. Table 2.4 is a summary of systems development definitions from previous research. The different definitions can be compared in order to establish if there are components that are universal.

Table 2.4: Definitions of a Systems Development Methodology

Author(s)	Methodology Definition
(Avison & Fitzgerald, 2006)	"A Systems Development methodology is a recommended means to achieve the development, or part of the development, of information system: based on a set of rationales and an underlying philosophy that supports, justifies and makes coherent such a recommendation for a particular context. The recommended means usually includes the identification of phases, procedures, tasks, rules, techniques, guidelines, documentation and tools. They might also include recommendations concerning the management and organisation of the approach and the identification and training of the participants."
(Repa, 2004)	"A methodology is a set of recommended steps, approaches, rules, processes, documents, control procedures, methods, techniques, and tools for the developers, which covers a whole life cycle of an Information System"
(Riemenschneider <i>et al.</i> , 2002)	"A comprehensive guide to developing a system"
(Whitten <i>et al.</i> , 2001)	"A Systems development methodology is a very formal and precise systems development process that defines a set of activities, methods, best practices, deliverables, and automated tools for systems developers and project managers to use to develop and maintain most of or all information systems software"
(Iivari <i>et al.</i> , 2000)	"An information Systems Development Methodology has been interpreted as an organisational collection of concepts, methods, beliefs, values, and normative principles supported by material resources."
(Roberts <i>et al.</i> , 1998)	"A methodology comprises an overall strategy for computer-based information systems development that includes a flexible framework of the sequence of development tasks along with the techniques used to accomplish each task"
(Hardy <i>et al.</i> , 1995).	"A methodology is the aim of breaking down complex problems into manageable units in a disciplined approach"
(Westrup, 1993)	"A methodology acts to prescribe developers' and users' behaviour while aiming to make the intermediate results of this process more visible to aid managerial control"

Author(s)	Methodology Definition
(Avison & Wood-Harper, 1990)	"A collection of procedures, techniques, tools and documentation aids, which help the systems developers in their efforts to implement a new information system."
(Orr <i>et al.</i> , 1989)	"A methodology is a collection of methods based on a common philosophy that fit together in a framework called the systems development life cycle."
(Veryard, 1985)	"A tentative definition of a methodology might be a generalised set of methods and procedures used on projects."
(Maddison <i>et al.</i> , 1983)	"A Methodology is a recommended collection of philosophies, phases, procedures, rules, techniques, tools, documentation, management and training for developers of Information Systems"

It is clear that from all the definitions in Table 2.4 that certain components of the definitions are repeated. The definition of a systems development methodology should include the following components (Huisman & Iivari, 2006):

A systems development approach:

This involves the philosophical view on which the methodology is built. It is the set of goals, guiding principles and beliefs, fundamental concepts, and principles of the systems development process that drive interpretations and actions. Examples are the structured, object-oriented and information-modelling approaches.

A systems development process model:

A process model is a representation of the sequences of stages through which a system evolves. Some examples are the linear life cycle model and the spiral model.

A systems development method:

A method is a systematic way of conducting at least one complete phase of systems development, consisting of a set of guidelines, activities, techniques, and tools, based on a particular philosophy and the target system. Examples include information engineering.

Systems development techniques:

Development techniques can be defined as procedures, possibly with a prescribed notation, to perform a development activity, for example construction of entity relationship diagrams.

The term 'systems development methodology' is therefore defined with the collection of previous components as is summarised in Figure 2.4.

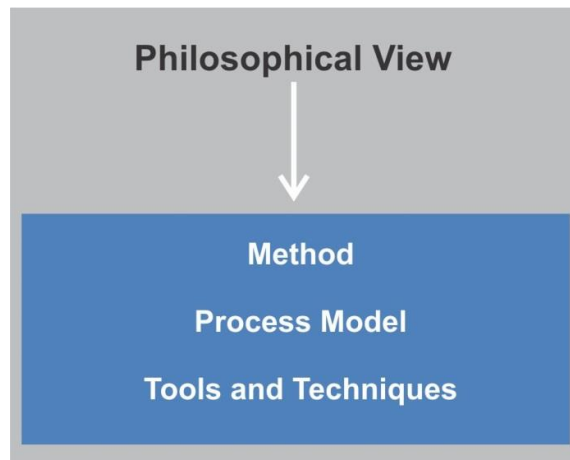


Figure 2.4 Systems development methodology components

The definition of a SDM that was determined by Huisman & livari, (2006) will be used this study.

2.3.2 Evaluation of SDMs

The evaluation of SDMs is important for this study because it will be used to achieve one of the objectives of this study, namely to evaluate different SDMs to determine if Green objectives are incorporated into any current SDMs. The theory explained in this section will be applied in section 2.4.3.

New systems development methodologies are constantly being developed or adapted from previous methodologies because there is not one SDM that is suited for all situations (Siau & Rossi, 2011; Avison & Fitzgerald, 2003). These new methodologies are designed for specific projects or situations. There are different reasons why different SDMs need to be compared, but the two main reasons are for academic and practical purposes (Avison & Fitzgerald, 2006). The academic reason is to establish the characteristics of a SDM, to

determine how to classify it and to use the comparison so that system development can be improved. The practical comparison of SDMs is used to establish which SDM would work the best, or could be adapted the best, for a specific project or organisation. These techniques can therefore also be used to compare different SDMs with each other.

Different researchers will each have a different view when comparing or evaluating SDMs, therefore it is not easy to do. There are several problems when trying to compare different SMDs, namely methodologies are constantly changing and evolving, the necessary documentation for comparing an SDM is not available to organisations that have not bought the SDM, using an SDM is sometimes different to what the documentation describes, terminology can be interpreted differently and lastly, the comparisons are often subjective. Therefore comparisons and evaluations have a high probability of being criticised. Avison and Fitzgerald (2006) and Siau and Rossi (2011) identified the three categories of SDM evaluation methods, namely feature-driven, theoretical and conceptual investigation and lastly, empirical investigation.

The first category is **feature-driven comparison**. This technique works by identifying specific features that an ideal SDM needs to have and then using these features to compare the different SDMs. It can be used to compare methodologies with the same philosophical approach, as well as different philosophical approaches. There is however a problem with this method. The features used in order to compare the SDMs and the interpretation of the comparison of SMDs to the features may not be subjective (Avison & Fitzgerald, 2006). An advantage of the method is that is easy to perform if the features are defined clearly.

The second is **theoretical and conceptual investigation**. These types of evaluations are done for a specific subject area, which eliminates the problem of subjectivity, as well as problems with terminology. Some of the evaluation techniques used include meta-modelling, metrics analysis, paradigmatic analysis, contingency identification, ontological evaluation and cognitive evaluation.

The last category is **empirical evaluation**. Empirical evaluations include different data collection methods, including surveys, experiments, case studies, action research and

verbal protocols, which can be analysed in order to make certain observations regarding SDMs (Oates, 2006).

There are many different examples of evaluation frameworks that can be found in literature. Two examples include the framework of Avison and Fitzgerald (2006) and Jayaratna (1994). The framework by Avison and Fitzgerald (2006) compares methodologies according to seven elements, namely philosophy, model, techniques, scope, outputs, practise and product. Jayaratna (1994) proposed the Normative Information Model-based System Analysis and Design (NIMSAD) framework. The NIMSAD framework evaluates SDMs according to three criteria: the context or problem situation of the SDM, the person who will use the methodology and the problem-solving process.

There are many more different frameworks that all have different criteria for evaluating SDMs (Alter & Ginzberg, 1978; Davis, 1982; Gremillion & Pyburn, 1983; Burns & Dennis, 1985; Shomonta *et al.*, 1983; Bjorn-Andersen, 1984; Benyon & Skidmore, 1987; livari, 1989; Avison & Wood-Harper, 1990; Saarinen, 1990). Feature-driven evaluation is the evaluation method best suited for this study and will be used to compare the different SDMs. The method will be used because the ideal features needed for a Green systems development methodology can be determined based on the literature reviewed in section 2.2.1. These features can then be used for the comparison. The evaluation is discussed in section 2.4.3.

The classification of SDMs is discussed next.

2.3.3 Classification of SDMs

There are more than one thousand methodologies and new ones are constantly being developed (Jayaratna, 1994). There are two lines of thought for classifying all these different methodologies that are mainly used in literature. The first is to classify an SDM according to the different eras of SDMs and the second is to use the dynamic framework of livari *et al.* (2000). Some researchers also use the different evaluation methods discussed in section 2.3.2 to classify SDMs.

There are four eras of SDMs, namely the pre-methodology era, the early-methodology era, the methodology era and the post-methodology era (Avison & Fitzgerald, 2003;

Avison & Fitzgerald, 2006). In the *pre-methodology era* ISs were designed without any formal SDMs. The developers did not have a clear understanding of business requirements and focussed more on technical aspects of systems development, such as programming. The *early methodology era* is known for the usage of different phases and stages to increase the control over the systems development process. The waterfall model, a sequential model, was developed during this stage. This model is also widely known as the Systems Development Life Cycle (SDLC). This model, however, was still not successful in developing ISs especially in projects with frequently changing requirements. The *methodology era* began due to the problems with the SDLC. In response to these problems, approaches called methodologies were introduced. The main methodologies that were used in this era can be classified as structured, data-oriented, prototypical, object-oriented, and participative, strategic or systematic methodologies. The last era is known as the *post-methodology era*, where the usefulness of methodologies was questioned. During this era some SDMs were abandoned, others were adapted for specific projects and new SDMs were developed.

This study will focus on the dynamic framework of Iivari *et al.* (2000) because of its theoretical foundations and because it allows the creation of new classes that can be inserted into the framework. The entire framework is shown in Figure 2.5.

Iivari *et al.* (2000) stated that SDMs can be divided into different abstract classes. Each of these classes has basic characteristics, which are inherited by the SDMs of that class. According to Iivari *et al.* (2000), the classification of SDMs is based on a four-tiered structure:

- Level 1: Techniques of SDMs (Lowest Level)
- Level 2: Methodologies
- Level 3: SDM approach
- Level 4: Paradigms (Highest Level)

Level 1, forms the different components that are used by the methodologies of the level above them. Iivari *et al.*, (2000:186) stated that a technique consists of a well-defined sequence of elementary operations that more or less guarantee the achievement of certain outcomes if executed correctly. These assumptions of the paradigm level are not

only embodied in the SD approaches and methodologies, but even in this level of the model (Avison & Fitzgerald, 2006).

Level 2 consists out of the "Methodology" class. The different methodologies are instances of their specific SDM approach and describe the approach in more detail. A methodology also describes the relationship between different techniques on the lowest level. Systems development methodologies have already been defined in section 2.3.1.

The third level is linked to the paradigm through the beliefs of the paradigm. The paradigmatic features, functionalism, social relativism, neohumanism and radical structuralism can be used to classify ISDAs. These paradigms are based on the four paradigms identified by Burrell and Morgan (1979) for sociology and organisational research. These paradigms were criticised by Hopper and Powell (1985). However, Hirscheim and Klein (1989) showed that these paradigms also existed in IS literature.

The *Functionalism paradigm* is concerned with social systems and how they interact. It also tries to explain social factors, such as the status quo, rational choices and the need of people to be satisfied. The *Social relativist paradigm* tries to explain subjectivity, consciousness of individuals and the difference in perception between a social actor and an observer of the action. The *Neohumanism paradigm* tries to create change within an organisation to ensure emancipation and reaching full potentiality. It also emphasises the social and organisational influences that need to be considered when trying to understand organisational change. Lastly, the *Radical Structuralism paradigm* has the primary goal of overcoming the limitations set on the current social and organisational structure (Zhang *et al.*, 2005). One possible problem with the above-mentioned paradigms is that some SDMs can contain characteristics of more than one paradigm (Hirscheim & Klein, 1989).

The different paradigms are all associated with different assumptions that will guide the SD process and result in different outcomes. Based on these assumptions, Iivari *et al.* (2000) identified different SDM approaches. This level is also called the SD approach class. An SD approach is a class of SDMs and all the SDMs in that class inherit the same characteristics or features. The approach can be seen as the collection of objectives, principles, basic concepts, and principles of systems development, which guides the team during systems development (Iivari *et al.*, 2000). When using an SDM that is an instance of a specific SD approach, all the implicit and explicit assumptions paradigms from which the approach is derived, will be inherited by the SDM (Nabende *et al.*, 2009).

This explanation of an SDM approach is equivalent to the definition specified in section 2.3.1. The following features of an SD approach were categorised by livari *et al.* (2000) as follows:

- **Goals:** Specifies the purpose of the SDM approach.
- **Guiding principles and beliefs:** The philosophy of the SDM approach, which is shared by all the users of that SDM.
- **Fundamental concepts:** Defines the nature of an IS implicit in the approach
- **Principles of the SDM process:** The aspects of the SDM process in the SDM approach.

livari *et al.*(2000) identified the following approaches in their model, namely Structured, Information Modelling, Decision Support Systems, Socio-Technical Design, Infological, Object-Oriented, Interactionist, Speech Act-based, Soft Systems Methodology, Professional Work Practice, and Trade Unionist. The first six approaches are functionalist approaches and the rest are non-functionalist approaches.

The *Structured approach* focuses on creating high quality software in an efficient manner. *Information Modelling* is used for applications, which are integrated across the enterprise and helps with coordinating the development, as well as the long-term maintenance of the ISs. *The Decision Support Systems* approach focuses on developing systems, which are primarily used for structured decision making. The *Socio-Technical Approach* is used to develop IS(s) that are user-friendly, by including users in the development process, as well as having technically sound users to produce an IS that functions well within the organisation. The *Infological approach* is used to make sure that only ISs that will truly contribute to the organisation will be used and understood by the users and ISs that are effective and easy to maintain are developed. Systems development with the *Object-Oriented approach* is done in such a manner that the development is successful in terms of scope, budget and timeframe. This also makes it easier to modify or fix any errors in the system quickly and to maintain the IS with newer technologies. The *Interactionist approach* helps with social issues regarding possible changes to the organisation when implementing ISs. The methodology of the *Speech Act-based approach* is used for communication modelling, especially with speech acts of changes. The *SSM approach* provides a continuously improving methodology, which can be used in order to determine necessary and possible changes. The *Trade Unionist approach* focuses on developing

conditions within the organisation so that the employees can effectively participate to establish good working conditions and a democratic work environment. The *Professional Work Practice Approach* is only used for one reason, which is to increase the degree of professionalism of IS designers. For a complete description of the different approaches, please refer to Iivari *et al.* (2000).

Each level consists of classes, which are an instantiation of a general class in the level above it. Level 4 of the model is the 'Paradigms' class. As explained in section 2.3.1, each SDM has an underlying philosophical view. These views can be used in order to group the SDM approaches into 'paradigmatic positions'. The paradigm can be seen as the different assumptions shared by its users, which facilitates the user to share different perceptions and therefore to use the same practices (Hirschheim & Klein, 1989; Iivari & Hirschheim, 1996; Kuhn, 1962). The paradigmatic positions can be split into four categories; the beliefs of the paradigm used when the SDM approach was developed:

- **Ontology:** The assumed nature of the IS.
- **Epistemology:** What human knowledge is and how it can be acquired.
- **Research Methodology:** Preferred research method and for continuing the improvement of the SDM approach, as well as the one that was used initially
- **Ethics:** The values that should guide information systems research.

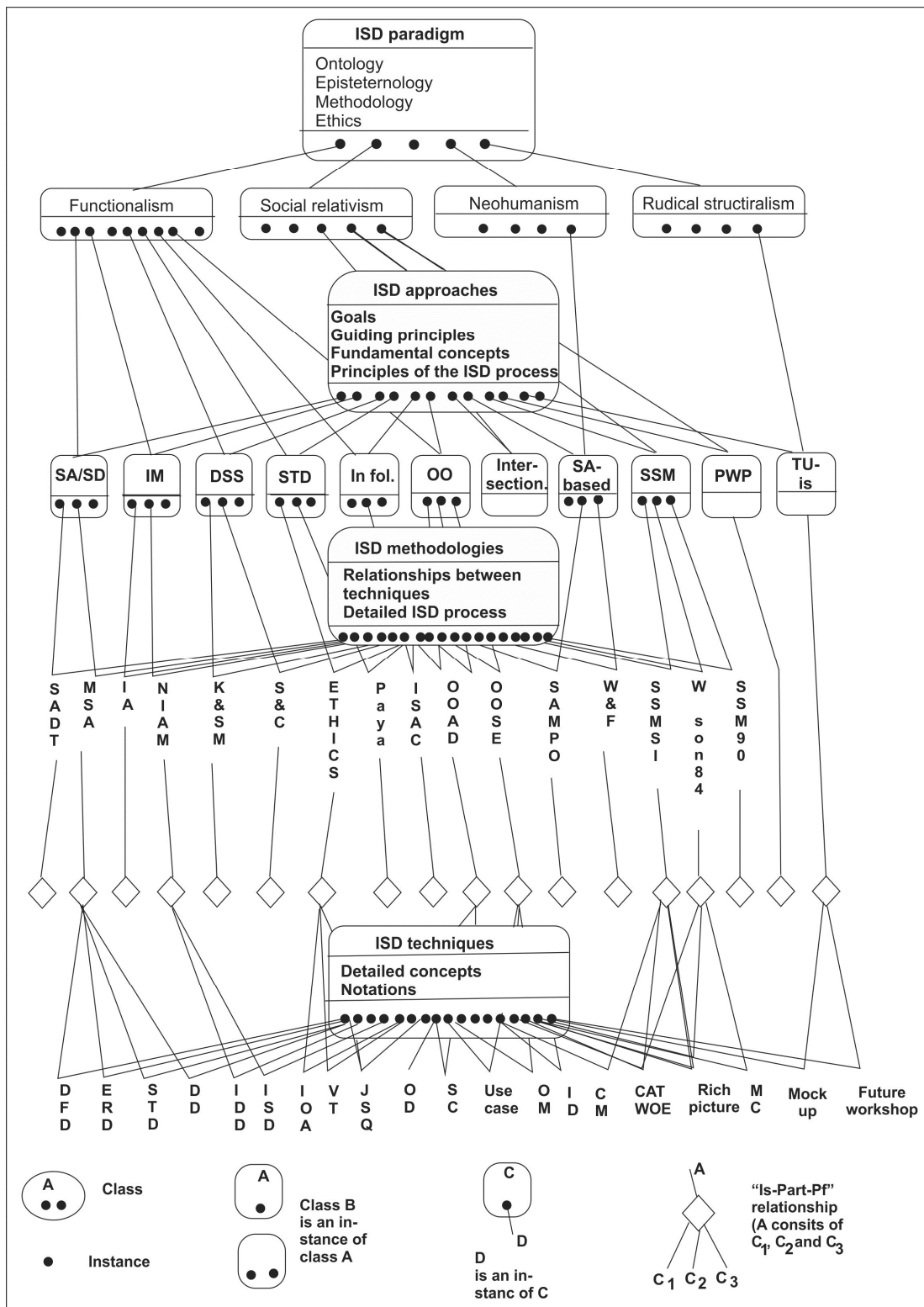


Figure 2.5: The Hierarchy of ISD Paradigms, Approaches, Methodologies and Techniques (Iivari et al., 2000)

The abbreviations for Figure 2.5 are as follows (Iivari *et al.*, 2000):

- Approaches
 - SA/SD = Structured Analysis/Structured Design
 - IM = Information Modelling
 - IE = Information Engineering
 - DSS = Decision Support Systems
 - STD = Socio-Technical Design
 - Infol. = Infological
 - OO = Object-Oriented
 - Interact = Interactionist
 - SA-based = Speech Act-based
 - SSM = Soft Systems Methodology
 - PWP = Professional Work Practice
 - TU-ist = Trade Unionist
- Methodologies
 - XP = Extreme Programming
 - Scrum = Scrum
 - SSAD = Structured Systems Analysis and Design
 - IE = Information Engineering
 - ETHICS = Effective Technical and Human Implementation of Computer-based Systems methodology
- Techniques
 - PP = Pair Programming
 - DFD = Data Flow Diagram
 - ERD = Entity Relationship Diagram
 - STD = State Transition Diagram
 - ISD = Information Structure Diagram
 - IOA = Input/Output Analysis diagram

The classification framework will be used in section 2.4.4 to classify a Green SDM. The next section will apply the theoretical knowledge gained from section 2.3 to Green systems development.

2.4 Green systems development

This section is very important for achieving the first research objective, which is to develop a Green approach towards systems development methodologies so that the development process, as well as the end product is greener. The first part of this section summarises the different Green IT techniques and strategies determined in section 2.2.1. These techniques will then be used together with the knowledge gained regarding evaluation of SDMs in section 2.3.2, to evaluate current existing Green SDMs. The section will also contribute to achieving two sub-objectives, namely to evaluate the different SDMs and to determine if any existing SDMs incorporate Green IT techniques. The current Green SDMs that could be found in literature are explained in section 2.4.2 and the techniques that these SDMs use will be used to partially achieve the objective of the different techniques or initiatives that can be used to reduce the negative impact of IT. The last part of the section also achieves the sub-objective of determining how a Green SDM should be classified.

The section starts by determining the different considerations that are required for a Green SDM. There is a wide variety of Green IT techniques that can be implemented in order to reduce the negative impact of IT on the environment. These techniques or approaches are usually uncoordinated and focus on specific areas of IT. By coordinating and implementing these techniques into a framework, they can be used efficiently to their full potential to help all organisations to maximally improve their environmental impact (Erek, 2011). The following sections describe different Green IT Strategies and techniques and which of these techniques can be implemented into a Green SDM.

2.4.1 Considerations for a Green SDM

After reviewing the different techniques listed in Table 2.2 and Table 2.3, ten considerations can be derived, which need to be considered when developing systems in a Green manner. These considerations were derived by grouping together the different techniques. These considerations are summarised in Table 2.5.

Table 2.5: Considerations that should be taken into account for a Green systems development process and end product

Factor	Description
Green Goals	Green goals should be incorporated into the design stage of system development, because the design will have a large impact on all the other stages of development, as well as the end product. Green goals or objectives should be regarded as a non-functional requirement. These goals include effort to reduce the impact on the environment of the system and the systems development process.
Paper Usage	There are several different initiatives to decrease the quantity of paper used, as well as the amount of printing, which should be incorporated throughout the entire development process. The paper used for the entire life cycle of the system should be minimised.
Green Software	Better programming techniques, which use less resources. The system should be coded with energy efficient constructs. Develop software with a longer life cycle, as well as software that can be re-used.
IT infrastructure	IT infrastructure has several considerations that need to be taken into account: It must be determined whether new IT equipment needs to be acquired or if the old IT equipment can be refurbished. When procuring IT infrastructure the entire life cycle of this equipment should be taken into account. Techniques should be chosen to use and manage the equipment so that it can be used as effectively as possible, while using as little energy as possible.
Physical Infrastructure	Physical infrastructure has several considerations. Cooling concepts with the least negative environmental impact should be chosen Energy usage should be effectively managed and renewable energy sources should be considered. It includes the entire physical infrastructure used for the system, as well as during the development of the system, such as buildings.
Retirement of System	The shelf life of the IS should be determined in order to plan how the retirement and disposal of the system will happen.
Communication	Communication should be as effective as possible, while eliminating negative effects that it may have on the environment. Electronic communication can be used to eliminate the need for travelling.

Factor	Description
Process Centric	The systems development should be focused on processes, which can be reengineered in order to make the organisation more environmentally friendly. Appropriate notational methods should be used in order to indicate the environmental impact of each process
Procurement/ Sourcing	For procurement/sourcing the vendor or dealer and the products should be evaluated to determine their impact on the environment. The vendor should also be analysed in terms of his/her impact on the environment.
Metrics	Different metrics should be incorporated into the IS so that the performance and different impacts on the environment could be continuously monitored and used for improvement.

These ten considerations will be used throughout the rest of the study. They represent the main considerations that should be incorporated into an SDM to ensure that all technology used, as well as the development process to create an IS, will be Green. These considerations will be referred to as the ten Green considerations throughout the rest of the study. The current existing Green systems development methodologies will be discussed next.

2.4.2 Existing Green systems development methodologies

Only a few researchers have recognised the importance of examining how systems development could be improved to become more environmentally friendly (Sheenoy & Eerata, 2011; Huang, 2008; Argarwal *et al.*, 2012; Begtsson, 2010; Naumann *et al.*, 2011). The SDM of Huang (2008) considers the entire systems development process and how it can be adapted to become more environmentally friendly. This is the only article that focuses specifically on systems development. The article of Begtsson (2010) includes economic, environmental and social sustainability but does not cover any of the three areas thoroughly. It lists only four phases of software development and does not have many considerations or techniques to improve sustainability as a whole. The Sheenoy and Eerata (2011) SDM focuses specifically on software development, including different considerations for a more environmentally friendly development process. It also includes additional supporting processes, which include considerations outside of the software development process. The article of Naumann *et al.* (2011) includes a thorough model that includes considerations for developing, using and maintaining software in an environmentally friendly way. This model includes considerations for the entire life cycle of

software products and it considers all possible effects that the use of IT can have on the environment. Lastly, the article of Argarwal *et al.* (2012) does not include a complete SDM but only three activities of software development. The article explains how the three activities can be done more environmentally friendly and that it is done conventionally.

In each article the author explains which phases or activities of systems development can be adapted and how to adapt them, so that they can be more environmentally friendly. Some of the researchers also include additional techniques and considerations, which are not included in a specific phase, but can be used throughout the entire development process. Table 2.6 is a summary of the environmental considerations taken during each phase of the different SDMs:

Table 2.6: Stages and considerations for a greener SDLC in each article

Article	Stages and Techniques adapted for a greener SDM
(Huang, 2008)	Systems planning • Most important stage to bring environmental issues into the system development • Determine solutions that could solve the problem, while not harming the environment or benefit the environment • For each alternative the environmental impact should be assessed • Environmental feasibility should be included to learn if it will be possible to develop solutions with minimal or negative impact on the environment. • Include environmental impact assessments in request proposals • If software development is outsourced the vendor's assessment should include environmental records Systems Analysis • Include existing environmental efforts in the requirement • It should include new efforts • Environmental requirements should be considered together with the same priority as organisational and user needs. ◦ Facilitate electronic document exchange, two-side printing, using printers that accommodate recycled paper

Article	Stages and Techniques adapted for a greener SDM
	Systems Design • Systems should use energy-efficient equipment ○ Use LCD and not CRT screens ○ Use laptops rather than desktops ○ New processors and storage equipment use less energy ○ Green network equipment ○ Use Virtualisation • Power management software ○ Energy star is most common ○ Different operating systems have different power saving functions ○ Specialised power management software Reduction of E-waste should focus on design, not disposal • Physical infrastructure should be energy efficient ○ Buildings ○ Adapt data Centres Systems implementation • Coding ○ Energy efficient codes - ï Emphasise computational efficiency, which makes the completion of a task quicker - ï Data efficiency: minimising data movement ○ Re-use of existing codes ○ Creating of codes that can be re-used in the future - ï Used additional resource-saving features of operating systems • Testing ○ Energy-consumption testing ○ Response-time testing ○ Energy-efficiency testing

Article	Stages and Techniques adapted for a greener SDM
	• Installation ○ Using a network instead of a CD or DVD would eliminate the need for disposable media ○ Distribute manuals electronically rather than on paper ○ Packing materials should be re-used or recycled ○ Dispose of old equipment in the correct manner ○ Migration process should be well planned so that the old system can be put off-line as soon as possible • Training ○ Train users so that the system can be used optimally and thus not use resources unnecessarily
	Systems maintenance • Proper maintenance extends the life cycle of the system • Proper maintenance ensures the system is working at its most efficient state • It can identify underutilised systems and put them off-line • Monitoring and tracking of energy usage of equipment can help identify energy-efficient equipment and replace them Systems Disposal • It is unavoidable to dispose of IT equipment eventually • Transfer of ownership • Destroy equipment, handle recyclable and non-recyclable materials
(Begtsson, 2010)	Planning • E-meetings to avoid emissions due to travel • Construction • Virtualisation of the development environment to minimise CO² • Testing • Set up remote testing environments to minimise travel

Article	Stages and Techniques adapted for a greener SDM
(Naumann <i>et al.</i> , 2011)	Used through the whole software development: • Sustainability retrospective take whole life cycle of system into account ○ Used for lessons learned and best practices, for future projects • Process assessment helps the environmental sustainability of the development process ○ Data of the development process is collected and the impact on the environment is assessed in order to identify factors that should be optimised. ○ Data is collected in a sustainability journal Requirements and Design: • Sustainability review and preview helps to develop a more environmental product ○ Review takes architecture, requirements and coding into account that will have an impact on the environment During the Testing phase: • Metrics that may be appropriate can be incorporated ○ Processing time estimations ○ Energy consumptions estimations ○ Energy consumptions measurements
(Sheenoy & Eerata, 2011)	Requirement gathering • Determine the shelf life of the software; period during which the software will be used. • The software should be able to run on legacy hardware, as well as new one (less disposal of hardware) • Capturing User Interface requirements ○ Choose colours that are not bright (use more power) ○ Include power management policies, which will switch off device when not in use or put in lower power mode • Throw-away prototyping should be avoided to elicit understanding the requirements. ○ A significant amount of power; power and hardware is used for this

Article	Stages and Techniques adapted for a greener SDM
	○ Design a re-usable prototype Design phase • The primary goal should be to achieve simplicity in design ○ Less complex results in less paper work ○ Complex designs may lead to re-design and higher documentation effort using computers and devices which may lead to higher power consumption, fuel consumption on account of travel and other resource usage • Re-use is important ○ Avoid re-implementation of components that are already available ○ Extendibility can bring re-usability ○ Plug in architecture • Repetitive change in design can prove expensive in terms of effort and resources Implementation • Use of Application Programming interface that is hardware-specific should be discouraged. (If hardware becomes obsolete, so will system) ○ Build a hardware abstraction layer ○ This can usually not be used on legacy hardware • Programming constructs to avoid ○ Use of Mutex for synchronisation of threads within a process ○ Use of nested loops ○ Retaining a database connection for a long time ○ Keeping redundant copies of data

Article	Stages and Techniques adapted for a greener SDM
	• Automation of repetitive tasks is very important ○ Reduce time to achieve task and less errors ○ Automatic code generation tools ○ Automatic code review tools • Pair programming can be enforced to reduce the number of resources (Computers) ○ Better understanding and improved implementation Testing • Test automation should be encouraged as it reduces manual errors ○ They emphasise re-use of test cases and standardising the testing process ○ Improves accuracy and productivity and reduces power consumption by additional resources in the manual testing process ○ Performance testing and resource profiling should be promoted as part of testing phase Deployment/Installation • Installation packet size is important ○ More time is needed for installation ○ Needs more storage • Online installation instead of using media that would add to E-waste • A single copy of the software could be deployed centrally and accessed when needed Maintenance • This phase bears impact of all the previous phases • Documentation should be stored electronically to avoid using paper. • Involve a member of the development team in maintenance so that software disassembling is not necessary, which wastes time, resources and power • Avoid software reengineering • System migration should be avoided as it leads to disposal of legacy hardware ○ System should be adaptable to future technologies Retirement • Source code should be disposed of only after determining the relevance of its use in the future.

Article	Stages and Techniques adapted for a greener SDM
	- Electronic resource should not be disposed of to avoid e-waste - Re-use it in other systems - Donate it
(Argarwal <i>et al.</i> , 2012)	Software Requirement Analysis and Specifications - Collect paper forms and questionnaires through electronic means - An Environmental Requirement needs to be a Non-Functional requirement, which is also measured against business needs - Environmental considerations should be considered when purchasing new hardware - Feasibility analysis should include impact of the project on the environment Software design - This phase should include specific measures and practices used to relate to the environment - using less hardware, use of virtualised systems - Software implementation and testing - Coding should focus on energy-efficient codes that minimise the use of system resources - Meet non-functional requirements using the least possible amount of system resources - Test cases should include system usage metrics, which need to be passed

Three of the different articles (Argarwal *et al.*, 2012; Sheenoy & Eerata, 2011; Naumann *et al.*, 2011) also include additional Green initiatives, which are not included in a particular phase. Table 2.7 is a summary of additional considerations during systems development.

Table 2.7: Additional considerations during systems development

Article	Additional considerations during systems development
(Naumann <i>et al.</i> , 2011)	Considerations during the complete Life Cycle of a System: - Development Consider energy necessary to operate IT infrastructure (networking devices, storage, servers) - Consider Infrastructure energy (heating, air conditioning, lights) - Distribution phases - Consider printed manuals (paper and ink)

Article	Additional considerations during systems development
	○ Consider paper, transport and infrastructure ○ Determine the best medium of distribution of the system. • Usage ○ Training of employees (properly trained might need less time to do task) ○ Installation of software patches or updates ○ Configuration of software and IT equipment ○ Configure the workstations to use less power or to shut down • Deactivation ○ Back-up size should be considered ○ The data stored in a format that can easily be converted in the future • Disposal ○ Determine the most efficient manner to dispose of the manuals, data mediums and packaging • Purchasing ○ It includes both purchasing of hardware and software ○ Ecological requirements should be clearly stated in tenders ○ Entire product life cycle should be addressed ○ Environmental sustainability of bidders should be taken into account ○ When custom software is purchased, Green goals should be part of the products non-functional requirements ○ Standard products should have energy efficiency and hardware life time as technical requirements
(Sheenoy & Eerata, 2011)	• Infrastructure ○ Meeting rooms - Natural lighting and ventilation • Store documents electronically and avoid paper usage, use digital signing • Travel ○ Avoid by using electronic communication • Metrics for measuring environmental friendliness of software and its development process.

Article	Additional considerations during systems development
(Argarwal <i>et al.</i> , 2012)	• Software should be developed as simply as possible ○ Software should require the least amount of resources, so that computers do not need to be upgraded or replaced. ○ Software should be developed so that it can be used for a longer period of time without any modification and/or improvement. This will minimise maintenance activities. ○ Develop more efficient algorithms, which will save time and costs and be greener, because software that is executed millions of times will make a big impact. ○ Do not re-use software, which will do more than is necessary and take up extra disk space and memory.

The methodology of Huang (2008) is called the 'sustainable system development life cycle (SSDLC)' This SDM is adapted from the traditional systems development life cycle (SDLC) and consists of six phases, namely systems planning, systems analysis, systems design, systems implementation, systems maintenance and systems disposal. Each of these stages has specific considerations that should be taken into account for a greener development process.

The *systems planning* phase ensures that the environment is taken into account from the start of the development process. The environmental impact of all the possible solutions should be investigated, to make sure that the solution will have the smallest possible negative impact on the environment. This phase also specifies that if outsourcing will be used for the development of the system, that the environmental records of the different vendors should be included in their assessments.

The *systems analysis* phase of the traditional SDLC is used to determine the specific requirements for the project. In this adapted version any current environmental initiatives of the organisation should be included as a requirement, as well as new initiatives. The *systems design* phase includes different recommendations to make sure that energy is conserved and that the amount of waste generated by the system is reduced. The recommendations include using energy-efficient equipment and power management software and choosing greener physical infrastructure.

The *systems implementation* of the system implements the requirements and designs of the previous stages. The implementation also needs to be done with the smallest possible negative impact on the environment. Huang (2008) suggests that the environmental focus during this phase should be put on the way that coding, testing, installation, migration as well as training the users to effectively use the system.

The *systems maintenance* phase is also considered to be very important for the SDLC. Properly maintaining the system can extend the lifetime of the system, will ensure the system is working as efficiently as possible and inefficient equipment can be replaced and put offline. The last phase of this greener SDM is the *systems disposal* phase. All systems will eventually have to be retired. The goal of this stage is to dispose of the system in the greenest possible manner. The author suggests either transferring the ownership of the system or disposing of the material in the correct manner.

The SDM of Begtsson (2010) considers environmental, economic and social sustainability. Only the environmental sustainability factors will be explained, since that is the focus of the current study. Begtsson (2010) identified four generic systems development phases, namely planning, construction, testing, and implementation. Only the first three stages include an environmental sustainability consideration and only one suggestion is made in each phase.

The Greensoft model of Naumann *et al.* (2011) takes the entire life cycle of systems into account. This model considers the first-, second- and third-order effects of the system on the environment, but for this study only the first-order effects will be investigated because the second and third order effects are beyond the scope of this study. This model consists of six phases, namely development, distribution, usage, deactivation and disposal. The *development* phase focuses on the impacts of the systems development process on the environment. The systems development process is a sub-procedure of this phase. The systems development process used here consists of four phases, namely requirements, design, implementation and testing. The process is illustrated below in Figure 2.6.

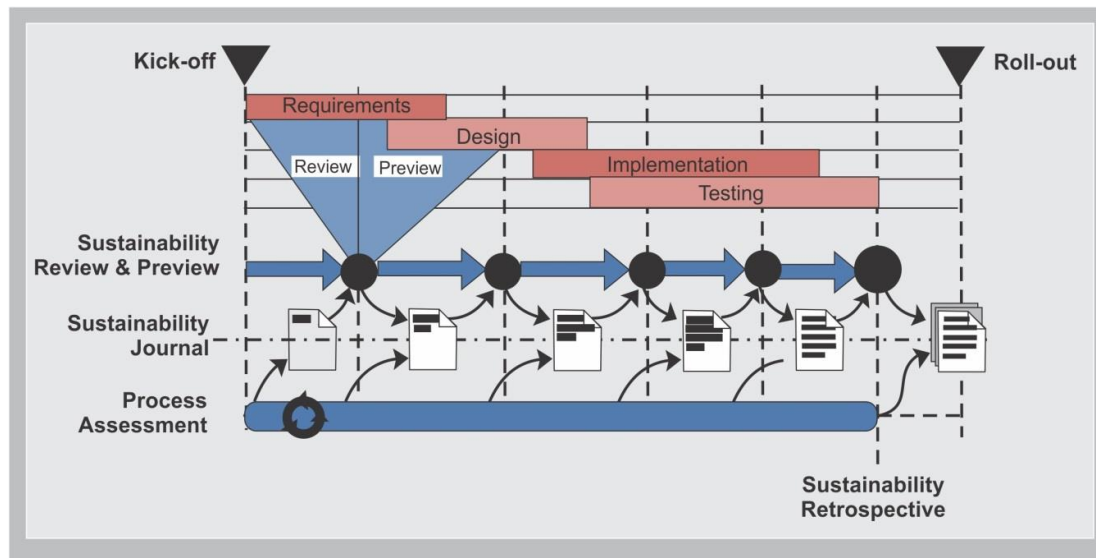


Figure 2.6: Systems development process of Naumann *et al.* (2011)

The process includes four enhancements, which can be used for a greener development process, namely sustainability review and preview, process assessment, sustainability journal and sustainability retrospective. 1. The *sustainability review and preview* assess the outcomes of each phase and then determine which measures can be implemented until the next review in order to make the development process as environmentally friendly as possible. This enhancement also assesses the impact of the development process on the environment. 2. The *process assessment* also monitors the development process throughout the entire development process, so that the systems development process can be adjusted to be as Green as possible. 3. The *sustainability* enhancement combines the data of the previous two enhancements so that the results can be analysed. These results can then be used in future projects in order to improve the overall impact of the systems development process on the environment. 4. The *sustainability journal* is used in order to document all the data of the development process in terms of environmental impact.

The *distribution* phase determines the impact of the distribution of the system and ways to make this phase greener. The *usage* phase accounts for the impact on the environment based on the implementation, usage and maintenance of the system. The *deactivation* phase is concerned with the storage of data once the system has been deactivated. The last phase, *disposal*, takes the impact of disposal and recycling of the system parts into account. This model also recommends a procedure for purchasing hardware and software, which includes several considerations as listed in the table.

Sheenoy and Eerata (2011) also adapted the traditional SDLC so that it can be greener. This SDM is called the 'Green software development model' and consists of seven phases, namely requirement gathering, design, implementation, testing, deployment/installation, maintenance and retirement. Each phase includes several practices that should be included for a greener systems development process. *Requirement gathering* takes into account the shelf life of the system, the power consumption and the prototyping technique. The primary objective of the *design* phase is to design the system as simply as possible. The system should also be designed in such a manner that parts of it can be re-used and that it will not need frequent changes during the rest of the SDLC. During the *implementation* phase no hardware specific application programming interfaces should be used and programming should be done without resource intensive constructs. Sheenoy and Eerata (2011) also recommend pair programming and the use of automated code generation tools. The *testing* phase should be done with test automation. Fewer resources will be used because test cases can be re-used, it standardises the testing process and it improves the accuracy of the testing. The performance and resource usage of the system should also be done to ensure that the least amount of resources is used. The *deployment/installation* phase considers the impact that the installation packet size can have and determines the most environmentally friendly medium for delivering the installation packet. All the previous phases have an impact on the *maintenance* phase. Sheenoy and Eerata (2011) suggest that documentation should be electronic so that paper can be saved, members of the development team should do the maintenance in order to avoid software archaeology and disassembling and avoiding system migration, which might lead to the disposal of legacy hardware. During the last phase, *retirement*, the system should be retired as Green as possible. The re-usable code should be stored for future use and the hardware can be donated. Sheenoy and Eerata (2011) included additional considerations that should be taken into account. These considerations include physical infrastructure, travelling, storage of data, the minimisation of paper usage and adding metrics for measuring the environmental friendliness of systems, as well as the development process.

Argarwal *et al.* (2012) do not provide an entire SDLC, but rather suggest different practices that can be used to improve normal tasks done during systems design and implementation. These practises are explained in terms of three activities, namely software requirement analysis and specifications, software design and software implementation and testing. All the practices of each phase are named in Table 2.6.

Argarwal *et al.* (2012) also suggests that software should be developed as simply as possible and the recommendations are included in Table 2.7.

2.4.3 Evaluation of Existing Green SDMs against Identified considerations

The five different Green SDMs explained in the previous part of this section each consists of different phases used for systems development. The phases are shown in Table 2.8. Three of the SDMs are based on the traditional SDLC (Huang, 2008; Sheenoy & Eerata, 2011; Argarwal *et al.*, 2012), but the phases are not exactly the same. The phases of the traditional SDLC are: feasibility study, systems investigation, systems analysis, systems design, implementation and review and maintenance (Avison & Fitzgerald, 2006). The article of Naumann *et al.* (2011) does not mention how they determined the steps to be used for the systems development process. Begtsson (2010) evaluated the different SDMs and determined four generic phases that were included in most SDMs.

Table 2.8 Different phases of the systems development process of each article

(Huang, 2008)	(Begtsson, 2010)	(Naumann <i>et al.</i> , 2011)	(Sheenoy & Eerata, 2011)	(Argarwal <i>et al.</i> , 2012)
Systems planning	Planning	Requirements	Requirement gathering	Software Requirement Analysis and Specifications
Systems analysis	Construction	Design	Design phase	Software design
Systems design	Testing	Implementation	Implementation	Software implementation and Testing
Systems implementation	Implementation	Testing	Testing	
Systems maintenance			Deployment/ Installation	
Systems disposal			Maintenance	
			Retirement	

The five different methodologies cannot be evaluated according to their phases, because the phases are not the same. Therefore they will be evaluated using feature comparison. The features that will be used for the evaluation are the ten Green considerations identified in section 2.4.1.

The evaluation of each of the Green SDMs will be done as follows:

1. All the considerations of each phase that were identified in Table 2.6 and Table 2.7 will be listed as well as which of the Green considerations identified in section 2.4.1 are fulfilled by them.
2. The SDM will then be compared against each of the Green considerations. All the techniques and considerations used in all phases that fulfil a Green consideration will be listed. A percentage will then be given for the Green Factor, depending on how much the SDM satisfies it. The value will be determined interpretively.

Once all the different SDMs have been evaluated, the results will be summarised in one table in order to be compared.

A Sustainable Systems development life cycle (Huang, 2008)

Step 1

Table 2.9: Considerations in each phase

Phases	Considerations during the phase	Green Considerations
<i>Systems planning</i>	1. Take environment into account and assess each alternative's impact on the environment. Include impact assessments in all the request proposals. 2. If software development is outsourced the vendor's assessment should include environmental records.	Green Goals. Procurement/ Sourcing
<i>Systems Analysis</i>	1. Include existing environmental efforts in the requirement. 2. Requirements should include new environmental efforts. 3. Facilitate electronic document exchange, two-side printing, and use printers that accommodate recycled papers.	Green Goals. Paper usage
<i>Systems Design</i>	1. Use energy-efficient hardware (LCD Screens, laptops, Green network equipment). 2. Use software to help with energy efficiency. 3. Reduction of E-waste should focus on design, not disposal. 4. Consider the physical infrastructure (Buildings, data centres)	IT Infrastructure. Physical Infrastructure. Green Goals.
<i>Systems implementation</i>	1. Coding should be efficient and re-usable. 2. Use the additional resource-saving functions of the operating system. 3. Testing should be done on energy consumption and energy efficiency. 4. Train users so that the system can be used at its best and thus not using resources unnecessarily. 5. Use materials for packaging, etc., which can easily be disposed of.	Green Software. Paper Usage. Retirement of system. IT infrastructure.
<i>Systems</i>	1. Proper maintenance extends the life cycle of the system.	Retirement of system. Metrics. IT

Phases	Considerations during the phase	Green Considerations
<i>maintenance</i>	- Proper maintenance ensures the system is working at its most efficient state. - It can identify underutilised systems and put them off-line. - Monitoring and tracking of energy usage of equipment can help identify energy-efficient equipment and replace them.	Infrastructure
<i>Systems Disposal</i>	- It is unavoidable to dispose of IT equipment eventually. - Transfer the ownership of the system. - Destroy equipment, handle recyclable and unrecyclable materials.	Retirement of system

Step 2

Table 2.10: Considerations that fulfil Green Considerations

Green Consideration	Considerations that fulfil Green considerations	Percentage
Green Goals	- Take environment into account and assess each alternative's impact on the environment. Include impact assessments in all the request proposals. - Include existing environmental efforts in the requirement. - Requirements should include new environmental efforts. - Reduction of E-waste should focus on design, not disposal.	100
Paper Usage	Facilitate electronic document exchange, two-side printing, and use printers that accommodate recycled paper	100

Green Consideration	Considerations that fulfil Green considerations	Percentage
Green Software	1. Coding should be efficient and re-usable. 2. Use the additional resource-saving functions of the operating system. 3. Testing should be done on energy consumption and energy efficiency.	80
IT infrastructure	1. Use energy efficient hardware. 2. Use software to help with energy efficiency. 3. Proper maintenance ensures the system is working at its most efficient state. 4. Train users so that the system can be used at its best and thus not using resources unnecessarily. 5. Maintenance can identify underutilised systems and put them off-line.	90
Physical Infrastructure	1. Consider the physical infrastructure.	50
Retirement of System	1. Use materials for packaging, etc., which can easily be disposed of. 2. Proper maintenance extends the life cycle of the system 3. Transfer the ownership of the system. 4. Destroy equipment, handle recyclable and non-recyclable materials.	100
Communication	NONE	0
Process Centric	NONE	0

Green Consideration	Considerations that fulfil Green considerations	Percentage
Procurement/ Sourcing	1. If software development is outsourced the vendor's assessment should include environmental records.	80
Metrics	1. Monitoring and tracking of energy usage of equipment can help identify energy-efficient equipment and replace them.	50

A sustainable software development framework (Begtsson, 2010)

Step 1

Table 2.11: Considerations in each phase

Phases	Considerations during the phase	Green Considerations
<i>Planning</i>	Avoid carbon emissions due to travel by using E-meetings.	Communication
<i>Construction</i>	Virtualisation of the development environment	IT infrastructure
<i>Implementation</i>	None	None
<i>Testing</i>	Use remote testing environments to minimise travel.	Communication

Step 2

Table 2.12: Considerations that fulfil Green Considerations

Green Consideration	Considerations that fulfil Green consideration	Percentage
Green Goals	None	0
Paper Usage	None	0
Green Software	None	0
IT infrastructure	Virtualisation of the development environment	10
Physical Infrastructure	None	0
Retirement of System	None	0
Communication	1. Avoid carbon emissions due to travel by using E-meetings. 2. Use remote testing environments to minimise travel.	70
Process Centric	None	0
Procurement/ Sourcing	None	0
Metrics	None	0

Green software development model (Sheenoy & Eerata, 2011)

Step 1

Table 2.13: Considerations in each phase

Phases	Considerations that fulfil Green consideration	Green Considerations
<i>Requirement gathering</i>	1. Determine the shelf life of the software. • The software should be able to run on legacy hardware, as well as new hardware, (less disposal of hardware). 2. Capture User Interface requirements (Use energy-efficient colours). 3. Use power management policies, which will switch off device when not in use or put in lower power mode. 4. Design a re-usable power type.	Green Goals. IT infrastructure.
<i>Design phase</i>	1. The primary goal should be to achieve simplicity in design. • Less complex results in less paper work. • Complex designs may lead to re-design and higher documentation effort using computers and devices, which may lead to higher power consumption, fuel consumption on account of travel and other resource usage. 2. Re-use is important. • Avoid re-implementation of components that are already available. • Extendibility can bring re-usability. • Plug in architecture.	Green Goals. Paper Usage.

Phases	Considerations that fulfil Green consideration	Green Considerations
	3. Repetitive change in design can prove expensive in terms of effort and resources.	
<i>Implementation</i>	- Use of Application Programming interface that are hardware-specific should be discouraged. - Build a hardware abstraction layer. - System should be able to work on legacy hardware. - Programming constructs to avoid - Use of Mutex for synchronisation of threads within a process. - Use of nested loops. - Retaining a database connection for a long time. - Keeping redundant copies of data. - Automation of repetitive tasks is very important. - It reduces time to achieve task and is done with less errors. - Automatic code generation tools. - Automatic code review tools. - Pair programming can be enforced to reduce the number of resources. - Better understanding and improved implementation.	IT infrastructure. Green Software.

Phases	Considerations that fulfil Green consideration	Green Considerations
<i>Testing</i>	Test automation should be encouraged as it reduces manual errors. • They emphasise re-use of test cases and standardising the testing process. • Improves accuracy and productivity and reduces power consumption by additional resources in the manual testing process. • Performance testing and resource profiling should be included.	IT infrastructure.
<i>Deployment/ Installation</i>	1. Installation packet size should be considered. • More time is needed for installation. • Needs more storage. 2. On-line installation instead of using media that would add to E-waste. 3. A single copy of the software could be deployed centrally and accessed when needed.	Green Goals. IT Infrastructure.
<i>Maintenance</i>	1. Documentation should be stored electronically to avoid using paper. 2. Involve a member of the development team in maintenance so that software disassembling is not necessary, which wastes time, resources and power. 3. Avoid software re-engineering. 4. System migration should be avoided as it leads to disposal of legacy hardware. 5. System should be adaptable to future technologies.	Paper Usage. IT infrastructure. Retirement of System.

Phases	Considerations that fulfil Green consideration	Green Considerations
<i>Retirement</i>	1. Source code should be disposed of only after determining the relevance of its use in the future. 2. Electronic resource should not be disposed of to avoid e-waste. • Re-use it in other systems. • Donate it.	Retirement of system.
<i>Additional Techniques</i>	1. Infrastructure should be considered. • Meeting rooms should have natural lighting and ventilation. 2. Store documents electronically and avoid paper usage, use digital signing. 3. Travel should be avoided by using electronic communication. 4. Metrics for measuring environmental friendliness of software and its development process should be used.	Physical infrastructure. Paper usage. Communication. Metrics.

Step 2

Table 2.14: Considerations that fulfil Green Considerations

Green Consideration	Considerations that fulfil Green consideration	Percentage
Green Goals	1. Determine the shelf life of the software. 2. The primary goal should be to achieve simplicity in design. - o Less complex results in less paper work - o Complex designs may lead to re-design and higher documentation effort using computers and devices, which may lead to higher power consumption, fuel consumption on account of travel and other resources usage. 3. Repetitive change in design can prove expensive in terms of effort and resources.	70
Paper Usage	1. Less complex results in less paper work 2. Documentation should be stored electronically to avoid using paper. 3. Store documents electronically and avoid paper usage, use digital signing.	90
Green Software	1. Programming constructs to avoid - o Use of Mutex for synchronisation of threads within a process. - o Use of nested loops. - o Retaining a database connection for a long time. - o Keeping redundant copies of data. 2. Pair programming can be enforced to reduce the number of resources.	100

Green Consideration	Considerations that fulfil Green consideration	Percentage
	3. The software should be able to run on legacy hardware as well as new one, (less disposal of hardware).	
IT infrastructure	1. Capture User Interface requirements (use energy-efficient colours). 2. Use power management policies, which will switch off device when not in use or put in lower power mode. 3. Use of Application Programming interface that is hardware-specific should be discouraged. 3. Automation of repetitive tasks is very important. ○ It reduces time to achieve task and is done with less errors. ○ Automatic code generation tools. ○ Automatic code review tools. 5. Test automation should be encouraged as it reduces manual errors. 6. Installation packet size should be considered 7. A single copy of the software could be deployed centrally and accessed when needed 8. Involve a member of the development team in maintenance so that software disassembling is not necessary, which wastes time, resources and power.	80

Green Consideration	Considerations that fulfil Green consideration	Percentage
Physical Infrastructure	Infrastructure should be considered. ○ Meeting rooms should have natural lighting and ventilation.	60
Retirement of System	1. The software should be able to run on legacy hardware, as well as new hardware (less disposal of hardware). 2. On-line installation instead of using media that would add to E-waste. 3. System migration should be avoided as it leads to disposal of legacy hardware. 4. System should be adaptable to future technologies. 5. Source code should be disposed of only after determining the relevance of its use in the future. 6. Electronic resource should not be disposed of to avoid e-waste. ○ Re-use it in other systems. 7. Donate it.	85
Communication	Travel should be avoided by using electronic communication.	50
Process Centric	None	0
Procurement/ Sourcing	None	0
Metrics	Metrics for measuring environmental friendliness of software and its development process should be used.	80

The GREENSOFT Model (Naumann *et al.*, 2011)

Step 1

Table 2.15: Considerations in each phase

Phases	Considerations during the phase	Green Considerations
<i>Requirements</i>	Sustainability review and preview help to develop a more environmental product by taking the environmental impact of the architecture and coding of the system into account.	Green Goals. IT Infrastructure. Green Software.
<i>Design</i>	Sustainability review and preview help to develop a more environmental product by taking the environmental impact of the architecture and coding of the system into account.	Green Goals. IT Infrastructure. Green Software.
Implementation	No specific techniques for this phase	None
Testing	Metrics that may be appropriate can be incorporated during testing. • Processing-time estimations. • Energy-consumption estimations. • Energy-consumption measurements.	Metrics
Additional Techniques	1. Considerations during the entire development process of the system. • Consider energy necessary to operate IT infrastructure (networking devices, storage, servers). • Consider infrastructure energy (heating, air conditioning, lights). 2. Considerations during distribution of the system. • Printed manual (Fernando & Atsuko, 2009).	IT Infrastructure. Physical Infrastructure. Paper usage. Retirement of system. Metrics. Procurement/ Sourcing

Phases	Considerations during the phase	Green Considerations
	- Consider paper, transport and infrastructure. - Determine the best medium for distributing the system. 3. Considerations during usage of the system. - Training of employees (properly trained might need less time to do task). - Installation of software patches or updates. - Configuration of software and IT equipment. <i>Configure the workstations to use less power or to shut down.</i> - Disposal of hardware 4. <i>Deactivation</i> of the system. - Back-up size should be considered. - The data stored in a format that can easily be converted in the future. 5. Sustainability retrospective takes whole life cycle of system into account and is used for lessons learned and best practices, for future projects. 6. Process assessment helps to assess the environmental sustainability of the development process. 7. Purchasing - It includes both purchasing of hardware and software. - Ecological requirements should be clearly stated in tenders. - Entire product life cycle should be addressed.	

Phases	Considerations during the phase	Green Considerations
	- Environmental sustainability of bidders should be taken into account. - When custom software is purchased, Green goals should be part of the product's non-functional requirements. - Standard products should have energy efficiency and hardware life time as technical requirements.	

Step 2

Table 2.16: Considerations that fulfil Green Considerations

Factor	Description	Percentage
Green Goals	- Sustainability review and preview - Considerations during distribution of the system.	100
Paper Usage	Considerations during distribution of the system.	50
Green Software	Sustainability review and preview	50
IT infrastructure	- Sustainability review and preview - Consider energy necessary to operate IT infrastructure (networking devices, storage, servers). - Training of employees (properly trained might need less time to do task). - Configure the workstations to use less power or to shut down.	70

Factor	Description	Percentage
Physical Infrastructure	Consider infrastructure energy (heating, air conditioning, lights).	60
Retirement of System	1. Consider disposal of hardware 2. Consider deactivation of the system.	60
Communication	None	0
Process Centric	None	0
Procurement/ Sourcing	Purchasing	80
Metrics	1. Metrics that may be appropriate can be incorporated during testing. • Processing-time estimations. • Energy-consumption estimations. • Energy-consumption measurements. 1. Sustainability retrospective takes whole life cycle of system into account and is used for lessons learned and best practices, for future projects. 2. Process assessment helps to assess the environmental sustainability of the development process.	70

Sustainable Approaches and Good Practices in Green Software Engineering (Argarwal *et al.*, 2012)

Step 1

Table 2.17 **Considerations in each phase**

Phases	Considerations during the phase	Green Considerations
<i>Software requirement analysis and Specifications</i>	1. Collected paper forms and questionnaires through electronic means. 2. An Environmental Requirement needs to be a non-Functional requirement, which is also measured against business needs. 3. Environmental considerations should be considered when purchasing new hardware. 4. Feasibility analysis should include impact of the project on the environment.	Paper Usage. Green Goals. Procurement/ Sourcing
<i>Software design</i>	This phase should include specific measures and practices used to relate to the environment, such as using less hardware, use of virtualised systems.	IT Infrastructure.
<i>Software implementation and Testing</i>	1. Coding should focus energy-efficient codes that minimise the use of system resources. 2. Meet non-functional requirements using the least possible amount of system resources. 3. Test cases should include system usage metrics, which need to be passed.	Green Software. Metrics
<i>Additional Techniques</i>	1. Software should be developed to be as simple as possible. • Software should require the least amount of resources, so that computers do not need to be upgraded or replaced. • Software should be developed so that it can be used for a longer period of time without any modification and/or improvement. This will minimise maintenance activities. • Develop more efficient algorithms, which will save time and costs and be greener, because software that is executed millions of times will have a large impact. • Do not re-use software, which will do more than is necessary and take up extra disk space and memory.	Green software.

Step 2

Table 2.18: Considerations that fulfil Green Considerations

Green Consideration	Considerations that fulfil Green consideration	Percentage
Green Goals	1. An Environmental Requirement needs to be a non-Functional requirement, which is also measured against business needs. 2. Feasibility analysis should include impact of the project on the environment.	80
Paper Usage	Collect paper forms and questionnaires through electronic means.	60
Green Software	1. Coding should focus energy-efficient codes that minimise the use of system resources. 2. Software should be developed to be as simple as possible. • Software should require the least amount of resources, so that computers do not need to be upgraded or replaced. • Software should be developed so that it can be used for a longer period of time without any modification and/or improvement. This will minimise maintenance activities. • Develop more efficient algorithms, which will save time and costs and be greener, because software that is executed millions of times will have a large impact. • Do not re-use software, which will do more than is necessary and take up extra disk space and memory.	100
IT infrastructure	1. Environmental considerations should be considered when purchasing new hardware. 2. Use less hardware, use of virtualised systems.	65
Physical Infrastructure	None	
Retirement of System	None	
Communication	None	
Process Centric	None	
Procurement/ Sourcing	1. Environmental considerations should be considered when purchasing new hardware.	60
Metrics	1. Test cases should include system usage metrics, which need to be passed.	50

Table 2.19: Results of the evaluation of the different Green SDMs

Green Considerations	(Huang, 2008) Value (100)	(Begtsson, 2010) Value (100)	(Sheenoy & Eerata, 2011) Value (100)	(Naumann et al., 2011) Value (100)	(Argarwal et al., 2012) Value (100)	Total: (500)	Percentage:	Percentage without (Begtsson, 2010)
Green Goals	90	0	70	100	80	340	68	85
Paper Usage	100	0	90	50	60	300	60	75
Green Software	80	0	100	50	100	330	66	82.5
IT infra-structure	95	10	80	70	65	320	64	77.5
Physical Infra-structure	50	0	60	60	0	170	34	42.5
Retirement of System	100	0	85	60	0	245	49	61.25
Communication	0	70	50	0	0	120	24	12.5
Process Centric	0	0	0	0	0	0	0	0
Procurement/ Sourcing	80	0	0	85	60	225	45	56.25
Metrics	50	0	80	70	50	250	50	62.5
Total: (1000)	640	80	615	545	415			

Green Considerations	(Huang, 2008) Value (100)	(Begtsson, 2010) Value (100)	(Sheenoy & Eerata, 2011) Value (100)	(Naumann et al., 2011) Value (100)	(Argarwal et al., 2012) Value (100)	Total: (500)	Percentage:	Percentage without (Begtsson, 2010)
Percentage:	64	8	61.5	54.5	41.5			
Percentage without Process Centric	71	8.8	68.3	60.55	46			
Percentage without communication	80	1.25	70.625	68.12	51.88			

The different SDMs are evaluated interpretively against the ten different considerations. The SDM is given a point out of hundred for each consideration. Each SDM is then given a point out of a thousand. The point is then also represented as a percentage.

The different Green considerations are also given points based on their inclusion in the five SDMs of the articles. Each Green consideration is then given a point out of 500. This point is also represented as a percentage.

Based on the evaluation, the SDMs can be ranked from most-thorough to least- thorough:

1. Huang (2008) with 64%
2. Sheenoy and Eerata (2011) with 61.5%
3. Naumann *et al.* (2011) with 54.4%
4. Argarwal *et al.* (2012) with 41.5%
5. Begtsson (2010) with 8%

The SDM of Huang (2008) scored the highest of the different SDMs with a score of 640 points and is therefore considered the most thorough. It thoroughly considered Green goals, paper usage, Green software, IT infrastructure, procurement/sourcing and retirement of the system. This SDM received a low score for physical infrastructure because the SDM only mentions that it should be considered, both buildings used and data centres, but does not include techniques to make it more environmentally friendly. Metrics were addressed but only in terms of energy usage and therefore also received low score. The SDM is not process centric and it did not consider environmentally friendly communication.

The SDM of Sheenoy and Eerata (2011) scored 615 points and is the second most thorough. The SDM thoroughly considers paper usage, Green software, IT infrastructure, the retirement of the system and metrics. It also addresses Green goals, physical infrastructure and communication but not in detail. The SDM does not consider procurement/sourcing and is not process centric.

The SDM of Naumann *et al.* (2011) scored 545 point. It considered Green goals the most thoroughly of all the SDMs, taking these goals into account during each phase and reviewing after each phase. It also thoroughly considered procurement/ sourcing. The article does consider IT infrastructure, physical infrastructure, retirement of the system, as well as metrics. The last-mentioned considerations, however, did not receive high marks because they were not thorough enough. The article did mention paper usage and Green software, but did not explain how they could be more environmentally friendly. This SDM is not process centric and does not include considerations for more environmentally friendly communication.

The SDM of Argarwal *et al.* (2012) scored 415. It thoroughly considered Green goals and Green software. It addresses paper usage, IT infrastructure and procurement/sourcing but not in great detail. The article also considers metrics, but only mentions it without any detail. The article is not process centric and does not consider on communication, physical infrastructure or the retirement of the system.

The SDM of Begtsson (2010) scored the lowest with 80 points. This article only addresses communication and listed on technique for IT infrastructure. The other eight considerations were not included in this SDM.

By comparing percentages, is clear that these SDMs do not sufficiently fulfil the different Green Considerations. The highest percentage is only 64%, the lowest is 8% percent and the average of the five articles is 45%.

The Green considerations that were included in the different SDMs can also be ranked from most considered too least considered:

1. Green Goals (340 points)
2. Green Software (330 points)
3. IT Infrastructure (320 points)
4. Paper Usage (300 points)
5. Metrics (250 points)
6. Retirement of the system (245 points)

7. Procurement/Sourcing (225 points)
8. Physical infrastructure (170 points)
9. Communication (120 points)
10. Process Centric (0 points)

Even though there are several process centric SDMs (Avison & Fitzgerald, 2006), not one of the five different SDMs focuses on processes. Communication was also only considered in two articles. The only consideration that was included in all five of the articles was IT Infrastructure. Green goals, paper usage, Green software and metrics were considered in all the SDMs except in the article of Begtsson (2010).

Green goals, paper usage, Green software and IT infrastructure all have a percentage higher than or equal to 60%. Retirement of the system, procurement/sourcing and metrics have a percentages of above 40%. The physical infrastructure, process centric and communication considerations have percentages below 40%. This means that only the first four considerations are addressed on a level, which is sufficient.

If the worst scoring SDM of Begtsson (2010) is left out of the interpretation, the results are better, but still not sufficient. Green goals, paper usage, Green software and IT infrastructure all have a percentage higher than or equal to 75%. This means that these four considerations were fulfilled. Retirement of the system, procurement/sourcing and metrics have percentages of above 50%. These considerations are addressed, but they should be further improved. The physical infrastructure, process centric and communication considerations have percentages below 50%. The last-named considerations are not addressed enough.

2.4.4 Classification of Green SDMs

The classification model of Iivari *et al.* (2000) consists of several different SD approaches and SDMs. Even though the model is thorough, sustainable systems development does not fit into any of the existing SD approaches. There is also not any sustainable SDM in this model. Based on this study the model should therefore be extended so that a sustainable SDM can fit into it.

livari *et al.* (2000) developed the framework that is dynamic and allowed SD approaches and SDMs to be added to the framework. By allowing the extension of the framework, it ensured that the framework would stay relevant for longer. There are several steps that need to be followed to extend the framework. The first step in extending the framework should be to determine whether an SD approach or an SDM is going to be inserted. If you want to add an SDM to the framework, you should determine if the features of the SDM are part of the approaches specified in the framework. In either of these two cases it should also be determined if the SDM can be incorporated into only one SD approach (single inheritance) or into several SD approaches (multiple inheritance).

In the case of single inheritance, there are two possible situations. The first is that the SDM is added to an existing class (SD approach) as a new instance. The second situation can occur if an existing class needs to be generalised and a new class is formed with certain features of the current class. The SDM should then be inserted as an instance of the new generalised class. This will then be a case of multiple inheritance and a new class that the SDM can relate to. This class will then be used between the SDM and the classes that the SDM features will fit into, as an intersection class. The superclasses of the intersection class can be existing classes or the generalisations of them.

In the second case, if it is determined that the features of the SDM are not part of the approaches specified in the framework, a new SD approach will have to be added. This approach will then be added to the second level of the framework. The new SDM can possibly fit into more than one approach, so it should be determined if single or multiple inheritance is necessary. If single inheritance is needed, the existing classes can be generalised and their features are modifiable. If multiple inheritance is required the intersection class should contain all the features that accommodate the features of the SDM.

In the case of adding an SDM rather than an SD approach, methodology engineering is used. Methodology engineering focuses on the relationship between methodologies and techniques (Kumar & Welke, 1992). Methodology engineering is to adapt a specific SDM to the environment where it is going to be used. This method has, however, been criticised for neglecting the underlying philosophy of the SDM (Avison & Wood-Harper, 1990). This problem can be solved by focusing on the SD approach instead.

If a new SD approach is created, it should be done in one of the following two ways: the methodology instance can be used as a basis for determining the necessary abstraction of the approach or by creating a unique set of features without the influences of any methodology.

In this study the methodology instance will be used as basis. In order to facilitate a Green SDM, this model requires a sustainable SD approach. The steps of livari *et al.* (2000) were followed in order to extend the framework, so that it includes a sustainable approach. Sustainability can be defined as the ability of one or more entities, either individually or collectively, to exist and thrive (either unchanged or in evolved forms) for lengthy timeframes, in such a manner that the existence and flourishing of other collectivities of entities are permitted at related levels and in related systems (Starik & Rands, 1995:2). A sustainable SDM approach can be described in terms of the three legs of sustainability, namely economic, social and environmental sustainability (Elkington, 1997; Epstein & Roy, 2001; United Nations, 2002; Goodland, 1995). Economic and social sustainability are outside the scope of this study and therefore only the environmental sustainability aspects of the new SDM approach will be discussed. The term Green will be used instead of environmental sustainability, as it is the main term used in this study. The adaption of the model for the purposes of this study is shown in Figure 2.7 below.

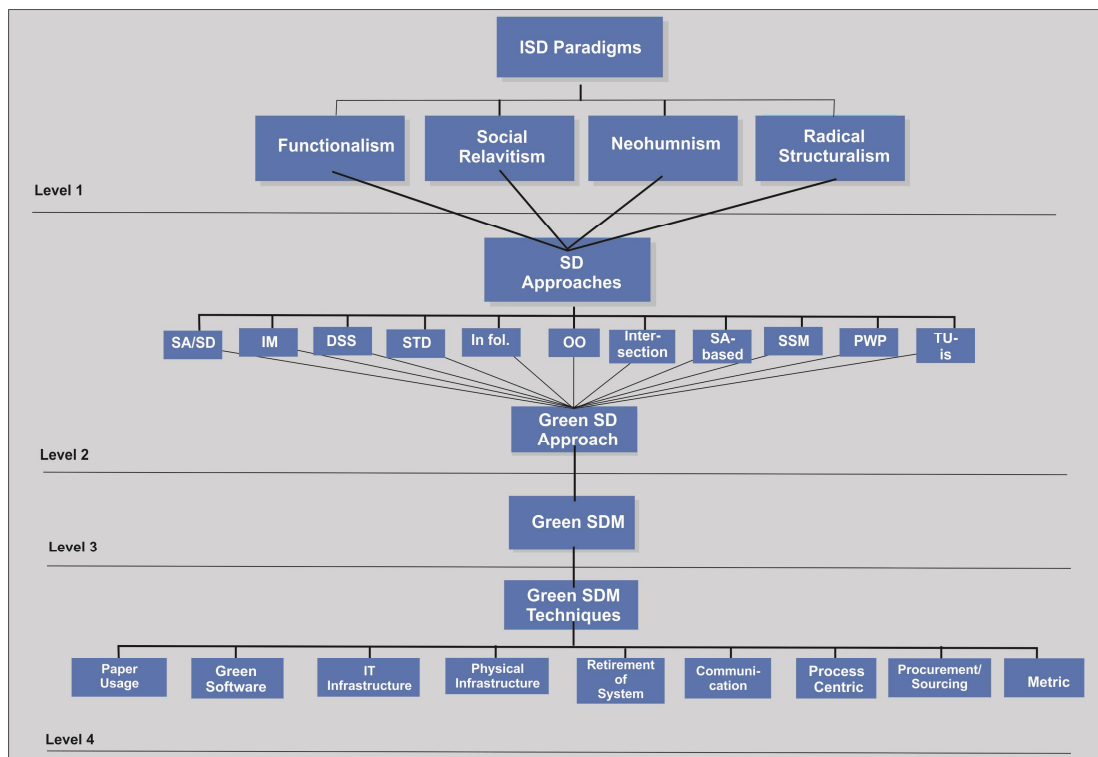


Figure 2.7: Add Green SD approach to classification model

As discussed in section 2.3.1, one of the main goals of an SDM is to make the systems development process more effective. If sustainability is incorporated into an SDM, the main goals of a sustainable SD approach should therefore be to develop ISs effectively, but also in a sustainable manner. A Green SDM therefore requires two different subsets of features; the first enables Green systems development and the second provides effective systems development. Based on these two entirely different subsets, the model of Iivari *et al.* (2000) is extended by including a new approach into the model. This approach serves as a subclass to all the other SD approaches. Therefore depending on the circumstances of an organisation, they can choose the SD approach that helps it to develop systems effectively. The Green SD approaches can then be used as a subclass to provide additional features to the first chosen approach. If the model is extended in this manner, both the main goals of the Green SD approach will be achieved.

Based on section 2.2, section 2.3.1 and section 2.3.3, the Green SDM approach can be summarised as follows:

- **Goals:** To provide an approach that will help to produce high quality systems, while eliminating or minimising negative effects on the environment during the systems development process. The IS that is developed, should also have the smallest possible negative effect on the environment.
- **Guiding principles and beliefs:** Processes form the basis of the information system, because processes can monitor and notated effectively in terms of impact on the environment. All standard systems development principles and techniques, depending on the superclass SD approach, are adapted in order to make them as environmentally friendly as possible. The IS should be developed with environmental sustainability as a critical requirement.
- **Fundamental concepts:** Primarily considerations for the environment.
- **Principles of the SDM process:** Continuous improvement of the SDM process, to improve its environmental impact.

2.5 Summary

This chapter was used to help achieve the first objective of developing a Green approach towards systems development methodologies. The terms 'Green IT' and 'Green IS' were defined and the difference between the terms was clarified in section 2.2.

This chapter achieved the research objective, which requires determining the different techniques and strategies that can be used to reduce the negative impact of IT, in section 2.2.1. This was done by conducting a literature review in order to find the different Green IT initiatives that are available.

Section 2.3 was used to gain a theoretical basis for the term SDM, as well as determining how to evaluate and classify an SDM.

The last section incorporated the first two sections of this chapter in order to reach the research objective of evaluating the different SDMs and to determine if any existing SDMs incorporate Green IT techniques. Current existing Green SDMs were identified and then evaluated using the feature-driven technique discussed in section 2.3.2. The Green IT techniques and strategies were summarised in section 2.4.1 and were used as the evaluation criteria in section 2.4.3. Lastly the classification framework of Iivari *et al.* (2000), explained in section 2.3.3, was applied and used to determine how Green SDMs should be classified in the hierarchy of SDMs. This section helped to achieve the sub-objective of evaluating different SDMs and to determine if any existing systems development methodologies incorporate Green objectives into the systems development methodology and determining how a Green SDM should be classified. Lastly the knowledge gained from the existing Green SDMs also partially achieved one of the sub-objectives of determining how current SDMs can be adapted to have a greener development process and a greener end product.

The next chapter investigates the adoption of Green IT and IS, which is necessary for achieving the second objective, namely determining the possible influences that could affect the adoption of Green IT and Green systems development.

CHAPTER 3

ADOPTION OF GREEN IT AND IS

3.1 Introduction

This chapter focuses on achieving the second main objective, namely to determine the possible influences that could affect the adoption of Green IT and Green systems development. In order to achieve this objective, the factors that motivate or inhibit organisations from adopting Green IT initiatives need to be determined. This chapter also aims to investigate the impact of organisational culture and national culture on the adoption of Green IT/IS, so that both these sub-objectives can be achieved.

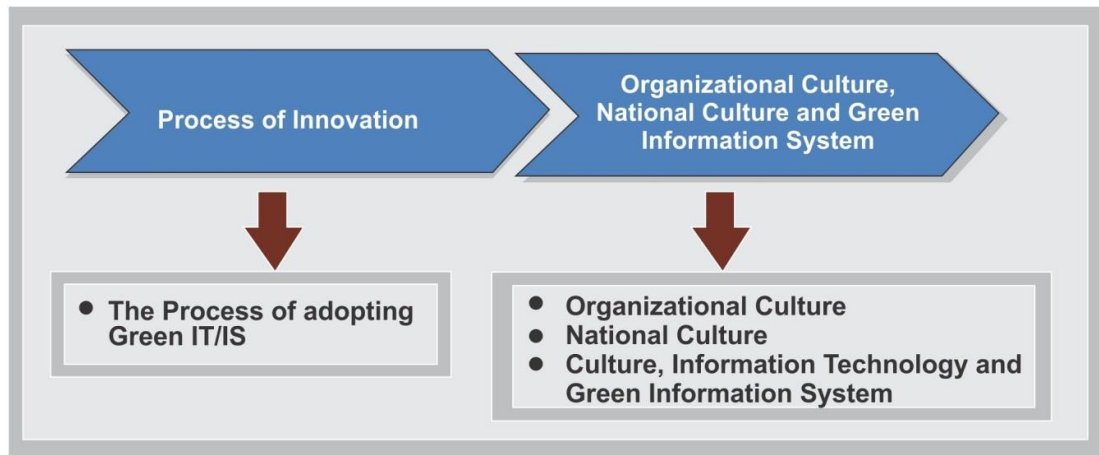


Figure 3.1: Flow of Chapter 3

This chapter will flow as shown in Figure 3.1. The first section will explain the process of adoption that an innovation in the IT/IS industries usually goes through. This is then used as a framework and applied to Green IT/IS in order to determine possible motivating or inhibiting factors, which is one of the research sub-objectives.

The next section focuses on another research objective, namely determining the influence of organisational and national culture on the adoption of Green IT/IS. The first part explains organisational culture (OC), as well as different types of OC. It also investigates different ways of measuring OC in an organisation and the effects of OC. National Culture(NC) is explained in the next part of the section, as well the different possible

dimensions thereof. The last part of this section then uses the first two parts and investigates the effects that OC and NC can have on Green IT/IS.

3.2 The Process of adopting innovations

In order to investigate the objective of determining possible influences that could affect the adoption of Green IT and Green systems development, the adoption process of the adoption of an innovation should first be investigated. An innovation is considered to be a new idea, practice, product, service or object that can either be adopted or rejected by the employees within an organisation (Raghavan & Chand, 1989; Kautz & Larsen, 2000; Rogers, 2003; Trott, 2005). Green IT and Green Systems Development can therefore both be considered innovations.

Rogers (2003:168) defines the innovation-diffusion process as 'the process through which an individual passes from gaining initial knowledge of an innovation, to forming an attitude towards the innovation, to making a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision'. The early assumptions were that a single actor was responsible for an innovation and diffusion process and the process was considered to be simple (Schumpeter, 1969; Fischer, 1999). It was later discovered that the innovation and diffusion process was indeed very complex, with several interactive processes. There are several models for interpreting diffusion of innovations (Van de Ven *et al.*, 1989; Moore, 1991; Mahanjan *et al.*, 1990; King *et al.*, 1994; Davis, 1989); however the model of Rogers (2003) will be used in this study because this model captures the different interactions of the innovation-diffusion process and it has been widely used in the IT and IS areas (Kwon & Zmud, 1987; Prescott & Conger, 1995; Perry & Kraemer, 1978; Kautz & Larsen, 2000). This model is also very significant to this study, since it has been used to explain the introduction and diffusion of SDMs (Raghavan & Chand, 1989; Kautz & McMaster, 1994; Al-Ghatani, 2003). The model has, however, been criticised for not taking the dynamic relationships between all stakeholders involved into account and that it focuses on the individual, thereby ignoring the organisation or population of the individual (Kautz & Larsen, 2000; Robertson *et al.*, 1996).

Green Initiatives will most likely follow this same process when becoming part of an organisation. The diffusion decisions of this framework are not made immediately, but over a period of time and in different stages. Diffusion refers to the steps taken to transfer technology from the creators of the technology to the users (Raghavan & Chand, 1989).

For the purpose of this study, diffusion is the steps taken to transfer SDMs from the creators of the SDMs to the users. Figure 3.2 is an illustration of the five stages of the Innovation Decision Process.

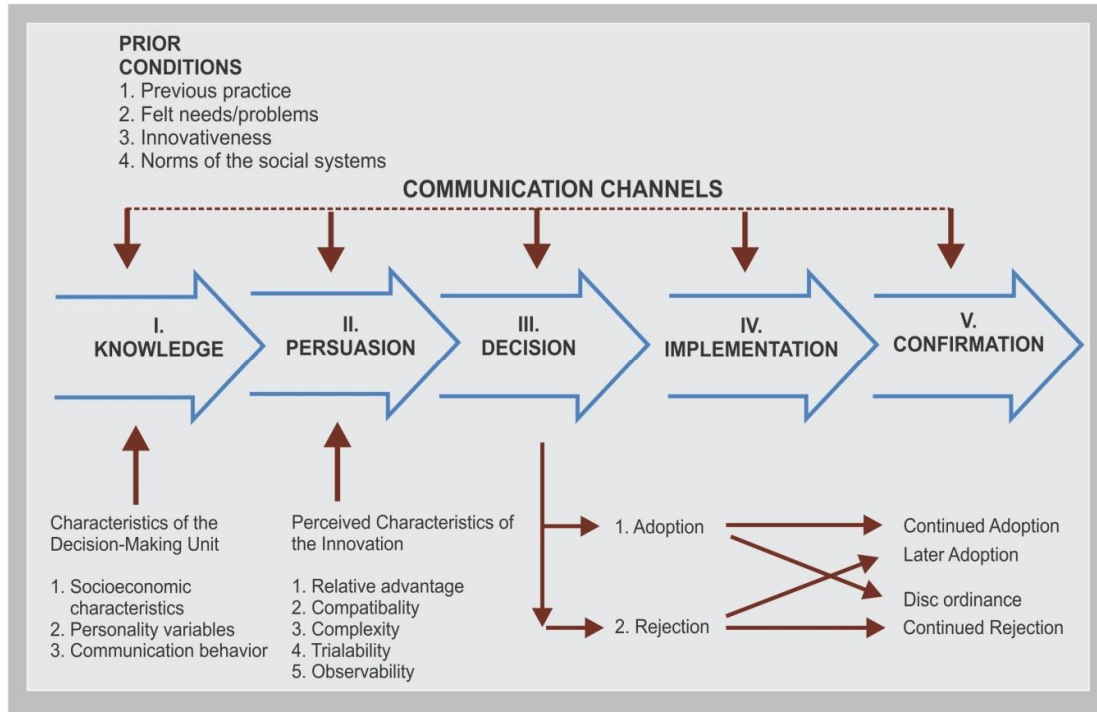


Figure 3.2: A model of the five stages of the Innovation-Decision Process (Rogers, 2003)

The different stages of the process are:

1. **Knowledge** – This first stage occurs when the innovation is shown and explained to an individual for the first time. This is the first time that the individual is informed of the innovation and gathers information about it. There are different types of knowledge that can be obtained by the individual (Kautz & Larsen, 2000). *Awareness knowledge* is the knowledge that a new innovation is available, as well as how to obtain more information about it. *Principle knowledge* is the gathering of information regarding how the innovation functions. There is also *how-to-knowledge*, which is all the information regarding how the innovation can be used. Lastly, there is *innovation-evaluation knowledge*, which consists of the information sought to understand the benefits and concerns of using the innovation.

2. Persuasion ĩ The person will either adopt a favourable or unfavourable attitude towards the innovation.
3. Decision ĩ The individual will have two choices, either to adopt the innovation or to reject the innovation. At this stage views will already be developed as to whether the innovation will affect the firm positively or negatively (Gopalakrishnan & Damanpour, 1997).
4. Implementation - This stage takes place if the individual adopts the innovation and uses the new idea.
5. Confirmation ĩ This stage takes place when the individual seeks confirmation about the implemented innovation-decision. If, however, the individual does not receive confirmation, this person might want to discontinue the usage of that innovation-decision.

The characteristics of the innovation play a major role in the adoption process. Rogers (2003) identified five characteristics, which influence the adoption of an innovation. These characteristics are: relative advantage, compatibility, complexity, trialability and observability. *Relative advantage* is how the innovation will benefit the adopter and how it compares to current innovations, which are in use. *Compatibility* is the level at which the innovation is perceived to be compatible with the potential adopters and their values. Compatibility includes determining if the innovation is aligned with the existing objectives of the adopters. *Complexity* is the perceived level of difficulty to understand and use the innovation. *Trialability* is the level of how experimentally an innovation can be used for a short duration. *Observability* is the degree of visibility that the results of implementing an innovation have. If these attributes are perceived well, there is a higher chance of a successful implementation (Kautz & Larsen, 2000).

The process also includes four elements that influence the diffusion process (Rogers, 2003). The elements are innovation, communication channels, time and social systems.

Innovation is defined in the beginning of this section. The *communication channels* are all mediums through which information of the innovation is shared and distributed to individuals. Possible mediums can be interpersonal channels such as face-to-face meetings or mass-media channels, such as television. This element also be classified as

cosmopolite channels or localite channels, referring to sources from outside the social system and/or internal sources respectively (Tornatzky & Klein, 1982).

Time is the amount of time that a person takes to complete the stages of the framework and either adopts or rejects the innovation. The adopters can be categorised into five categories, depending on the time they take to complete the five stages: innovators, early adopters, early majority, late majority and laggards. The *innovators* are the people who present new ideas to the social system. *Early adopter* adopts the innovation and promotes it to other individuals within the social system. The *early majority* also adopts the innovation, but they have a significant influence on the late majority and laggards. Their perspective of the innovation will play a critical role in the decision of the late majority to adopt or reject the innovation. The *late majority* category refers to individuals who did not gather sufficient knowledge regarding the innovation and therefore the previous three categories need to remove their doubt before they will adopt it. The *laggards* are the individuals who are too cautious and who will adopt the innovation lastly and rely mostly on internal communication channels to obtain knowledge (Tornatzky & Klein, 1982; Kautz & Larsen, 2000).

The last part of the model is the *social system*. This element refers to the environment where the diffusion process will occur, as well as the different groups that work together to achieve the same goal. The social system consists of social structures, social norms, change agents and roles of opinion leaders, the adoption decision-making process and the consequences of adopting innovations. The difference between change agents and opinion leaders is that the first-mentioned do not need to be members of the social system, whereas the latter usually are (Kautz & Larsen, 2000).

The process of adopting Green IT/IS will be investigated next.

3.2.1 The Process of adopting Green IT/IS

The next section investigates the process of adoption of Green IT/IS, which is important, as it partially achieves the goal of the factors that motivate or inhibit organisations regarding the adoption of Green IT initiatives.

The model of Rogers (2003) discussed in section 3.2, can be used in two ways for Green IT/IS diffusion (Raghavan & Chand, 1989). The first way is as a descriptive model, meaning it is used as a theoretical basis for studies. If the model is used in this way, it could help to understand the diffusion of Green IT/IS better. The model has been used descriptively in many different fields, including IT and ISs as mentioned above and new studies can use the knowledge and techniques obtained from these previous methods.

The model can also be used prescriptively. This means that the model is used as a guideline for assisting innovation diffusion. This will help to ensure that the correct actions will be followed when a new innovation needs to be diffused. To do this, it should, however, be ensured that the different terminology of the model will be used in the context of systems development, the correct systems development skills are required, knowledge is obtained about the diffusion of Green IT/IS and pragmatic issues are taken into consideration. Lastly, it is critical that successful interaction between innovation, communication, adoption and the social system is achieved.

In this study the model will be used descriptively. The acceptance or rejection of Green IT/IS should also follow the five stages of the model. In order for the adoption process to be successful, each of the stages should be considered. In stage one, knowledge, the person responsible for the introduction of the Green IT/IS should ensure that the necessity and advantages are clearly illustrated. The stage should then hopefully influence stage two positively so that a favourable attitude towards Green IT will be adopted. The individual to whom the Green IT/IS initiatives are presented will hopefully be persuaded favourably so that he/she chooses to adopt the initiatives in stage three. The implementation stage is also very important, since it will determine the outcome of the final stage's decision to either continue the use of the Green IT initiatives or to discontinue their use. The implementation should be carefully planned and executed.

In this study the focus will be on the 'decision' stage of the model and to determine possible motivational or inhabitant factors that influence it. Based on the reviewed literature in section 3.1 and 3.2.1, five possible motivations for Green ISs are:

- Economic
- Ethical
- Technological

- Regulatory
- Culture

There are many different *economic* factors that could be possible motivations for adopting Green IT/IS. It can also reduce the costs of an organisation by managing resources more effectively (Erek, 2011; Sinnett, 2010; Fernandez *et al.*, 2003; Harmon *et al.*, 2010; Ijab *et al.*, 2010). These resources include energy, the price of which is rapidly rising (Hart, 1995). Green IT/IS can also provide indirect economic benefits, such as attracting and keeping skilled employees, providing competitive advantage, as well as improving the reputation with stakeholders (Porter & Kramer, 2006; Porter & Van der Linde, 1995; Harmon *et al.*, 2010; Sinnett, 2010; Fernandez *et al.*, 2003; Sharma & Vredenburg, 1998; Harmon *et al.*, 2010; Argarwal *et al.*, 2012; Erek, 2011; Ivari & Ivari, 2011). By becoming Greener, it can also have a positive impact on consumers by indicating that the organisation is ethically correct to buy from (Jenkin *et al.*, 2011; Harmon & Auseklis, 2009). Lastly literature also indicates that Green IT/IS can be used for marketing purposes (Erek, 2011).

The *ethical* factor is the second possible motivational factor for Green IT/IS. This factor means that organisations are motivated to adopt Green IT/IS, because they care for the environment (Molla, 2009a; Dedrick, 2010; Lampe *et al.*, 1991). This is often in response to greater awareness of environmental problems, such as climate change (Begtsson, 2010; Harmon & Auseklis, 2009). Literature suggests that doing the ethical thing could be one of the biggest motivators for the adoption (Molla, 2009a; Ehmcke *et al.*, 2009). IT managers often consider adopting Green IT/IS as doing the right thing (Jenkin *et al.*, 2011).

The *technological* factor simply means that technology is available, which can help organisation to be Green and therefore they adopt it (Jenkin *et al.*, 2011; Starik & Rands, 1995). This means that the organisation has the capability to implement Green IT/IS.

Regulatory factors include different laws, regulations or even standards, which force organisations to adopt Green IT/IS (Jenkin *et al.*, 2011; Chen *et al.*, 2010; Starik & Rands, 1995; Ijab *et al.*, 2010). Regulatory factors ensure organisations adopt Green IT/IS, even if they do not want to (Gonzalez, 2005; Olson, 2008). If an organisation does not comply with these regulations it can be very costly and can cause the organisation to

lose revenue, to lose a positive reputation with stakeholders and even to be penalised severely (Avila, 2006; Goosey, 2007; Petzer *et al.*, 2011).

The last possible motivational factor is *culture*. Culture can also possibly influence the adoption of Green IT/IS. The relationship between culture and IT and ISs will be explained in more detail in section 3.3.3.

The research regarding inhibiting factors of Green IT and ISs is currently still very limited. However, based on current literature, possible reasons might be

- cost;
- organizations do not see the business value;
- lack of government incentives or regulations;
- lack of business leadership; and
- inadequate skills and training.

A survey conducted in Australia and New Zealand indicated that the primary inhibitor of Green IT/IS is the *cost* involved (Molla, 2009a). Green practices are often viewed as an unnecessary cost to organisations (Marthur & Marthur, 2000). The economic state of the world is very negative at the moment and this could mean that organisations do not have the capital to invest in Green IT/IS.

The second possible inhibitor of Green IT/IS is that organisations does not see its potential *business value*. This might be due to two reasons. Firstly, that Green IT/IS technology can take a longer time than other investments to produce a positive return on investment (Olson, 2008). The second reason could be that organisations are not aware of other non-monetary benefits, as mentioned above in the economic motivational factor explanation.

As explained earlier in the section, *government incentives or regulations* are a possible motivating factor. In South Africa there are currently no incentives or regulations and this could possibly be inhibiting the adoption of all Green practices (Petzer *et al.*, 2011).

Lack of business leadership is the fourth possible inhibiting factor. The adoption of Green IT/IS is currently very limited around the world. In order for the adoption to increase, executive managers should start to drive the adoption in organisations with a top-down approach (Sinnnet, 2010). Literature suggests that more and more top managers are driving the adoption of Green IT/IS and that this should be part of their responsibilities (Jenkin *et al.*, 2011; Molla, 2008; Waldman *et al.*, 2006). This is, however, not the case in South Africa (Petzer *et al.*, 2011), and a lack of top management leadership could lead to the inhibiting of the adoption of Green IT/IS (Zutshi & Sohal, 2004). Another problem worldwide could also be that even though top management has intentions of adopting Green practices, they do not implement these practices (Esty & Winston, 2006; Olson, 2008).

The last inhibiting factor is *inadequate skills and training*. Even if top management does enforce adoption of Green IT/IS, employees that are properly trained and have the right skills are critical to the success of the adoption (Molla *et al.*, 2011; Molla, 2006). The lack thereof can severely inhibit the adoption process. Therefore sufficient experience and training is necessary for successful adoption of Green IT/IS.

These different motivational factors and inhibiting factors can be used as a starting point to determine what influences the decision stage of adopting Green IT/IS.

3.3 Organisational Culture, National Culture and Green Information Systems

This section aims at achieving the sub-objectives of determining the influence that organisational culture and national culture have on the adoption of Green IT initiatives and the incorporation of Green IT techniques into systems development.

Culture is not an easily definable concept, which makes studying culture difficult (Davison & Martinsons, 2003; Ngwenyama & Nielsen, 2003; Straub *et al.*, 2002). Even in older literature, 164 definitions of culture already existed (Kroeber & Kluckhohn, 1952). Even though hundreds of definitions exist, Groschl and Doherty (2006) and Hofstede (1991) both describe culture as having different levels. People belong to five groups, which are classified as levels of culture. Figure 3.3 shows the different levels of culture that influence a person.

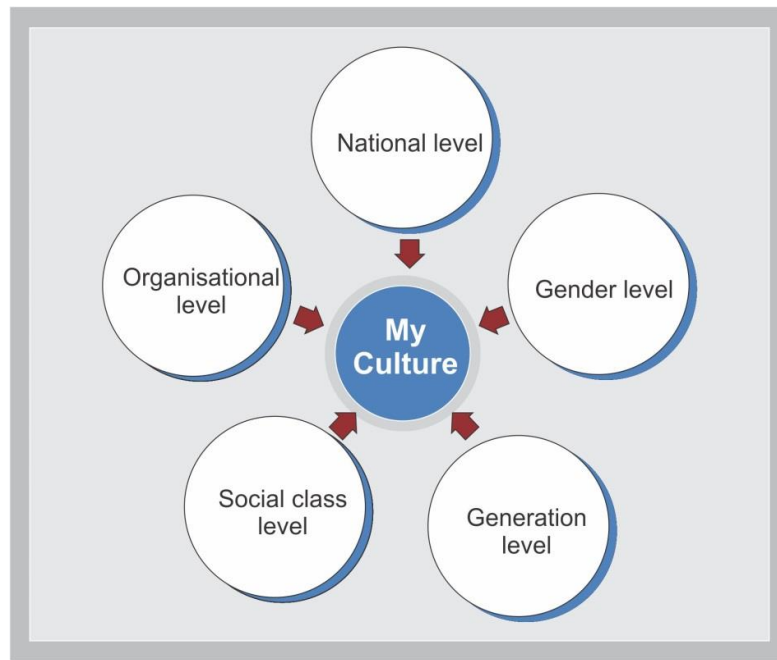


Figure 3.3: Levels of Culture (Brits, 2011)

The *organisational level* is the effect of the culture of the organisation on the employees. The *national level* is the influence of the culture of countries on their residents. The *gender level* is how the gender of the person affects the person's culture. The *generation level* is the influence of when a person was born on his culture. Lastly, the *social class level* is considered as the impact of the person's education and profession on his culture.

Only the organisational and national level will be discussed for this study, since the generation level and the social level is beyond the scope of it. The terms "National Culture" and "Organisational culture" are often used in the same context as the term "cultures" but they are two separate levels of culture and are regarded as two different research areas (Wilkins & Ouchi, 1983; Hofstede *et al.*, 1990; Leidner & Kayworth, 2006). Organisational culture differentiates between the culture of the employees of a specific organisation from that of other organisations and national culture differentiates between the cultures of different nationalities (van Oudenhoven, 2001). In this section both of these terms will be discussed. It is important to discuss exactly what organisational and national culture are in order to effectively determine their impact on the adoption of Green IT initiatives and the incorporation of Green IT techniques into systems development. The section will also describe how these two terms are applied in this particular study.

3.3.1 Organizational Culture

Organisational Culture (OC) is not a new concept and has been studied in early sociological studies (Gouldner, 1954; Selznick, 1949). Organisational culture is identified as a key construct in understanding and managing the behaviour of people within the boundaries of an organisation and in implementing organisational change (Cabrera *et al.*, 2001). This topic that has been and still is widely studied by several researchers in many different fields (Denison, 1990; Schein, 1985; Schein, 1990; Schneider, 1990), but the term still does not have a universally accepted definition (Carmeli *et al.*, 2008; Hofstede *et al.*, 1990). Many different researchers have defined OC (Flamholtz *et al.*, 1985; Martin, 2002; Smircich, 1983; Schein, 1985; Harrington & Guimaraes, 2005; Pekala, 2001; Jones & George, 2007; Robbins, 2001; Lee & Yu, 2004; Tolfo & Wazlawick, 2008; Chiavenato, 1999; Hofstede *et al.*, 1990; Kaarst-Brown *et al.*, 2004; Uttal & Fierman, 1983), identifying components such as beliefs, norms, habits, behaviour, values, practices, rituals and physical manifestation. A person takes on these components through interaction within the organisation (Pascale, 1985; Hofstede, 1991). For the purpose of this study OC will be defined, based on definitions in previous literature, as

All the components (beliefs, norms, habits, values, rituals, etc.) are shared by the individuals of an organisation, which influences their actions and thoughts.

Even though most of these definitions and their components are different, it is established that organisational culture has several levels with different degrees of consciousness with regard to the people of an organisation (Hofstede *et al.*, 1990; Schein, 1985; Groschl & Doherty, 2006). Schein (1985) divides OC into a surface level, intermediate level and the deepest level. The surface level consists of visible and audible patterns, the intermediate level of values and beliefs and the deepest level of basic assumptions. Values are considered to be easier to study than assumptions or cultural artefacts. Hofstede *et al.* (1990) also divided culture into different levels called "categories of elements" as shown in Figure 3.4

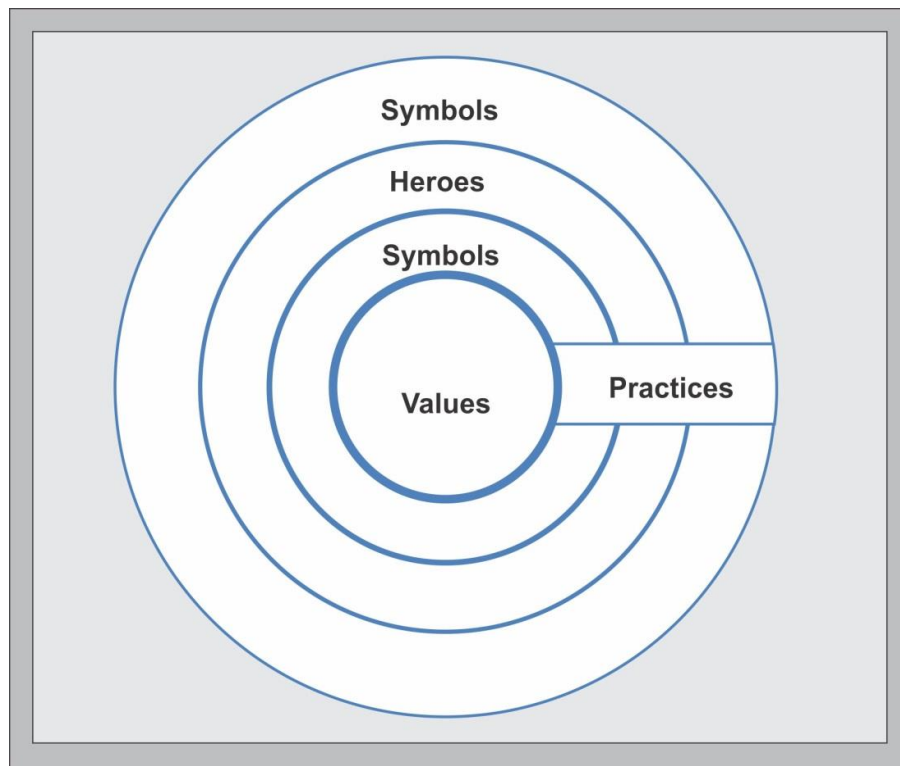


Figure 3.4: Categories of Cultural elements (Hofstede *et al.*, 1990)

Symbols are all the specific semantics, such as words, objects and gestures that are used in a culture. *Heroes* are people, living or dead, who are accurate representations of characteristics, which are sought after within a specific culture. *Rituals* are unnecessary activities performed within a specific culture, which hold meaning and are essential to that culture. *Values* are how people within a specific culture respond or feel towards things. It can also be used to explain why people within an organisation behave in certain way (Shih & Huang, 2010). Values include what people consider to be right or wrong and are associated with what an organisation considers as ethical behaviour. Values are at the core of this model (DeLong & Fahey, 2000; O'Reilly & Chatman, 1996). Values determine what a group considers to be important and can be used to distinguish one group from another; therefore this study will focus mainly on values (Shih & Huang, 2010).

OC can be classified using different models. The model suggested by Wallach (1983) classifies an OC as bureaucratic, innovative or supportive. An organisation with a *bureaucratic culture* emphasises control and power. This type of culture is stable and has a hierarchical structure. The structure is divided into different compartments, each with clear authority and responsibilities. *Innovative cultures* are well suited for driven and

entrepreneurial people. They usually have a high-risk and creative environment to work in. An organisation that has a *supportive culture* makes employees feel as if they are part of a family. This culture has a harmonious environment, which supports the employees and makes them feel safe. O'Reilly *et al.* (1991) suggested seven characteristics, which can be used to identify the organisational culture of an organisation. The seven characteristics are: aggressiveness, detail orientation, innovation and risk, outcome orientation, people orientation, stability and team orientation. OC can also be categorised as relation- and transactional-oriented (McAfee *et al.*, 2002) or flexibility control-oriented (Lewis & Boyer, 2002; Khanzanchi *et al.*, 2007).

The Competing Values Framework (CVF) developed by Quinn (1988), Quinn and Rohrbaugh (1983) and Quinn and Kimberly (1984) consists of four types of cultures, namely rational cultures, hierarchical cultures, group cultures and development cultures. The CVF has two different axes as shown in Figure 3.5. The first axis represents internal-external focus. The axis shows if an organisation prefers to focus on internal or external events. If the organisation focuses internally, it focuses on maintaining and improving the organisation, while an external focus reflects competition, adaption and interaction with the external forces on the organisation (Khanzanchi *et al.*, 2007; Stock *et al.*, 2007; Jackson, 2011). The second axis represents change-stability and indicates if an organisation emphasises change or stability. Change reflects flexibility and spontaneity, whereas stability reflects stability, control and order (Shih & Huang, 2010; Khanzanchi *et al.*, 2007; Berthon *et al.*, 2001; Jackson, 2011). These two axes divide OC into the four types, namely group culture, development culture, hierarchical culture and rational culture.

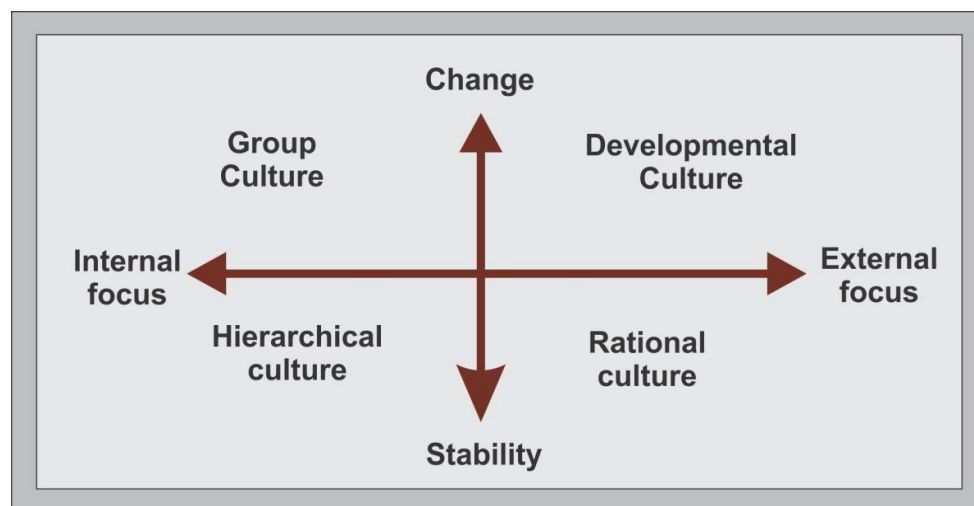


Figure 3.5: Competing Values Framework of organisational cultures (Iivari & Huisman, 2007)

The *group culture* (change and internal focus) focuses on the human aspects of the organisation, such as teamwork, loyalty and human development. The main values of this type of culture include trust and teamwork. A group culture feels that the development of individuals is very important (Cameron & Quinn, 2006; Dastmalchian *et al.*, 2000; livari & Huisman, 2007; Denison & Spreitzer, 1991; Quin & Kimberly, 1984; Shih & Huang, 2010).

The *hierarchical culture* (stability and internal focus) is very strict and formalised. It is security- and control-oriented. This organisational culture prefers to have a strict routine and enjoys a regulative environment, which helps to maintain control and stability (Cameron & Quinn, 2006; Dastmalchian *et al.*, 2000; livari & Huisman, 2007; Denison & Spreitzer, 1991; Quin & Kimberly, 1984; Shih & Huang, 2010).

The *development culture* (change and external focus) focuses on future growth, innovation and adaption. This is a very effective organisational culture, as it tends to create future growth by acquiring resources, emphasis creativity of individuals and adapting to external influences (Cameron & Quinn, 2006; Dastmalchian *et al.*, 2000; livari & Huisman, 2007; Denison & Spreitzer, 1991; Quin & Kimberly, 1984; Shih & Huang, 2010).

Lastly, the *rational culture* (stability and external focus) is achievement-, goal- and result-oriented. The focus of the culture is productiveness and achievements of individuals (Cameron & Quinn, 2006; Dastmalchian *et al.*, 2000; livari & Huisman, 2007; Denison & Spreitzer, 1991; Quin & Kimberly, 1984; Shih & Huang, 2010).

Organisations are unlikely to fit precisely into one quadrant, but will rather have a combination of values with some more dominant than others (Denison & Spreitzer, 1991; Shih & Huang, 2010; Quin & Kimberly, 1984; Jones *et al.*, 2005; Zammuto *et al.*, 2000; Jackson, 2011). Organisations can also frequently form subcultures if the organisation is very large, leading to different departments within an organisation developing their own culture (Smircsh, 1983; Cabrera *et al.*, 2001; Jermier *et al.*, 1991; Gregory, 1983). There are other models available to measure organizational culture with quantitative data, such as the Organisational Culture Inventory (Cooke & Rousseau, 1988) but their complexity does not make them feasible for this particular study.

In this study the CVF will be applied only to the IT departments of organisations. This framework will be used to measure the OC, since it focuses on values as the main component of an OC. The CVF is also applicable to this particular study because it can be used with quantitative data and is relevant to the IS field, (Denison & Spreitzer, 1991; Quinn & Rohrbaugh, 1983; Quinn & Kimberly, 1984; Dastmalchian *et al.*, 2000; Leidner & Kayworth, 2006; Hauser & Paul, 2006; McDermott & Stock, 1999; Ngwenyama & Nielsen, 2003; Ruddle & Harrington, 2001). It will also be used because even though it has been criticised for not being suitable for studying the internal dynamics of an organisation (Jackson, 2011), it is widely accepted in the scientific community. Lastly, it will be used because it has been used in several studies to classify organisational culture (Shih & Huang, 2010; Ivri & Huisman, 2007; Ancarani *et al.*, 2009; Ivri & Ivri, 2011; Deshpande *et al.*, 1993; Igo & Skitmore, 2006; Obenchain & Johnson, 2004; Stock *et al.*, 2007; Ngwenyama & Nielsen, 2003; Lau & Ngo, 2004). It has also been empirically validated and can be used in innovation adoption studies (Khanzanchi *et al.*, 2007; Deshpande *et al.*, 1993; Ralston *et al.*, 2006; Cameron & Quinn, 2006).

3.3.2 National Culture

On the national level a person's culture will be measured as part of his/her specific country (Hofstede, 1991). The way that individuals within an organisation think, is influenced by their national background and can affect how they cooperate with people from a different nation (Hofstede, 1983a; Horwitz *et al.*, 2006). The National Culture (NC) influences the organisational culture of a person, and affects his/her decision-making and leadership style (Heales *et al.*, 2004). NC forms part of an individual through many influences, such as families or schools where they take on prevailing values of that nation (Van Oudenhoven, 2001). When children reach the age of ten, they will already have established most of their values (Hofstede *et al.*, 1990). All of the individual's life experiences and influences come from within a specific group (Hofstede, 1983b). People who live in different countries throughout their lifetime will be affected by each of those countries' cultures (Hofstede, 1991).

NC is very important, since organisations need to be able to work with many different cultures and national backgrounds (Hofstede, 1983a). The increase in industrial globalisation, outsourcing activities and the use of virtual teams makes understanding national cultures even more important (Braun, 2007; Kankanhalli *et al.*, 2007; Powell *et al.*, 2004; Horwitz *et al.*, 2006; Bird & Stevens, 2003; Nicholson & Sahay, 2001; Barrett *et al.*, 1996). If organisations do not take it into account, it can lead to many misunderstandings

and conflicts between people from different geographical locations (Cartwright & Cooper, 1993; Cartwright & Cooper, 1996; Olie, 1994) . By understanding national culture, organisations are able to determine if intercultural cooperation will be problematic, as well as be able to find possible solutions to the problem (Krick & Vob, 2007). NC has a much larger effect on the values of individuals than their organisational membership (Hofstede *et al.*, 1990; Ralston *et al.*, 1997).

Hofstede (1983) developed a quantitative way to measure national culture. From the study done by Hofstede (1983b) four dimensions were identified that could be used to show differences between different countries. An index is used to quantify the different dimensions. The dimensions of Hofstede (1983b) are

1. Power Distance, which measures to what degree each member of a group, accepts that power in organisations is unevenly distributed. If the power distance index (PDI) is high, subordinates will not be comfortable to talk to their superiors or to reason with them. When the PDI is low, subordinates will be able to talk to their superiors and to reason with them without any fear (Krick & Vob, 2007; Hofstede, 2001; Hofstede & Hofstede, 2005).
2. Uncertainty Avoidance, which is how anxious members of a group get when they are in an unfamiliar situation. A high uncertainty avoidance index (UAI) indicates that individuals are more likely to follow formal rules and are more rigid. A low UAI indicates that people are more flexible and open in the work environment (Krick & Vob, 2007; Hofstede, 2001; Hofstede & Hofstede, 2005).
3. Individualism, where individuals prefer to be more independent and a loose knit group. Collectivism is the opposite of individualism. It is the preference of a close group, where the individuals are dependent on each other. A high individualism index (IDV) shows that individuals feel that sufficient time is necessary for their personal life and that their work environment should allow employees to work independently. A low IDV shows that it is important for employees to be able to improve themselves and develop new skills in the workplace. These individuals also prefer working in teams (Krick & Vob, 2007; Hofstede, 2001; Hofstede & Hofstede, 2005).
4. Masculinity is where the male role in a group is emphasised and differentiated by a need to be assertive and to achieve, as well as being strong. Femininity stands for a group where the roles of a male and female overlap and both sexes are characterised by humility, affection and support for the weak. A high masculinity

index (MAS) indicates a management style that is aggressive and rigid and where financial success is the most important. A low MAS indicates a more democratic management style and that money is not as important as having a sufficient amount of leisure time (Krick & Vob, 2007; Hofstede, 2001; Hofstede & Hofstede, 2005).

5. Long-term Orientation. This dimension was not part of the original findings of Hofstede *et al.* (1990), but it was later added (Hofstede & Bond, 1988). Positive values indicate thrift and perseverance and a negative value in this dimension indicates a great respect for traditions and fulfilling the requirements of the group. The dimension has been critiqued by Fang (2003), who doubts the validity of the dimension. This dimension will not be used within this particular study.

The differences among cultures in these dimensions, has many implications for management practices at organisational level. The PDI and IDV have a large effect on which type of leadership skills will be effective within a specific country. If the power distance is small, democratic leaders are the most effective, whereas if the power distance is large, an autocratic leader is preferred. Individualist cultures prefer incentives given to individuals rather than given collectively in a group, which is effective for collectivist cultures. The MAS and UAI affect the way that people are motivated. People will take more personal risk in a culture where uncertainty avoidance is low and in a masculine culture competition will be more effective for motivation. When the power distance and uncertainty avoidance dimensions are combined, they affect the people's perception of an organisation. Organisations with a large power distance are seen as more centralised, whereas an organisation with stronger uncertainty avoidance is associated with greater formalisation. In the Long-term Orientation dimension, negative values can negatively influence the quality and rate of work in a specific national culture. It can also have a negative effect on work due to people try to conform to the standards of a group (Krick & Vob, 2007; Hofstede, 2001; Hofstede & Hofstede, 2005; Hofstede *et al.*, 1990; Hofstede & Bond, 1988).

There are different models that can be used to measure NC (Hofstede *et al.*, 1990) (House *et al.*, 2004; Schwartz, 1994; Smith, 2006; Krick & Vob, 2007; Schein, 1985; House *et al.*, 2002). Other researchers also identified other dimensions that could help to measure national culture in the IS field, such as the dimension of perception of time by Hall (1984), the dimension of IS designer values by Kumar and Bjorn-Andersen (1990) and the Indulgence versus Restraint Index and the Monumentalism Index of Minkov

(2007). The Globe model of (House *et al.*, 2002; House *et al.*, 2004) consists of nine cultural values. The dimensions are: power distance, uncertainty avoidance, future orientation, institutional collectivism, in-group collectivism, humane orientation, performance orientation, gender egalitarianism and assertiveness. This model was developed over ten years and evaluated culture in terms of values and practices. This model has significance for future national culture studies and is based on reliable and validated estimates (Javidan *et al.*, 2004; Heales *et al.*, 2004).

The model of Hofstede *et al.* (1990) and the dimensions explained above will be used in this study. The main reasons why this model will be used in this study is because it is compatible with quantitative data and even though some criticism exists, the different dimensions have been validated (Ronen & Shankar, 1985; Shackelton & Ali, 1990; Newbury & Yakova, 2006; Tsui *et al.*, 2007; Van Oudenhoven, 2001) and it has been widely used and accepted in literature (Chand & Ghorbani, 2011; Chandy & Williamns, 1994; Bochner, 1994; Chow *et al.*, 1991; Kogut & Singh, 1988; Smith *et al.*, 1998; Sondergaard, 1994). This model has been criticised for categorising culture into dichotomous frames and not being able to understand the different complexities of each dimension (Alvesson, 1998; Ford *et al.*, 2003). Some researchers also did not find the same patterns in their studies, and identified different value classifications (Fernandez *et al.*, 1997). Van Oudenhoven (2001) suggested that the difference in patterns could be because the conclusions of Hofstede *et al.* (1990) were primarily derived from male IBM employees. The employees of IBM may also not be representative of their nation. A second possible reason may also be that the study was conducted several years ago, and the world has changed significantly since that time. At least another possible reason may be that Hofstede also did not clearly separate perceived culture and desired culture in the study.

These dimensions have also been used in several empirical IT studies (Png *et al.*, 2001; Straub, 1994; Watson *et al.*, 1994; Tan *et al.*, 1998; Tan *et al.*, 1998; Meijas *et al.*, 1997; Martisons & Westwood, 1997; Ein-Dor *et al.*, 1993; Keil *et al.*, 2000; Leidner & Kayworth, 2006).

The measurement instrument of the model used for capturing and comparing different values and beliefs of employees is called the *Values Survey Module* (Hofstede *et al.*, 2008). This survey can be used for comparing the national values of different countries, as well as different regions from a single country, but not organisations.

The relationship between culture and IS and IT is discussed next.

3.3.3 Culture, Information Technology and Green Information Systems

In a review of the literature on culture in IT and IS(s), Leidner and Kayworth (2006) determined that research in these areas can be categorised into six groups, namely:

1. Culture and IS development
2. Culture, IT adoption, and diffusion;
3. Culture, IT use, and outcomes
4. Culture, IT management, and strategy
5. IT's influence on culture
6. IT culture.

The studies conducted in the *Culture and IS development* group identified that culture and values led to different perceptions and approaches to systems development. The dominant perception of the second group, namely *Culture and Information Technology Adoption and Diffusion*, was that uncertainty avoidance had a significant effect on the adoption and diffusion of IT. It is concluded that because IT is usually perceived as being risky, higher uncertainty avoidance leads to lower adoption rates of IT. The *Culture, Information Technology Use and Outcome* group had two central research questions. The first question was if different cultures will result in different usage of IT, as well as different benefits from using IT. The second question was in respect of which cultural values result in the best user satisfaction and have the highest IT implementation success rate. The fourth group, *Culture, IT Management and Strategy* focused on decision making and the management of information technology. Group number five investigates if the inverse of the previous groups is possible, namely if IT could impact on culture. *IT culture* is the last group and determined whether a group could attribute values to IT.

The groups that are relevant to this study are culture, IT adoption, and diffusion and culture and IS development.

3.3.3.1 The relationship between IT usage and diffusion, and culture

The relationship between IT usage, diffusion and culture is not a new topic and has already received significant attention from researchers (Jie & Fuming, 2011). Several studies have indicated that their organisational culture can affect the success of implementing and using IT in organisations (Al-Gahtani *et al.*, 2007; Harper & Utiey, 2001; Hoffman & Klepper, 2000; Leidner & Kayworth, 2006; Cooper, 1994; Zhang & Tansuhaj, 2007; Weber & Pliskin, 1996; Ruppel & Harrington, 2001; Robey & Azevedo, 1994;

Harper & Utiey, 2001). Leidner and Kayworth (2006) found 31 articles that focused on IT adoption at an organisational level.

The adoption and implementation process of IT can also specifically be affected by the organisational culture (Liu *et al.*, 2010; Krumbholz & Maiden, 2001). Culture not only has an influence on whether organisations implement IT, but also on how it is implemented (McRary, 1995; Straub, 1994). Several literary works exist that indicate how organisational culture can impact innovation adoption (Khanzanchi *et al.*, 2007; Stock *et al.*, 2007; McDermott & Stock, 1999; Marchewka & Wu, 1997) and IT adoption barriers (Carter & Weerakkody, 2008; Mao & Palvia, 2006; Lippert & Volkmar, 2007; Kitchell, 1995). If the organisational culture is not correct, the usage of IT might not only be strongly resisted, but also modified or even purposefully harmed. The correct organisational culture is therefore required in order to develop good IT competence and effective IT strategies (Zhang & Tansuhaj, 2007; Kanungo *et al.*, 2001).

Organisational culture has been proven to be able to stimulate innovation in an organisation (Ahmed, 1998; Elkvall, 1996; Martins & Terblanche, 2003; McLean, 2005; Mumford, 2000; Chang & Lee, 2007; Higgins & McAllaster, 2002; Lau & Ngo, 2004; Obenchain & Johnson, 2004; Ruigrok & Achtenhagen). Organisational culture can also negatively impact innovation. Adhocracy cultures have a positive impact on innovation, where hierarchy culture negatively influences innovation (Naranjo-Valencia *et al.*, 2011; Detert *et al.*, 2000; Menzel *et al.*, 2007; Droge *et al.*, 2008; Yinghong & Neill, 2004; Skerlavaj *et al.*, 2010; Claver *et al.*, 1998).

The impact of national culture on IT adoption has not received much attention until the last decade (Png *et al.*, 2001; Copper & Zmud, 1990; Geisler & Kassicieh, 1997; Grover *et al.*, 1997). Leidner and Kayworth (2006) identified 51 articles that examined IT at a national level. The different studies revealed that national culture has a definite effect on IT adoption (Erumban & de Jong, 2006; Straub *et al.*, 2001; Straub *et al.*, 1997; Tan *et al.*, 1995) and that national culture can limit IT adoption (Moghadam & Assar, 2008; Straub, 1994).

Leidner and Kayworth (2006) identified three types of conflict that can occur because of difference in values of organisational culture, national culture and subunit culture. The first type is *System Culture* and refers to conflict when the cultural values embedded in specific IT differs from the individuals who are using the system. *Contribution culture*

occurs when the cultural values of a group of individuals are different from the group's IT values. Lastly *Vision Conflict* occurs when the embedded cultural values of IT are different than the group's IT values.

3.3.3.2 The relationship between culture and IS development

The research of culture and IS development determined that culture is also a critical factor in IS management and interest in the relationship between culture and ISs has significantly increased over the last couple of decades (Jackson, 2011; Davison & Martinsons, 2003; Watson *et al.*, 1997). Studies suggest that the culture influences how an IS is used and that the IS can influence the culture of an organisation (Martinsons & Westwood, 1997; Soh *et al.*, 2000; Cabrera *et al.*, 2001; Cooper, 1994). Information systems can even be different according to the culture in which it was developed (Robbins & Styliano, 2003). Culture also impacts the development process of an IS. The culture can influence the entire development process in terms of how both developers and users act (Walsham, 2002; Nicholson & Sahay, 2001), the characteristics of the IS, the acceptance or resistance of the IS and how the IS is used (Kappos & Rivard, 2008).

Several studies on the relationship between culture and ISs have also been done at organisational level (Dube & Robey, 1999; Ngwenyama & Nielsen, 2003; Shih & Huang, 2010; Davison & Martinsons, 2003; Leidner & Kayworth, 2006; Cabrera *et al.*, 2001; Barrett, 1999; Gallivan & Srite, 2005; Hoffman & Klepper, 2000) and national level (Dagwell *et al.*, 1983; Hunter & Beck, 2000; Keil *et al.*, 2000; Peterson & Kim, 2003; Kumar *et al.*, 1990; Tan *et al.*, 2003; Walsham, 2002; Krumbholz & Maiden, 2001). The common conclusion arrived at from these studies was that culture influences the way in which ISs are developed. An organisational culture misfit can also lead to an IS, which is sabotaged, used differently than it was designed for or is a complete failure (Martinsons & Chong, 1999; Hatcher, 1992; Romm *et al.*, 1991; Jarvenpaa & Staples, 2001; Weber & Pliskin, 1996; Robey & Boudreau, 1999; Jackson, 2011; Evaristo, 2003; Rivard *et al.*, 2011; Olie, 1994). Therefore, some studies also focused on identifying compatible culture types of ISs, while others concentrated on adjusting the implementation process of the IS to the culture of the organisation (Iivari, 2006). In a case study done by Pliskin *et al.* (1993), the reason for a failed implementation of an IS was because of conflicts in the organisation caused by presumptions incorporated into the system in the design stage due to organisational culture.

Studies also indicate that national culture can affect ISs. The differences in IS effects may be explained by differences in national culture (Deans & Ricks, 1991). Dagwell and Weber (1983) found that different countries approach IS development in different manners. In another study the importance of understanding organisational culture when a new software development method is implemented in the organisation is emphasised (Dube, 1998). Some countries emphasised certain parts of the development process more than the other parts. Keil *et al.* (2000) determined that if the uncertainty in culture is high, the perception of a project's risk was also held high. Tan *et al.* (2003) revealed in their research that individualistic cultures reported bad news about IT projects more than collectivistic cultures did. Shih and Huang (2010) determined that organisations with a more hierarchical culture had less difficulty in deploying software process improvement. The study also indicated that a group culture might positively impact software process improvement. Romm *et al.* (1991) determined that to gain the full benefits of an IS, the organisational culture should be compatible with the system.

Even though studies have been done on IS development, limited studies have been specifically done on the relationship of culture and SDMs. Iivari and Huisman (2007) researched the relationship between OC and the deployment of SDMs. Their results determined that rational cultures were more critical towards the use of SDMs, whereas organisations with a hierarchical culture used SDMs more and believed they are beneficial. In a study of success factors of agile software projects done by Chow and Cao (2008), it was determined that culture has a definite influence on an organisation and on the success of software development projects. A newer topic is the fitting between an organisational culture and agile methodologies. A significant number of studies have indicated that there is a relationship between the successful use of agile methodologies and organisational culture (Boehm & Turner, 2005; Cockburn & Highsmith, 2011; Chow & Coa, 2008; Chan & Thong, 2009; Siakas & Siakas, 2007; Nerur *et al.*, 2005; Tolfo & Wazlawick, 2008; Vijayasarathy & Turk, 2008). Iivari and Iivari (2011) found in their study of the relationship between agile SDMs and organisational culture that hierarchical cultures are not suitable for agile SDMs, whereas developmental, group and rational cultures were. Group culture was the most strongly associated with agile methodologies.

Various studies also indicate that national culture can impact a system development. In one study several elements of national culture were identified, which influence system development (Ein-Dor *et al.*, 1993). Barrett *et al.* (1996) identified that the differences in national culture could lead to conflicts between team members of different nationalities.

Walsham (2002) identified that national culture can be an obstacle in successful system development. Only two articles could be identified that indicated that national culture has a specific influence on SDMs. Shore and Venkatachalam (1995) suggest that national culture can also affect certain part of the SDLC. This study discussed the importance of examining national culture during the systems analysis and design stage of the SDM. This research also led to the development of a framework, which suggests possible areas that can be influenced by the national culture. Thanasankit (2002) determined that national culture can affect the requirement engineering stages of an SDM and lead to changes in how processes are implemented.

3.3.3.3 The relationship between culture and Green IT and Green IS

It is clear from section 3.3.3 that research has been done regarding the relationship between culture and ISs and SDMs, although it is very limited. No literature could, however, be found regarding the relationship between Green IT or Green ISs and culture. Green IS as a whole has not been studied widely (Melville, 2010). The diffusion and adoption of Green IS and IT has also not been researched adequately (Chen *et al.*, 2008). When conducting research on the adoption of Green IT and IS, the moral implication must be investigated (Velasquez & Rostankowski, 1985). Based on previous literature, ethics and values have strong influences in terms of adopting and implementing Green Initiatives (Molla, 2009a; Lampe *et al.*, 1991). The CVF focuses on values and therefore it is well suited to determine if there is a relationship between organisational culture and the adoption of Green initiatives. Petzer *et al.* (2011) suggest that additional research should be done to determine the relationship between culture and Green values in South Africa. This study is therefore important in order to determine if OC and NC play a significant role in the adoption of Green SDMs and Green ISs.

3.4 Summary

The main goal of this chapter was to partially achieve the second main objective, namely to determine the possible influences that could affect the adoption of Green IT and Green systems development.

The first section explains the process of the adoption framework of Rogers (2003). This framework is then applied to Green IT/IS in order to determine possible motivational or inhibiting factors, which is one of the research sub-objectives.

Section 3.3 focused on another research sub-objective, namely determining the influence of organisational and national culture on the adoption of Green IT/IS. Organisational cultures, as well as different types of OC were explained and different ways of measuring OC in an organisation were investigated in section 3.3.1. National Culture, as well the different NC dimensions was explained in Section 3.3.2.

Section 3.3.3 investigated current literature in order to determine how OC and NC can possibly affect Green IT and IS.

The next chapter explains the research methodology that was used in this study, as well as the empirical data produced by the research.

CHAPTER 4

RESEARCH METHODOLOGY AND EMPIRICAL RESULT

4.1 Introduction

The aim of this chapter is to explain the research methodology that was used for this particular study. The chapter also presents the empirical results of this study in terms of each of the research objectives that they achieved.

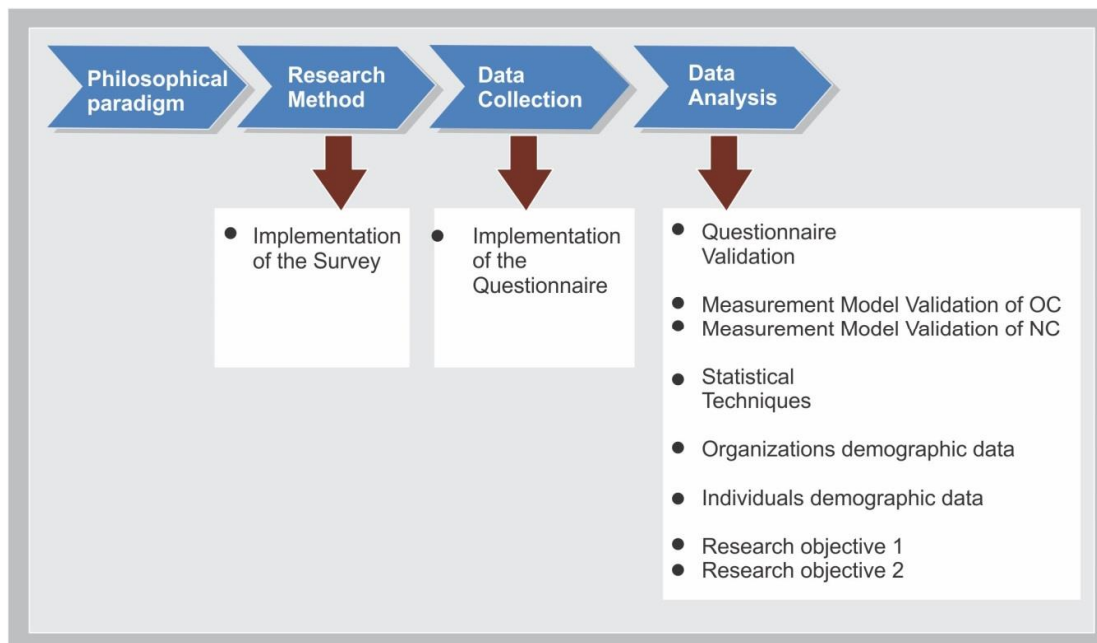


Figure 4.1: Flow of Chapter 4

The flow of the chapter is depicted in Figure 4.1. The aim of this chapter is to explain the research methodology that was used to conduct this study and to present the empirical results that were produced from it. The research methodology consisted of four components: philosophical paradigm, research method, data collection techniques, and data analysis techniques.

The chapter is structured to these four components and starts with an explanation of the paradigm, namely the positivistic paradigm, which is used to conduct this study. The different

characteristics of the paradigm are explained and the reasons are given why this paradigm was chosen.

The research method is explained next. This part of the chapter names the different research methods that are suitable to be used together with the positivistic paradigm. The chosen method for this study is a survey and is explained together with the advantages and disadvantages of its use. The reasons why the research method is best suited for this study are also given. The implementation of the survey and how it was conducted in order to achieve the research objectives are also explained.

The penultimate section focuses on the data collection part of the research methodology. The reasons for choosing a questionnaire are given, as well as the specific type of questionnaire that was used. The implementation of the questionnaire is explained next, followed by why the different questions were necessary to achieve the different research objectives.

Lastly, the data analysis of the study is explained. The questionnaire is validated first, using measurement analysis. The OC models, as well as the different NC models are validated in order to ensure that only valid data is reported. Once the reliable data is established, the different empirical results are presented. The demographic data of the organisations, as well as that of the individuals are presented first in order to describe the sample of the survey better. The remaining empirical results are then presented in terms of the two main research objectives stated in Chapter 1.

This chapter is primarily based on Oates (2006), but additional references are provided.

4.2 Philosophical paradigm

There are three possible philosophical paradigms that can be used in Information System (IS) studies, namely positivism, interpretivism and critical research (Chua, 1986). Each paradigm differs in terms of ontology and epistemology. Ontology gives the views of the different paradigms with regard to the nature of our world and epistemology is the way that knowledge about our world can be obtained. The philosophical approach that was chosen for this study is the positivism approach for several reasons that are explained next.

The positivistic paradigm is the oldest research paradigm (Babbie & Mouton, 2001; Olivier, 2004; Khazanchi & Munkvold, 2002) and is the most used paradigm in IS research (Chen & Hirscheim, 2004; Arnott & Pervan, 2005). This paradigm is based on clearly defined facts and the obtained results are measureable (Burke, 2007). When this paradigm is used, research is conducted in the natural sciences, and is called the scientific method. Positivism underlies this approach. The two basic assumptions of this approach are that the world is not random, but regular and ordered and that it can be objectively investigated (Cecez-Kecmanovic, 2007; Wardlow, 1989; Babbie & Mouton, 2001; Myers, 1997; Cooper & Schindler, 2011; Guo & Sheffield, 2008; Popkewitz, 1980). Knowledge obtained by using this approach should be objective and verifiable (Olivier, 2004; Cecez-Kecmanovic, 2007; Babbie & Mouton, 2001; Delanty, 2005).

Researchers using positivism seek to find universal patterns, relationships or laws of the world and believe that they can be objectively investigated in a structured manner (Orlikowski, 1991; Cecez-Kecmanovic, 2007; Guo & Sheffield, 2008; Delanty, 2005). This paradigm focuses on testing different theories and understanding specific phenomena (Myers, 1997; Polit & Beck, 2006).

Researchers using this paradigm should remain objective and rational, and should not let any emotions or personal feelings influence the way that they do their research. The scientific method uses three basic techniques: reductionism, repeatability and refutation. *Reductionism* is used to divide a complex problem into smaller, more manageable components, which can be studied easier (McCutcheon & Jung, 1990). *Repeatability* is used to ensure that researchers do not rely on the result of a singular experiment. Experiments should be repeated several times in order to ensure that the same results are obtained and the first was not just a coincidence. This technique is also used to ensure that the researcher did not influence a set of results or environment and research instruments in which the experiments were conducted. *Refutation* is used if the result of the original researcher cannot be obtained by experiments done by another researcher. The hypothesis is then refuted. If many tests try to refute a particular hypothesis and it can stand up to these tests, the hypothesis is considered to be strong (Cecez-Kecmanovic, 2007).

Positivism has unique characteristics, which should be taken into consideration before choosing this paradigm. The first characteristic of this paradigm is that the researchers who use it believe that *the world exists independently of humans*. Even if humans did not exist,

the physical and social world would still exist. Universal laws, such as gravity, would continue to work (Cooper & Schindler, 2011; Wardlow, 1989; Marsh & Smith, 2002). Secondly, it has unique way of *measurement and modelling*. The world is studied by making different observations and measurements of it. Once this has been done, different models, such as theories, hypotheses and concepts can be produced. Each model will correspond only to one aspect of the world (Orlikowski, 1991; Cecez-Kecmanovic, 2007; Dowding, 2001; Hay, 2002). The next characteristic is *objectivity*. The researcher's personal beliefs and perceptions do not influence the discoveries made on the world. The researcher should be neutral to all observations made by him/her (Cooper & Schindler, 2011; Babbie & Mouton, 2001; Taylor, 2006; Wardlow, 1989; Cecez-Kecmanovic, 2007; Myers, 1997). *Hypothesis Testing* is a very important characteristic of this paradigm. The research is based on the models that were produced or the hypothesis that was formed. The hypothesis must be tested and will either be confirmed or refuted (Orlikowski, 1991; Khazanchi & Munkvold, 2002; Wardlow, 1989; Cecez-Kecmanovic, 2007; Watcharabon, 2010; Popkewitz, 1980; Bryman, 2001). This paradigm mainly collects *quantitative data*, which is mathematically modelled and proofed. The data analysis is done with statistical analysis and the results are measureable. Mathematics is ideal for this paradigm, since it can analyse observations and results objectively, and logically (Orlikowski, 1991; Khazanchi & Munkvold, 2002; Wardlow, 1989; Wardlow, 1989; Cecez-Kecmanovic, 2007; Burke, 2007). The last characteristic of this paradigm is *universal laws*. One of the purposes of conducting positivistic research is to be able to generalise. This means that universal laws, facts or patterns, which are identified, are independent of the researcher or the occasion on which they were identified (Orlikowski, 1991; Khazanchi & Munkvold, 2002; Wardlow, 1989; Cecez-Kecmanovic, 2007; Watcharabon, 2010; Delanty, 2005).

When judging the research conducted by a positivistic researcher, the validity of the research must be ensured. This is to ensure that his/her findings are correct and can be referenced in future research. The following can be used as criteria for assessing positivistic research: firstly, *objectivity*. Possible interest of the researcher needs to be identified. This is very important, especially when the researcher is sponsored by an organisation that would benefit from this research (Braa & Vidgen, 1999). The next criterion is *reliability*. If the same research instruments and environment were used repeatedly, would the result be the same? Are the research instruments reliable in terms of accuracy and objectivity? Research instruments include the data collection methods used, such as questionnaires or experiments. This also includes the data analysis techniques. The mathematical or statistical analysis should be done accurately and in the appropriate manner (Braa & Vidgen, 1999).

Internal Validity is also very important. The research should be designed in such a manner that the correct subjects are examined or the correct data is collected from the correct source. The generated data should truly lead to the findings or result claimed by the researcher. Relationships or patterns identified by the researcher should also be verified (Braa & Vidgen, 1999; Walker & Evers, 1999). The last criterion is *external validity*. Can the research conducted be generalised? It is important for positivist research to have a high degree of generalisability. The representativeness of the samples of the population chosen by the researcher will determine the generalisability of the research (Braa & Vidgen, 1999; Walker & Evers, 1999).

The positivistic paradigm is used mainly for research on the natural world. The social world includes people, organisations, group structures and cultures and semiotics of this world. The positivistic research is not well suited for the social world and therefore several criticisms against positivism are made. The first criticism is *reductionism*. Reductionism is not always possible, and might even distort the results of the research by not taking into account the problem as a whole. A holistic view is sometimes needed in order to clearly see all the complex relationships. *Repetition* might also not always be possible. There may sometimes be only one instance of a particular occurrence, and therefore that occurrence cannot be studied again or by a different researcher. Another criticism is made with regard to *generalising*. This property is not always desired by researchers. Sometimes unique or specific occurrences or subjects are also useful to be studied. Such a study may be very valuable to one entity even though it may not be useful to any other entities (Lee & Baskerville, 2003; McGregor & Murnane, 2010). Another critique is that *the world is not perceived by everyone in the same way*. A good example of this is the old glass-half-empty or glass-half-full metaphor. Because people do not perceive the world in the same way, studies can be done to determine how different people experience the same thing. These interpretations can be very interesting and valuable knowledge can be gained (Blumberg, 1932). Lastly, it is suggested that *regular laws and patterns are the construction of people, even though they appear observable in the social world*. Some views are not a law of nature, but a shared view between all people within a specific population or sample. These views lead to a new need to be able to study the social world and the different interpretations and perceptions of the subjects within it.

The main reasons why this paradigm was chosen is that the research needed to be conducted objectively and quantitative data was required. Empirical data regarding the Green IT and Green IS was very limited and therefore by gathering quantitative data, this

research can make an important academic contribution. The quantitative data is well suited for reaching the objectives specified in Chapter 1. It is important that this study is conducted objectively. This will ensure that accurate generalisations, which is another characteristic of positivistic research, can be made regarding the findings of this study. Lastly, this paradigm is used because it is well suited for identifying patterns and relationships within data. This is very important to this particular study, since it will be used to achieve the second main objective of determining influences on the adoption of Green IT and ISs. Each of the influences is a relationship between different factors that were identified in the literature.

4.3 Research method

The following research methods can be used in the positivistic paradigm: design and creation, experiments and surveys (Bhattacharjee, 2012). Research methods are used to answer the research questions. Every research question will usually have a research method, therefore if there is more than one question more research methods could be used. Surveys were chosen for this study and it is the most used research method in IS research (Guo & Sheffield, 2008). Surveys are used in order to attain data, in a standardised and systematic way, from single or different samples within a population (Kelley *et al.*, 2003). The data is then analysed in order to find patterns that can be generalised to the entire population and to test different hypotheses (Wynekoop & Russon, 1997; Clock, 1967). Determining the correct sample is critical, and it will impact the accuracy of the generalisation (Dillman, 2007; Newsted *et al.*, 1998; Pinsonneault & Kraemer, 1993). Surveys are mostly used in the positivistic paradigm. However, interpretive and critical researchers also utilise them (Orlikowski, 1991; Chen & Hirschheim, 2004). The research method is effective for determining what is happening, how it is happening and why it is happening (Newsted *et al.*, 1998).

According to Pinsonneault and Kraemer (1993) surveys have three distinct characteristics:

- Surveys are used to produce quantitative data that describes a specific set of characteristics of a particular population.
- The data collection is done with pre-determined questions which are answered by a specific population or subset of a population.
- Only a specific set of people from a population, a sample, is used for the data collection. The data should, however, be gathered in such a way that the results can be generalised to the greater population.

Surveys have the following advantages:

- Surveys cover a wide range of people or organisations, which will likely result in a good representation of the whole population. Due to this good representation, more accurate generalised conclusions can be made (Kelley *et al.*, 2003; Bell, 1966).
- This technique is relatively low cost and data can be produced rapidly. These attributes make planning and management easier, since the cost and time can be estimated in advance (Kelley *et al.*, 2003; McIntyre, 1999).
- Surveys collect quantitative data, which impresses many research readers.
- The surveys are repeatable and the results can be replicated. The surveys could be distributed to the same group of people and to a different group and the same results should be obtained. This advantage means that results obtained by these surveys can be tested again in order to confirm or refute the results. This repeatability and replication is essential to the usage of the scientific method.
- The method can be used to collect data from many different geographical areas (Siau & Rossi, 1998).

The characteristics and advantages of surveys make this research method well suited for this particular study. It is well suited since a large population needs to be included in this study and this research project has limited funding. Since Green IT/IS is a relatively new research topic, especially in South Africa, quantitative data will be very useful to get an overall idea of what is going on in the country. Surveys are very useful, if they are implemented correctly, otherwise they could have several disadvantages.

Surveys have the following disadvantages:

- Surveys focus on broad coverage and lack in-depth research. This means that there is not a great deal of detail collected (Kendall, 2008).
- They only focus on numerical data, which can be counted, measured and are subject to statistical analysis. This often leads to aspects of the research topic being left out, since they cannot be represented numerically.
- Data collected by means of surveys only represent one specific point in time. They do not examine on-going change and processes.

- This technique only shows relationships and patterns, without identifying and cause and effect.
- The researcher usually does not observe subjects who respond to the surveys and therefore cannot observe their body language to judge the accuracy of their responses.
- The response rate of the surveys is usually very low (Kelley *et al.*, 2003; Bell, 1966).

The researcher should take the different advantages into account when conducting a study using surveys. The next section explains how the survey was conducted for this particular study and how possible risks due to disadvantages of the survey were mitigated.

4.3.1 The Implementation of the Survey

In order to do a survey, the data requirements should first be determined. The data requirements are based on the research objectives that were described in section 1.5. Some of the objectives were literature-based, but others required that an empirical investigation should be conducted. These objectives were as follows:

- Determine the effectiveness of Green IT techniques or initiatives.
- Determine the factors that motivate or inhibit organisations from adopting Green IT initiatives.
- The influence that the characteristics of organisations has on Green IT and Green IS.
- Determine the impact that organisational culture has on the adoption of Green IT initiatives.
- Determine the impact that national culture has on the adoption of Green IT initiatives.

These data requirements can be satisfied by using a questionnaire to collect the necessary data. The data collection method used for this study will therefore be a questionnaire, which will be fully explained in the next section of the chapter.

In section 4.3 the different disadvantages of using a survey are mentioned. One of the problems with using surveys is that they often have a very low response rate (Siau & Rossi, 1998; Pinsonneault & Kraemer, 1993). This is a big problem, especially in the IT industry, since people almost always have very strict deadlines and their time is valuable. They do not necessarily have additional time to complete the survey. To increase the response rate, all

the companies were first contacted telephonically in order to thoroughly explain the survey. The importance of the research was then explained, especially that Green IT is important in our country since the government is considering regulative actions to lower our country's negative impact on the environment. The organisations were also promised that once the research had been completed, the results would be sent to them. The organisations were promised that their data would be kept confidential and that the people in the organisation, who filled in the questionnaire, could do so anonymously. Lastly, the organisations that did not return the questionnaires by the given deadline were frequently contacted and reminded of it. Hereafter the all the companies that were chosen for this study, were e-mailed with the questionnaire. These companies that were used was from the 12th Edition of Impumelelo that included a list of software and systems development companies in South Africa (Impumello, 2012). The survey was distributed to all the companies on the list in order to gather as much data as possible.

Surveys are an effective research method, but IT has been criticised that it lacks depth. To avoid this, several open-ended questions were added in the questionnaire. The questionnaires were also sent to various organisations of different sizes and industries to ensure that the appropriate level of detail was obtained. Because the questionnaires were completed anonymously, this hopefully ensured that the employees answered the questions in the appropriate amount of detail and with honesty.

The survey was done between 1 May 2012 and 31 August 2012. 138 questionnaires were collected from 54 different organisations. Four of the 138 questionnaires were not usable, leaving 134 questionnaires, which were analysed. The response rate is given in the table below.

Table 4.1: Response rate of Questionnaires

Number distributed	Number Returned	Response Rate
540	138	25.5%

The response rate is satisfactory compared to other studies on the use of SDMs (Hardy *et al.*, 1995; Russo *et al.*, 1995; Eva & Guilford, 1996; Poo & Cung, 1998; Huisman, 2000; Livermore, 2008; Vrazalic *et al.*, 2002).

4.4 Data Collection Techniques

Interviews, documents, questionnaires and observations can all be used in the survey research method (Kaplan & Maxwell, 1994). For this particular study a questionnaire was chosen for the data collection technique.

Oates (2006:219) defines questionnaires as a 'pre-designed set of questions (items), assembled in a pre-determined order'. The people within the sample should answer all the pre-defined questions so that their responses can be analysed and interpreted by the researcher (Woolfolk, 1998). The questionnaire should be unambiguous and effective (Cohen & Mannion, 1985; Kelley *et al.*, 2003). Once the responses are complete, the researcher looks for patterns in order to make generalisations with regard to the views or actions of the whole population (Kendall, 2008; Oppenheim, 1992; Harris & Brown, 2010). Questionnaires are most frequently associated with surveys, but can also be used in case studies, action research or design and creation.

Questionnaires can be administered in two ways:

- Self-administered, where they are completed without the researcher being present.
- Researcher-administered, where the researchers ask each question and writes down the responses of the respondent. It can either be done face-to-face or over the telephone, as a type of structured interview. When administering questionnaires in this way, the researcher should be aware of how he/she could influence the responses with his/her appearance and interaction with the respondents.

The advantages of questionnaires are:

- They allow the respondents to answer pre-determined questions (Ramajan, 1994).
- The questionnaire can be completed in the respondent's own time and when it suits him/her the best (Ramajan, 1994).
- They are useful for gathering many different opinions and perceptions, because a larger sample can be reached (Ramajan, 1994).
- It is less time consuming than other data collection techniques (Ramajan, 1994).
- The questionnaires are very cost effective, especially if distributed electronically (Ramajan, 1994; Newsted *et al.*, 1998; Ilieva *et al.*, 2002; Jack & Clarke, 1998).

- They can be used in order to collect data from a large sample (Newsted *et al.*, 1998; Jack & Clarke, 1998).
- The data from the questionnaires can be statistically analysed and used to generalise to the greater population.

Questionnaires provide an easy manner of collecting data from many people and are therefore widely used in research. The situations where they are most effective are if the researcher

- needs data from a many people;
- wants to obtain uncontroversial and simple data from the people;
- wants standardised data from the people. This can easily be done with questionnaires, by giving each respondent the same questions and limiting the answers to a pre-defined set form, which he/she can choose;
- expects the people of the sample to be able to read, understand and answer the questions;
- has the necessary resources. The researcher must have the money to create, distribute and collect the questionnaires. The researcher should also have the time to wait for the respondents to give their questionnaires back after they have been distributed; and
- wants to obtain a large amount of data at a low cost (Newsted *et al.*, 1998).

Questionnaires often sound simple, but it is important that they are designed and constructed after careful planning (Oppenheim, 1992). The questions need to be written in such a manner that all the respondents will be able to read them, without misinterpreting them. The researcher should ensure that the answer the respondents will give, will address the requirements. Each question should relate to the research questions or hypothesis. The questions should be neutral and written in such a manner that they will not lead the respondents to a specific answer. The length of the questionnaire should not be too long and the respondents should be able to complete the questionnaire in 10 to 15 minutes (Comley, 2002; McIntyre, 1999).

Questionnaires are a very effective data collection technique, but they have a few possible disadvantages:

- The researcher will never be sure the questionnaire was actually completed by the person to whom it was given (Marshall, 2005).
- After the questionnaire has been analysed, the results can be used to generalise to the greater population. It is, however, very important that the sample is correctly chosen. If the sample size is too small or the questionnaire was not created correctly, the generalisation will be inaccurate (Newsted *et al.*, 1998; Oppenheim, 1992).
- Questionnaires can be difficult to analyse if many open-ended questions are asked (Bell, 1993).
- The questions can be misinterpreted (Bell, 1993).
- The respondents must answer from a pre-determined set of answers, which might not be what they truly feel is the answer (Bell, 1993).

This questionnaire could be used to repeat the survey if the data needed to be verified. This is important because the study is done in the positivistic paradigm, which requires a study to be repeatable.

4.4.1 Implementation of the Questionnaire

There are many different reasons why a questionnaire was chosen for this study. The data required for this study needed to be collected from a large sample of people. The data that was gathered is quantitative and can easily be analysed using statistics. The study was also done over a short period of time. The requirements therefore made the questionnaire the ideal data collection method for this study.

The questionnaire was self-administered, meaning that the respondents completed the questionnaire on their own. This saved the researcher a lot of time and more people could be asked to complete it. This type of administration makes sure that the respondents do not try to please the researcher by giving him/her answers that they think the researcher wants to hear (Dillman, 2007). Lastly, this form of administration is effective because the questions are given to respondents in the same manner, compared to interviews, where the tone of voice of the interviewer can affect how the person hears the question.

The construction of the questionnaire is important. The questionnaire has an introduction page, which explains its purpose, promises confidentiality of the data and thanks the

respondent for his/her time. The introduction page also includes the contact details of the researcher's supervisors so that companies can make sure that the study is official. The questionnaire mostly consists out of closed questions, which use a 5-point likert scale. This scale is the most frequently used response scale (Conger, 1994) and therefore it is easy to understand.

Open-ended questions allow respondents to elaborate on a particular issue and gain additional information (Struwig & Stead, 2001; Salant & Dillman, 1994). They can, however, be time-consuming for the respondent and should therefore be kept to a minimum (Struwig & Stead, 2001). There are two open-ended questions with enough space that the respondent will be able to write his/her entire answer, but not so much space that it might discourage the respondent and he/she does not write anything. The questionnaire was also designed to be as short as possible, while still gathering the necessary data.

Once the questionnaire was constructed it, it was pilot-tested by two people; first by an academic staff member of the North-West University and then by an organisation in the industry in Gauteng, South Africa. This was done to make sure that all the questions were understood correctly, which is very important for both the researcher and the respondents (Murray, 1999). They marked all the questions where they did not understand clearly and their commentary was then used to further improve the questionnaire. The respondents also commented on the questionnaire if the questions were leading them to choose specific answers. Once the pilot testing was done, the questionnaire was adapted, based on the respondents' comments and sent back to the respondents to ensure that the adaptations were correct.

The questionnaires were e-mailed to the different organisations. E-mailing the questionnaires was chosen because this could be used to collect a large quantity of data from many different locations and organisations at a low cost (Ilieva *et al.*, 2002). E-mailed questionnaires were used instead of printing out the questionnaires in order to save paper. Many different organizations were e-mailed in order to obtain information from as many organizations as possible. This was done because data from one respondent from many different organisations are more valuable than data of many respondents from a single organisation for this particular study. This is because a wider variety of Green approaches and techniques will be identified, when more organizations are included.

Once all the questionnaires were collected, they were entered record by record into a Microsoft Excel spreadsheet. The data from each questionnaire was checked to make sure that there was no inaccurate data transfer. The data was then imported into SPSS.

4.4.1.1 The questionnaire

The questionnaire consisted of 34 questions, which were used in order to gather data based on the research objectives. The complete questionnaire can be referenced in Appendix A.

The different questions on the questionnaire are summarised in Table 4.2

Table 4.2 **Questions of the questionnaire**

Question number	Number of items	Research variable	Reference
1.1	1	Business area of the organisation	Huisman (2000)
1.2	1	Size of the organisation	Huisman (2000)
1.3	1	Size of the IS department	Huisman (2000)
1.4	1	IS department's development activities (Percentage of Efforts)	Huisman (2000)
1.5	1	Systems development process	Huisman (2000)
1.6	1	Time that the systems development process has been in use	Iivari and Huiman (2007)
1.7	1	Horizontal use of systems development process	Iivari and Huiman (2007)
1.8	1	Effectiveness of Green IT initiatives	
1.9	1	Green Initiatives used in the system development process of the organisation	
2.1	1	Role of the Individual during the systems development process	
2.2	1	Highest qualification of the Individual	Huisman (2000)
2.3	1	Years of experience in system development of the Individual	Huisman (2000)
2.4	1	Motivational factors for the adoption of Green IT initiatives within the organisation.	Section 3.2.1
2.5	1	Factors that inhibit the organisation from adopting Green IT initiatives	Section 3.2.1
2.6	1	Future expectations regarding Green IT adoption	
3.	14	3. Organisational Culture	Quinn & Rohrbaugh (1981; Iivari & Iivari (2011)
	18	4. National Culture	Hofstede <i>et al.</i> (2008)

The questionnaire consisted mostly of closed question, but a few questions included an "Other" option to ensure that the individual could add a response if it was not listed in the options. This was very important for certain questions, as summarised in Table 4.3.

Table 4.3: Questions with the "Other" option

Question	Reason
1.8	Many different Green IT initiatives have been identified from previous literature, as discussed in section 2.1. However, new techniques may already be in use. Therefore this question includes the "Other" option so that new Green IT initiatives can be identified.
2.4	Many possible motivations for Green IT initiatives have been identified from previous literature. However, only one study regarding this factor has been done in South Africa (Petzer <i>et al.</i> , 2011). Therefore there might be additional factors in South Africa that have not yet been identified. Only the term Green IT will be used in the heading of this question, because the term Green IS is still relatively unknown in our country and might confuse respondents.
2.5	From previous literary studies, several possible factors that might inhibit organisations from adopting Green IT initiatives were identified. There have not been any such studies in South Africa and therefore the "Other" option was added to ensure that if the country has unique factors, they can be identified within the study. Only the term Green IT will be used in the heading of this question, because the term Green IS is still relatively unknown in our country and might confuse respondents.

The questionnaire also included two open-ended questions, namely question 1.5 and question 1.9. Question 1.5 asks the respondent to describe the systems development process. There are too many different SDMs to list them all (Masrek *et al.*, 2008; Jayaratna, 1994) and therefore it would not be possible to list them all. It allows the researcher to gain insight regarding how the companies that do not use an SDM develop their systems. Question 1.9 requires a respondent to describe how Green IT initiatives are supported by their systems development process or how they can adjust the process to support Green IT initiatives. The question needs to be open-ended, since every organisation can use Green IT initiatives in their own unique way during the systems development process. Organisations can also adjust the process in their own unique way, and therefore it is not possible to create a list of possible answers.

Section 1 of the questionnaire is used to gather information regarding the background of the organisation, as well as the IS departments of those organisations.

Question 1.1 measures the core business area of the organisations that were surveyed. The results give a clear description of the organisation types.

Question 1.2 and question 1.3 are used to further describe the organisations that were surveyed. Question 1.2 measures the size of the entire organisation and question 3 measures the size of the IS department.

Questions 1.4 - 1.7 are used to gather information regarding the use of SDMs within the organisation. Question 1.4 determines what percentage of time the organisations' IS departments devote to different activities. Question 1.5 enquires about the systems development process of the IS department. This is to find out the types of methodologies, approaches, tools and techniques used during the development process of the IS departments that were surveyed. Question 1.6 is used to establish the length of time that the IS department has used the specific systems development process and question 1.7 determines the proportion of projects to which the systems development process is applied.

Question 1.8 and question 1.9 are focused on the Green IT initiatives of the organisation. Firstly, question 1.8 determines which Green IT initiatives are used within the organisation, as well as how effective they are perceived to be. The different techniques are listed and each one in the list can be rated on a likert scale from 1 (not effective) to 5 (very effective). Question 1.9 is used to establish if any Green IT initiatives are used within the systems development process of the IS department and how the process supports the initiatives. This question further enquires how the systems development process can be adjusted in order to support Green IT initiatives. This is important for research sub-objective of determining how current SDMs can be adapted to have greener development process and a greener end product.

Section 2 of the questionnaire is used to gather information about the respondent.

Questions 2.1 - 2.3 are used to determine the respondent's role during the systems development process, the education level, as well as number of years of experience in systems development. It will help if one of these variables has an influence regarding the adoption of Green IT or greener systems development processes.

The next questions, question 2.4 - question 2.6, are used to establish why the respondent thinks an organisation has or does not have Green IT initiatives and what the respondent predicts for the future in terms of Green IT usage. Question 2.4 enquires about possible reasons why the organisation adopted Green IT initiatives. Question 2.5 determines what factors the respondent feels inhibit the organisation from adopting Green IT initiatives. The objective of question 2.6 is to find out what the respondents predict in terms of future usage of Green IT initiatives within their organisation.

Sections 3 and 4 are used to measure culture. Section 3 measures organisational culture and question 4 measures national culture.

The data analysis of the data that was collected using the questionnaire in the survey is discussed next.

4.5 Data Analysis

Researchers can collect two types of data namely, quantitative data and qualitative data. Quantitative data is usually used when working in the positivistic paradigm and surveys are an effective research method for gathering this type of data (Bryman, 2001). Quantitative data is perfectly suited for the philosophical paradigm, research method and data collection method used in this study and will be able to help achieve the research objectives.

Quantitative data was gathered in this study with the questionnaire. Quantitative data is represented with precise numeric values and can be used to count and measure things (Loehnert, 2010; McGregor & Murnane, 2010; Johnson & Onwuegbuzie, 2004). This type of data is also considered reliable and can be effectively used for generalisation (Bryman, 2001). Statistics are used to analyse quantitative data (Thomson *et al.*, 1996).

Advantages of Quantitative Data analysis:

- It is regarded as scientific analysis and is widely respected by researchers. Some researchers even feel that only quantitative data generation and analysis is scientific research.
- The techniques used for the analysis have been used for a long time and are well established. These techniques give the researchers the confidence that their data will be analysed correctly.
- Statistical analysis is not subjective and therefore it can be verified by other researchers.
- Software programs enable researchers to analyse large volumes of data very quickly.

Disadvantages of Quantitative Data analysis:

- Not all people like working with numbers and therefore do not like to use statistical analysis.
- People may lose sight of the original purpose of the research project when they get distracted by sophisticated statistical tests, which they might not even fully understand.
- The analysis is dependent on the data that was generated. The quantitative data only focuses on what can be measured and therefore disregards any non-quantitative factors that might be useful for the research.
- Before any data can be generated the type of data required, as well as the statistical test must be determined.
- Statistical analysis appears to be objective. Researchers can, however, still influence the results of the research. Examples of this may be of a researcher adjusting the size of the groups, which are used in frequency counts or adjusting the scales on the x- and y-axis.

The data that was gathered by the questionnaires needed to be analysed with different types of statistics in order to obtain the results of the study. The software that was used for the analysis was SPSS, which is a commonly used statistical package (Thomspon *et al.*, 1996).

Once data has been collected, the researcher needs to ensure that the results are reliable. In order to determine if the empirical results are reliable, the questionnaire needed to be validated first. The validation of the questionnaire is explained next.

4.5.1 Questionnaire Validation

Structural equation modelling (SEM) is a technique used to evaluate the theories and factors, which were included in the data collection instrument (Kelloway, 1995). It can simultaneously evaluate several dependence relationships, instead of only single relationships for which factor analysis is better suited (Byrne, 2001). This is done by computing the variance and covariance matrices and comparing them with the sample variance-covariance matrix (Petter *et al.*, 2007).

Variance measures the dispersion of a specific variable and covariance measures whether and how much two variables change together. There should be a linear dependency between two variables in order for them to have a covariance value other than zero. If two variables change in the same direction, the covariance will be positive and if they change in opposite directions, the covariance will be negative (Field, 2009).

Variance and covariance are both measures of association, but they are not standardised. Correlation is an example of standardised measure of association, which means that it is not dependent on the unit in which variables are measured. The correlation coefficient used in this study is the Pearson correlation coefficient (r).

The variance-covariance matrix, also called an observed sample covariance matrix, is calculated from the data and lists the variance and covariance of the different variables (Schumacker & Lomax, 2004). An estimated population variance-covariance matrix, which is based on the measurement model, is also computed based on the path estimates of the model. These path estimates are represented as beta coefficients (β). The two matrices are then compared and if the sample variance-covariance matrix and the population variance-covariance matrix are similar, the model fits the data (Petter *et al.*, 2007). If the two matrices are exactly the same, the measurement model correlates perfectly to reality. The difference between the matrices is the element mostly used in SEM and it results in many different indices that can be used in order to indicate how well the model fits. Different indices should be used as there is not a specific index, which can be sufficiently used alone (Schumacker & Lomax, 2004; Hancock & Mueller, 2010). The indices that will be used in this study include absolute fit indices, as well as incremental fit indices, which are explained in section 4.5.1.2 and 4.5.1.3.

SEM is done in two phases, namely measurement model validation and structural model validation (Schumacker & Lomax, 2004). In this study, however, only measurement model validation is necessary. The measurement model validation of the questionnaire that was used in this study will be explained next.

4.5.1.1 Measurement Model validation

The measurement model refers to the validation of the questionnaire that was used to gather data for this study. The measurement model represents the connection between measurement variables and different factors. In order to ensure that a measurement model is valid, it should be established that the measurement reliability and validity are acceptable (Segars & Grover, 1993). This is especially important when using SEM in the study, because an invalid measurement model could lead to unreasonable SEM estimations, which cannot be interpreted. It is therefore important that the structural model is evaluated only after the measurement model validation has been done and it is determined that it is adequate (Cook & Campbell, 1979).

Confirmatory Factor Analysis (CFA) will be used together with SEM to perform the measurement model validation. CFA is used to identify the pattern of loadings of the measurement items on the variables in the measurement model. The standardised factor loading is determined for each measurement item. The Kaiser criterion will be used to determine the number of factors to retain (Berkman & Reise, 2012; Field, 2009).

Before the CFA the Kaiser-Meyer-Olkin measure of Sampling Adequacy (KMO) and the Bartlett's Test of Sphericity will be used to check for linearity of different variables to determine if the data that was collected is suitable for factor analysis. This has to be done because the covariance will be zero if there is no linear dependency between the variables (Field, 2009). A KMO value of 0.5 and above is acceptable and the Bartlett's Test of Sphericity requires a significant value.

The KMO is computed using the sum of the correlations. Factor analysis is not acceptable if the sum of a subset of correlations is large relative to the sum of the correlations, indicated by a 0. A KMO measure of 1 indicates that factor analysis may be done. This study will accept a KMO value of 0.5 and above.

Bartlett's Test of Sphericity is used to evaluate if there is a strong linear association in the correlation matrix of the data. It tests the hypothesis that variables in the population are not correlated. The hypothesis is that each variable does not correlate with any other variable, but correlates perfectly with itself. The Bartlett's Test of Sphericity should have a significant value in order for factor analysis to be appropriate.

Shumacker and Lomax (2004) recommend the following five distinct phases when evaluating a measurement model:

1. *Model specification* – During this phase the relationship between different factors and their variables should be specified. AMOS is used to link observed variables to the different latent variables. Rectangles are used to represent observed variables, ovals for latent variables and circles are used to represent measurement errors on observed variables. The variance of the latent variables is set to zero and all the path coefficients between observed variables and latent variables are unfixed. The latent variables are then correlated.
2. *Model Identification* – In this phase it should be determined if the model is over-identified. An over-identified model means that each parameter can be estimated with more than one way. This is determined by using the number of observations and determining if it is greater than or equal to the number of model parameters (Kline, 2005). The number of observations is computed, based on the number of covariances in the covariance matrix.
3. *Model Estimation* – Model estimation is not required for this study and will therefore not be done.
4. *Model testing* – Fit indices are used in this phase to determine if the measurement model fits the data. In this study, reliability and validity will also be included in this step. The reason for this is because as mentioned earlier in this section, that an invalid measurement model could lead to unreasonable SEM estimations.
5. *Model Modification* – If the fit indices are not sufficient, the measurement model should be modified in order to get the best fit possible.

In the fourth step, namely Model Testing, reliability and validity need to be performed. Both these terms are briefly described in the following paragraphs.

Reliability

A measurement model is considered reliable if it can produce the same results even in different scenarios or, as stated by Field (2009), it should "consistently reflect the construct that it is measuring". A reliable measurement instrument is therefore as free from errors as possible (Conger, 1994). Reliability can be divided into two dimensions, namely internal consistency and repeatability (Straub, 1989).

- *Repeatability* indicates that if a measurement instrument is completed by the same sample for more than one time, the same data should be collected.
- *Internal consistency* is determined by correlating different measurement items, which measure a specific factor, in order to estimate the reliability of the measurement instrument (Straub, 1989). In this study the correlations will be computed using Cronbach's alpha, which is one of the most common methods of methods of determining internal consistency (Hair *et al.*, 2006; Field, 2009). A Cronbach alpha of 1 indicates that all the measurement values of a factor measure the same thing. If the Cronbach's alpha is low, it is an indication that the questions used to measure a specific factor were not very sufficient, whereas a high Cronbach's alpha indicates that the questions were sufficient (Churchill, 1979).

The acceptable level for Cronbach's alpha in this study is values above 0.6, since this value is accepted in different literature (Bagozzi & Yi, 1988; Iivari, 2006; Nunnally & Bernstein, 1994; Sethi & King, 1991; Roberts *et al.*, 1998).

Validity

Measurement **validity** can be established in different ways. In this study it will be done by determining content validity, which is considered to be essential in determining validity (Nunnally & Bernstein, 1994; Bollen, 1989).

Content validity determines if a measurement model includes all the possible measures of the factors that are being investigated and has representative questions (Straub, 1989). In order to ensure that content validity, a thorough literature review must be done regarding the different factors under investigation and experts regarding the different factors should be referenced (Churchill, 1979; Carmines & Zeller, 1979).

The questionnaire that was used in this study is based on a very thorough literature review and several experts were referenced, therefore the content can be considered to be valid.

4.5.1.2 Measure of Absolute Fit

Absolute fit indices are used to determine the degree to which the estimated population variance-covariance matrix can reproduce the observed sample variance-covariance matrix (Hair *et al.*, 2006). There are two absolute fit indices used in this study: the Chi-square index (χ^2) and the Root Mean Square Error of Approximation (RMSEA).

- The Chi-square index is the most important fit index and it can detect very small deviations from the theoretical model (Schumacker & Lomax, 2004; Hancock & Mueller, 2010; Field, 2009). It is used to test the null hypothesis that the model fits sufficiently (Byrne, 2001; Gordon & Schaumberger, 1978). The χ^2 is influenced significantly by the size of the sample and samples smaller than 200 are unlikely to obtain non-significant χ^2 . Since the sample of this data is smaller than 200, other fit indices will also need to be examined. In order to lower the impact of the sample size, the χ^2 can be represented in relation to its degrees of freedom (df) (Kelloway, 1998; Mueller, 1996; Berkman & Reise, 2012).
- The RMSEA is calculated based on residuals and the smaller the value is, the better the fit of the model is (Schumacker & Lomax, 2004).

4.5.1.3 Incremental Fit measures

Incremental fit measures how successfully an observed sample variance-covariance matrix compares with the baseline model. The baseline model assumes that the observed variables are not correlated (Hair *et al.*, 2006). There are several incremental fit indices used for this study, namely the Comparative Fit Index (CFI), Tucker Lewis Index (TLI) and the Normed-Fit Index (NFI). The CFI should be considered first when conducting an SEM analysis, because it is not affected by the sample size as much as the other indices (Schumacker & Lomax, 2004; Grimm & Yarnold, 2000). The values for all these indices should be higher than 0.9 in order to indicate a good fit (Marsh & Hau, 1996).

4.5.1.4 Cut-off Criteria for Fit Indices

The different fit indices each have specific acceptable criteria. Specific acceptable values are difficult to designate because the effectiveness of the indices are not the same in all situations (Hu & Bentler, 1999). Table 4.4 is a summary of different acceptable values for each of the indices (Browne & Cudeck, 1993; Hatcher, 1994; Kline, 2005; Hu & Bentler, 1999; Marsh & Hau, 1996).

Table 4.4 **Fit Indices criteria**

Chi-Square	1. χ^2 / df should be ≤ 2 (Hatcher, 1994) 2. χ^2 / df should be < 3 (Kline, 2005) 3. χ^2 / df should be between 3 and 5 (Mueller, 1996) 4. χ^2 should be between 2 and 5 (Kelloway, 1998) 5. χ^2 should have a non-significant value (Schumacker & Lomax, 2004)
Comparative Fit index	1. The CFI should be ≥ 0.9 (Marsh & Hau, 1996; Hair <i>et al.</i>, 2006; Mueller, 1996) 2. The CFI should be ≥ 0.95 (Hu & Bentler, 1999)
Tucker Lewis Index	1. The TLI should be ≥ 0.9 (Marsh & Hau, 1996; Hair <i>et al.</i>, 2006) 2. The TLI should be ≥ 0.95 (Hu & Bentler, 1999)
Root Mean Square Error of Approximation	1. The RMSEA should be ≤ 0.06 (Hu & Bentler, 1999) 2. The RMSEA should be < 0.10 (Blunch, 2008) 3. If RMSEA is (Browne & Cudeck, 1993): a. ≤ 0.05 it is a good fit b. Between 0.05 and 0.08 it is a fair fit c. ≥ 0.1 it is a poor fit 4. If RMSEA is (Hair <i>et al.</i>, 2006): a. ≤ 0.08 it is a reasonable fit b. ≤ 0.05 it is a good fit c. ≤ 0.01 it is an excellent fit

Hair *et al.* (2006) suggest using the Chi-square to degrees of freedom, along with two incremental fit indices, as well as another absolute fit index to measure a model.

4.5.2 Measurement Model Validation for organisational culture

This section describes the measurement model validation of the organisation culture factors. The process follows the five steps as described in Schumacker and Lomax (2004).

4.5.2.1 Model Specification

The OC measurement model of Hofstede (1991) consists of four different types of organisational culture, which are represented by four factors (the number in brackets is the variable name used in the measurement model):

- Factor one represents Group culture and is measured by the following variables:
 - How personal the IS department is (OC_7.1).
 - Commitment to the IS department (OC_7.5).
 - Level of morale in the IS department (OC_7.9).
- Factor two represents Developmental culture and is measured by the following variables:
 - The level of risk taking of the IS department (OC_7.2).
 - The level of innovativeness of the IS department (OC_7.6).
 - Emphasis on acquiring new resources (OC_7.10).
- Factor three represents Hierarchical culture and is measured by the following variables:
 - Level of bureaucracy of the IS department (OC_7.3).
 - Level of rigidity of the IS department (OC_7.7).
 - Level of stability of the IS department (OC_7.11).
- Factor four represents Rational culture and is measured by the following variables:
 - Level of productiveness of the IS department (OC_7.4).
 - Level of goal orientation (OC_7.8).
 - Level of achievement orientation (OC_7.2).

These factors are based on the measurement model. Each of these factors was given a variable abbreviation in brackets next to the factor. In the next sections, only the variable abbreviations will be referenced.

4.5.2.2 Model Identification

Model Identification is used to determine the degrees of freedom of the model. This is done by determine the amount of sample moments, minus the amount of parameters used in the model. The degrees of freedom are shown in Table 4.5.

Table 4.5 Computation of degrees of freedom of the OC model

Number of distinct sample moments:	90
Number of distinct parameters to be estimated:	42
Degrees of freedom (90 - 42):	48

The number of sample moments more than number of parameter, therefore the model is considered over-identified.

4.5.2.3 Model Testing

In order to perform CFA on the OC model, the KMO and Bartlett's Test of Sphericity must first be computed in order to determine if the data that was collected is suitable for CFA.

Table 4.6 KMO and Bartlett's Test of the OC model

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	.771
Bartlett's Test of Sphericity	Approx. Chi-Square
	631.670
	df
	91
	P-value.
	.000

Table 4.6 indicates that the KMO value is 0.771, which is above the recommended value. The value of Bartlett's Test of Sphericity is also significant. The KMO and Bartlett's test therefore indicate that the data is suitable for factor analysis.

The CFA on OC is calculated and the resulting pattern matrix is shown in Table 4.7.

Table 4.7 CFA on Organisational Culture

	Factor			
	Group Culture	Developmental Culture	Hierarchical culture	Rational Culture
OC_7.2	.818			

OC_7.1	.663			
OC_7.5	.583			
OC_7.9	.582			
OC_7.6	.552			-.414
OC_7.12	.437	.252		-.355
OC_7.3		.778		
OC_7.11	.298	.610		
OC_7.7		.533		-.408
OC_7.10	.370	.443		
OC_7.14			.825	
OC_7.13			.707	
OC_7.8	.237			-.695
OC_7.4				-.276
Mean	3.609	3.547	3.229	3.448
Cronbach's Alpha	0.652	0.686	0.711	0.524

The different patterns identify which variables group together for each factor. They also indicate the Cronbach's alpha values of above 0.6 for all of the factors, except for rational culture.

The fit indices are calculated next in order to determine if the model fits the data adequately. In this study the Chi-square index (χ^2), the Comparative Fit Index (CFI), Tucker Lewis Index (TLI) and Root Mean Square Error of Approximation (RMSEA) will be used to determine if the OC model is adequate. The results of the different indices are presented in tables 4.8 to 4.11.

Table 4.8 CMIN of OC Model

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	42	150.379	48	.000	3.133
Saturated model	90	.000	0		
Independence model	24	583.416	66	.000	8.840

Table 4.9 Baseline Comparisons of OC Model

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.742	.646	.809	.728	.802
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

Table 4.10 RMSEA of OC Model

Model	HI 90	RMSEA	LO 90	PCLOSE
Default model	.150	.127	.104	.000
Independence model	.261	.243	.225	.000

Tables 4.8 - 4.10 are summarised in Table 4.11 along with a recommended value, in order to improve readability.

Table 4.11 Summary of Indices of OC Model

Fit Indices	Observed Fit indices	Recommended value
χ^2/df	3.133	Between 2 and 5
CFI	0.802	≥ 0.9
TLI	0.728	≥ 0.9
RMSEA	0.127	< 0.08

As shown in Table 4.11, χ^2/df indicates a good fit because the value is between 2 and 5. The CFI, TLI and RMSEA are just outside their recommended ranges. However, the χ^2/df is the most important and the model therefore fits the data sufficiently.

4.5.2.4 Model Modification

The pattern matrix indicates that the variable OC_7.4 has a very low correlation with the variables OC_7.8 and OC_7.12. Therefore rational culture will only be measured using OC_7.8 and OC_7.12. The variable OC_7.4 will be left out, which then improves the Cronbach's alpha of rational culture to 0.738. The rational culture factor is then significantly more reliable.

4.5.3 Measurement Model Validation for National Culture

This section describes the measurement model validation for the part of the questionnaire that measured organisation culture. The process follows the five steps as described in Schumacker and Lomax (2004).

4.5.3.1 Model Specification

The NC model consists of four factors, namely the different dimensions of national culture:

- Factor one represents Power Distance Index (PDI) and is measured by the following variables:
 - Level of respect of individual for his/her superior (NC2).
 - Level of inclusion of individual for decision making (NC7).
 - Level of fear of individual of contradicting a superior (NC23).
 - If two superiors allowed for one subordinate (NC26).
- Factor two represents Individualism Index (IDV) and is measured by the following variables
 - Level of importance of personal life of individual (NC1).
 - Level of importance of having job security (NC4).
 - Level of importance of having an interesting job (NC6).
 - Level of importance of having a job that is respected by others (NC9).
- Factor three represents Masculinity Index (MAS) and is measured by the following variables
 - Level of importance of receiving recognition (NC3).
 - Level of importance of working with pleasant people (NC5).
 - Level of importance of staying in a desirable area (NC8).
 - Level of importance of having chances of promotion (NC10).
- Factor four represents Uncertainty Avoidance Index (UAI) and is measured by the following variables
 - Level of stress (NC16).
 - Condition of health (NC20).
 - Importance of being a knowledgeable superior (NC24).
 - Level of rigidity of rules in the organisation (NC27).

4.5.3.2 Model Identification

Model Identification is used to determine the degrees of freedom of the model. This is done by determining the number of sample moments, minus the number of parameters used in the model. The degrees of freedom are shown in Table 4.12.

Table 4.12 Computation of degrees of freedom of the NC model

Number of distinct sample moments:	14
Number of distinct parameters to be estimated:	12
Degrees of freedom (14 - 12):	2

The number of sample moments is more than the number of parameters therefore the model is considered over-identified.

4.5.3.3 Model Testing

In order to perform CFA on the NC model, the KMO and Bartlett's Test of Sphericity also needed to be computed in order to determine if the data that was collected is suitable for CFA. There are many different variables that form part of the NC model, therefore each factor (NC Dimension) was analysed separately.

Table 4.13: KMO and Bartlett's Test of the different NC dimensions

	PDI	IDV	MAS	UAI
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	.505	.662	.766	.455
Bartlett's Test of Sphericity	53.887	67.226	141.475	14.456
Df	6	6	6	6
Sig.	.000	.000	.000	.025

Table 4.13 indicates that the KMO value of all four the NC dimensions was above 0.5, which is the recommended value. The value of Bartlett's Test of Sphericity is also significant for all the dimensions except UAI. The KMO and Bartlett's test therefore indicate that the data is suitable for factor analysis except for the UAI dimension.

The pattern matrix of each of the dimensions is presented next.

Table 4.14: Pattern matrix of PDI and UAI

4	Variables	Factor	
		1	2
PDI	NC7	.751	
	NC2	.751	
	NC26		.386
	NC23		.386
UAI	NC27	.629	
	NC16	-.433	
	NC20		.655
	NC24		-.175

The pattern matrix of PDI and UAI both indicated that the variables that are used to measure these dimensions did not group together perfectly, but were split into two different factors.

Table 4.15: Pattern matrix of IDV and MAS

Dimension	Variables	Factor 1
IDV	NC6	.677
	NC4	.580
	NC1	.536
	NC9	.428
MAS	NC10	.771
	NC3	.752
	NC5	.674
	NC8	.534

The pattern matrix of IDV and MAS grouped together perfectly and indicates that they only measure IDV and MAS.

For the reliability and validity of the National Culture Models, the Cronbach's alpha was calculated and used to determine if the data can be used or not.

Table 4.16: The Cronbach's Alpha of the National Culture Models

Model	Cronbach's Alpha	Mean

PDI	0.308	3.851
IDV	0.606	4.175
MAS	0.775	4.278
UAI	-0.505	3.013

For a model to be reliable, the Cronbach's Alpha needs to be above 0.6 as explained earlier in this section. In this case, the PDI model and the UAI model had values below 0.6 and are therefore not reliable enough to be used in the study. The pattern matrixes also indicated that these two dimensions were not accurately represented by the variables used to measure them.

The different fit indices are also calculated and will be used to determine if the different factors of NC are adequate. The model testing is only performed for the PDI factor and UAI factor, since the other models are not reliable enough to be used in this study.

Model Testing of IDV

Table 4.17: CMIN, Baseline Comparisons and RMSEA of the IDV dimension

Model		NPAR	CMIN	DF	P	CMIN/DF
CMIN	Default model	12	6.360	2	.042	3.180
	Saturated model	14	.000	0		
	Independence model	4	68.892	10	.000	6.889
Model		NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Baseline Comparisons	Default model	.908	.538	.935	.630	.926
	Saturated model	1.000		1.000		1.000
	Independence model	.000	.000	.000	.000	.000
Model		RMSEA	LO 90	HI 90	PCLOSE	
RMSEA	Default model	.128	.022	.246	.089	
	Independence model	.210	.165	.259	.000	

The main indices of Table 4.17 are summarised in Table 4.18 in order to improve readability.

Table 4.18 Summary of Indices of IDV

Fit Indices	Observed Fit indices	Recommended value
χ^2 / df	3.180	Between 2 and 5
CFI	.926	≥ 0.9
TLI	0.728	≥ 0.9
RMSEA	0.127	< 0.08

Table 4.18 gives a summary of the different indices of the IDV model. It shows that the χ^2 / df is 3.180, which is within the recommended range of between 2 and 5. The CFI is greater than 0.9. The TLI is lower than 0.9, with a value of 0.728 and the RMSEA is higher than 0.08. Even though the TLI and the RMSEA indices were not in the recommend range of values, both the CFI and the χ^2 / df indicates that the model had a good fit. The CFI is a good indication in the case of this study, because it is not affected by sample size as much as the other indices.

Model Testing of MAS

Table 4.19: CMIN, Baseline Comparisons and RMSEA of MAS

Model		NPAR	CMIN	DF	P	CMIN/DF
CMIN	Default model	12	1.816	2	.403	.908
	Saturated model	14	.000	0		
	Independence model	8	143.818	6	.000	23.970
Model		NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Baseline Comparisons	Default model	.987	.962	1.001	1.004	1.000
	Saturated model	1.000		1.000		1.000
	Independence model	.000	.000	.000	.000	.000
Model		RMSEA	LO 90	HI 90	PCLOSE	
RMSEA	Default model	.000	.000	.167	.514	
	Independence model	.416	.358	.476	.000	

The main indices of Table 4.19 are summarised in Table 4.20 in order to improve readability.

Table 4.20 Summary of Indices of MAS

Fit Indices	Observed Fit indices	Recommended value
χ^2 / df	.908	Between 2 and 5
CFI	1.000	≥ 0.9
TLI	1.004	≥ 0.9
RMSEA	.000	< 0.08

Table 4.20 is a summary of the different indices of the MAS model. The χ^2 / df is much lower than 2 with a value of 0.908. The CFI and the TLI are both higher than 0.9. The RMSEA had a perfect value of 0.000. The only indices in this model that did not indicate a good fit, were χ^2 / df . A possible reason for this is that the sample used in this study was not very large, which can influence this value.

4.5.3.4 Model Modification

The model could not be altered in any way to improve the model. Therefore only the IDV and MAS models will be used further in this study.

4.5.4 Statistical Techniques that were used

There were two types of statistical techniques, which were used for this study namely:

- Descriptive statistics; and
- Inferential statistics.

4.5.4.1 Descriptive Statistics

Descriptive statistics are used to describe the sample of the study and to organise the collected data. This information can be used for several functions, such as determining characteristics of the sample, which may impact the results of the study. It can also be used to compare this sample with other samples used in different studies. For descriptive statistics, frequency distributions and percentages are used to describe the different ordinal and nominal data. These distributions are the number of respondents for each possible option in a question and are often represented in percentages of the sample. Frequency distributions can be represented using visual techniques, such as graphs or tables or with numbers. Descriptive statistics also include measures of central tendency, indicating what the middle value of a sample is. In this study, means will be used to describe central

tendency, since it is the most used measure of central tendency. It calculates the average of the variable or factor. It is sensitive to outliers. (Thomson *et al.*, 1996; Berkman & Reise, 2012; Gordon & Schaumberger, 1978)

The descriptive data can also be used in order to check if any errors occurred when data was transferred from the questionnaires to the Microsoft Excel spreadsheet. It is important to establish if the data was transferred correctly before the data from the questionnaire can be analysed.

The data cleaning was performed as follows:

- The data was checked for any values that are outside the range of possible values. These errors can easily be detected using the descriptive statistic. The only errors that were identified were as a result of incorrectly transferring the data. The errors did occur because certain data was represented using binary values, 1 and 0. The errors that did occur were, for example placing a value 2 in the second column of the spreadsheet instead of a 1. The few incorrect values that were detected were corrected by using the questionnaires to find the correct values.
- The data was checked for any missing values. A few respondents did not answer all the questions. The researcher could not contact the respondents to ask them to complete these questions, because the survey was done anonymously. The researcher also could not complete the questions based on what the researcher estimated the value should be, because this would affect the integrity of the data. The only solution was, therefore to report the missing values in the descriptive statistics.
- Lastly, the data was checked for respondents who marked more than one answer for a single question. This type of data was handled in two different ways, namely:
 - If several respondents gave more than one answer for a specific question, the analysis of the question was changed. Each possible answer of the question was then analysed separately and the frequencies and percentages of respondents were then based on each possible answer. An example of this is question 2.4, which reads 'If you have Green IT initiatives in your organisation, which of the following factors motivated you to adopt them?' Several of the respondents marked more than one answer and therefore the frequencies of each possible answer could be computed and represented separately.
 - The second possible solution was to determine if one of the answers included the other answer as well. An example of this can be found in question 2.1, which reads

“What is your primary role in systems development?” Several of the respondents marked the answer “System analyst” as well as “Analyst/programmer”. Since “Analyst/programmer” includes an analyst, it was then used as the only value.

4.5.4.2 Inferential statistics

Inferential statistics are used to find results based on the data collected from the sample, which can be generalised to the entire population. It examines relationships between different variables and factors. In order to analyse the data correctly, it is important that the right types of statistical tests will be performed on the data (Thomspon *et al.*, 1996; Gordon & Schaumberger, 1978).

There are two categories of inferential statistics, namely parametric and nonparametric. Nonparametric statistics are used for data, which are nominal or ordinal and do not have a normal distribution. The Chi-square statistic is the only nonparametric statistic that will be used in this study (Thomspon *et al.*, 1996; Siegel, 1957).

Parametric statistics are used for data that is measured on a scale or in ratios and the data should be normally distributed. These tests can effectively be used to make observations regarding a specific population (Thomspon *et al.*, 1996; Siegel, 1957). In this study, the analysis of variance (ANOVA), Cross Tabulation, T-tests and Pearson correlation coefficient are the statistics that are best suited for the research objectives of this study and can be used on the collected data. The results of these tests will be reported in the next section.

The probability associated with the test statistics is called the *p*-value (Rumsey, 2011). A *p*-value of 0.5 or smaller is considered to be statistical meaningful (Thomspon *et al.*, 1996; Field, 2009). In the following sections only data that has a statistical meaningful *p*-value will be reported.

Effect sizes will be used in the following sections to establish if the relationships between data are important or not. The values of effect sizes depend on the type of statistical test that are performed and therefore they will be given separately for each test in the following sections. Relationships that have large effect sizes are considered to be practical significant and only these relationships will be reported in the following sections.

This study used three types of inferential statistics, namely:

- ANOVA tests
- Cross Tabs
- T-test
- Correlations

These four techniques will each be briefly explained in the following paragraphs.

ANOVA Tests

ANOVA works with interval and ratios data. It is used to determine differences of different groups, based on the mean of each group adjusted for the effect of the covariate. The ANOVA test is very popular because it can be done on any number of groups, unlike tests, such as the T-test, which can only be computed for two groups (Berkman & Reise, 2012; Thompspon *et al.*, 1996; Field, 2009).

The variable F is used to indicate how much variance there is between the different groups (Berkman & Reise, 2012; Field, 2009). In this study F will be reported as follows: $F(X,Y) = Z$ where :

- X is the degrees of freedom for the effect of the model.
- Y is the degrees of freedom for the residuals of the model
- Z is the value of F.

Only data relationships that have an effect size of 0.5 or more are reported in this study. An effect size above 0.5 indicates a practical visible difference between different groups and an effect size of 0.8 indicates a large practical significant difference between groups (Cohen, 1988).

Cross Tabs

Cross-Tabs are also known as contingency tables and can be used to present grouped data. This technique represents the classification of two or more variables of the same category. A cross-tab consists out of a grid with the levels of the variables and the frequencies of the variables in each category. The intersections of the different categories are called cells. A cross-tab calculates an estimated number of observations for each cell and then compares them with the actual number of observations in each cell. The larger the difference is

between the estimated value and the observed value, the higher the chance is for a statistical significant relationship (Field, 2009; Gokhale & Kullback, 1978; Thomspson *et al.*, 1996).

Each of the cells should have an estimated count of more than 5. In this study only the cross-tabs that have 25% or less cells with less than 5 expected counts, will be reported (Thomspson *et al.*, 1996; Steyn *et al.*, 1994).

Only data relationships that have an effect size of 0.3 or more are reported in this study. An effect size above 0.3 indicates a practical visible difference between different groups and an effect size of 0.5 indicates a large practical significant difference between groups (Cohen, 1988; Ellis & Steyn, 2003).

T-test

T-tests are used in order to determine whether there is a significant difference between two sets of data. Only two different sets of data can be compared with each other. The sets of data that are used should be independent of each other. T-tests are based on the mean and standard deviation of the two sets, and these values are used to compute whether the differences between the sets are by chance (Berkman & Reise, 2012; Thomspson *et al.*, 1996; Field, 2009).

The value *t* is used to indicate the difference between the means of the groups that are being compared (Berkman & Reise, 2012). Only data relationships that had an effect size of 0.5 or more are reported in this study. An effect size above 0.5 indicates a practical visible difference between different groups and an effect size of 0.8 indicates a large practical significant difference between groups (Cohen, 1988).

Correlations

The Pearson correlation coefficient is used to describe the degree of linearity in relationships between variables. It is the most frequently used statistic for describing relationships between data. It works with interval and rations data and is used to compute a standardised covariance between two variables. The correlation coefficient is then calculated by using the covariance of two variables and dividing it by the standard deviation of each of the variables (Thomspson *et al.*, 1996; Berkman & Reise, 2012; Rodgers & Nicewander, 1988).

The coefficient is interpreted as follows (Thomspon *et al.*, 1996):

- The coefficient of value 1 means a perfect correlation between two variables. The closer the correlation is to 1 (positive or negative), the stronger the correlation is. A coefficient value of between 0.3 and 0.7 is an acceptable correlation.
- Positive coefficients indicate a positive relationship between two variables. This means that if the value of one variable increases, the value of the other variable will increase as well.
- Negative coefficients indicate a negative relationship between two variables. This means that if the value of one variable increases, the value of the other variable will decrease.
- If the coefficient is zero, then there is no correlation between two variables.

Only data relationships that have a correlation of 0.3 or more are reported in this study. A correlation above 0.3 indicates a practical visible difference between different groups and a correlation of 0.5 indicates a large practical significant difference between groups (Cohen, 1988).

4.5.5 Demographic data of organisations that participated in the survey

In order to understand the organisations that participated in the survey better, the different characteristics of these organisations were determined. The demographic data that were measured were: Core business area, number of people employed in the organisation, number of people employed in the IS department, tasks of the IS department, the SD process used by the IS department, the maturity of SD process and proportion of IS(s) developed using the SD process. These characteristics are presented next, using descriptive statistics.

The **core business area** of the organisations is presented first and the results are shown in Table 4.21. Most of the organisations, namely 69 (51.5%), were software houses or were doing software consulting. The administrative services and retail and wholesale business areas had the least number of respondents, with both areas only having one respondent 1 (0.7%) of the sample. Twenty one (15.7%) of the organisations consisted of organisations from the Finance, Banking and Insurance industry and 7 (5.2%) consisted of organisations from the manufacturing industry. Several of the respondents, 29 (21.6%), were from other

different business areas. These areas included telecommunication, tourism, agriculture, auditing and insurance.

Table 4.21 Core business area of the organisations

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Administrative Services	1	.7	.7	.7
	Finance/Banking/Insurance	21	15.7	15.7	16.4
	Software house/ Software Consulting	69	51.5	51.5	67.9
	Manufacturing	7	5.2	5.2	73.1
	Retail/Wholesale	1	.7	.7	73.9
	Education	6	4.5	4.5	78.4
	Other	29	21.6	21.6	100.0
	Total	134	100.0	100.0	

The **size of the different organisations** is shown in Table 4.22. The size is based on the total number of employees of an organisation. For the reporting purposes an organisation with 1 to 50 people is classified as a small organisation, an organisation of 51 to 200 people as a medium organisation and an organisation of 200 or more employees as large.

Most of the organisations that participated in this survey, namely 72 (53.7%), consisted of large organisations. Thirty-three (24.6%) of the organisations were small and 26 (19.4%) were medium-sized organisations. Only three (2.2%) respondents were from micro-organisations.

Table 4.22 Number of employees in the organisations

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 - 4	3	2.2	2.2	2.2
	5 - 50	33	24.6	24.6	26.9
	51 - 200	26	19.4	19.4	46.3
	More than 200	72	53.7	53.7	100.0
	Total	134	100.0	100.0	

The **size of IS departments** was also determined and it is classified as follows: 1 to 5 people is a micro IS department, 6 to 20 employees is a small IS department, 20 to 50 employees is a medium IS department, 50 to 100 employees is a larger IS department and more than 100 employees is a very large IS department.

Table 4.23 indicates that most of the respondents, 57 (42.5%), had a very large IS department, consisting of more than 100 employees. The smallest number of respondents, 13 (9.7%), had small IS departments followed by IS 16 (11.9%) respondents from organisations with a micro-IS department. Thirty (22.4%) of the respondents were from medium-sized IS departments and 18 (13.4%) from large IS departments.

Table 4.23 Number of employees in the IS departments

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid 1 - 5	16	11.9	11.9	11.9
6 - 20	13	9.7	9.7	21.6
20 - 50	30	22.4	22.4	44.0
50 - 100	18	13.4	13.4	57.5
More than 100	57	42.5	42.5	100.0
Total	134	100.0	100.0	

The **task of the IS department** was determined next. As shown in Table 4.24, 43.75% of the IS departments' efforts went to systems maintenance and support. The results show that 42.36% of the IS departments' efforts were devoted to the development of new applications and only 13.88% of the efforts were allocated to package customisation.

Table 4.24 Activities of the IS departments

	N	Minimum	Maximum	Mean	Std. Deviation
Development of new applications	134	0.00	100.00	42.3575	25.16800
Systems maintenance and support	134	0.00	100.00	43.7530	22.99040
Package customisation	133	0.00	50.00	13.8789	12.37591
Valid N (list-wise)	133				

The **SD process** of the organisations is divided into two categories, namely formal SD processes and informal SD processes. The organisations mostly used formal SD processes, 81(56%) respondents, and with informal SD processes being used by 59 (44%) of the respondents. The formal SD processes can also be further divided into traditional SD and agile systems development. The results indicate that 46 (52.87%) of the organisations that use formal SD processes, use traditional SD, 35 (40.22%) use agile SD and six (6.9%) of the organisations use a both traditional and agile SD, depending on the specific situation.

Table 4.25 Systems development process used by IS departments

		Frequency	Percent	Valid Percent	Cumulative Percent
Informal Systems Development	.00	75	56.0	56.0	56.0
	1.00	59	44.0	44.0	100.0
	Total	134	100.0	100.0	
Traditional Systems Development	.00	88	65.7	65.7	65.7
	1.00	46	34.3	34.3	100.0
	Total	134	100.0	100.0	
Agile Systems Development	.00	99	73.9	73.9	73.9
	1.00	35	26.1	26.1	100.0
	Total	134	100.0	100.0	

The results of the **maturity of the SD process** used by organisations in the survey are presented next. As indicated in Table 4.26, 36 (27.1%) of the organisations have been using their SD process for 3 - 5 years, 33 (24.8%) have been using it for over 10 years and 23 (17.3%) of the organisations for 5-10 years. The smallest portion, 19 (14.3%), of the respondents—organisations have only been using the SD process for between 1 and 2 years and 21(15.8%) indicated that they did not know how long the SD process had been in use.

Table 4.26 **Years that the SD process has been in use**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 1 year	1	.7	.8	.8
	1 - 2 years	19	14.2	14.3	15.0
	3 - 5 years	36	26.9	27.1	42.1
	5 - 10 years	23	17.2	17.3	59.4
	Over 10 years	33	24.6	24.8	84.2
	I do not know	21	15.7	15.8	100.0
	Total	133	99.3	100.0	
Missing	System	1	.7		
Total		134	100.0		

This **horizontal use of the SD process**, meaning how widely the SD process is used across the organisation, was also determined. This is based on the proportion of projects, which are developed by the IS department, using the specific SD process. The horizontal SD process is used because according to Wynekoop and Russon (1997) and Hardy *et al.* (1995), it cannot be assumed that if an organisation is using a methodology, that it is being used extensively. This is important because organisations that used their methodology extensively, use it differently than organisations that use it less often (Huisman & livari, 1997). Other terms for horizontal use include breadth of use and frequency of use (Vavpotic & Bajec, 2009; Khalifa & Verner, 2000; Huisman & livari, 2006).

The largest portion of the organisations, namely 68 (51.5%), applied the SD process to over 75% of the development projects and 37(28%) applied it to between 51 and 75 percent. Only 13 (9.8%) of the respondents indicated that less than 25% of the development projects used the SD process knowledge.

Table 4.27 Proportion of projects on which this SD process is applied

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	7	5.2	5.3	5.3
	1 - 25%	6	4.5	4.5	9.8
	26 - 50%	14	10.4	10.6	20.5
	51 - 75%	37	27.6	28.0	48.5
	Over 75%	68	50.7	51.5	100.0
	Total	132	98.5	100.0	
Missing	System	2	1.5		
Total		134	100.0		

4.5.6 Demographic data of individuals that participated in the survey

The different characteristics of the individuals that participated in the survey were also measured. These characteristics were: primary role in SD, highest level of qualification and personal experience in SD. These characteristics are all presented next, using descriptive statistics.

There are many roles that can be fulfilled by an individual during SD and therefore the **primary roles** of the respondents were determined. The sample consisted mainly of developers and analysts and programmers, 33 (24.6%) and 25 (17.2%) responses respectively. Table 4.27 also indicates that 19 (14.2%) of the respondents were project managers, 15 (11.2%) were IS managers, 10 (7.5%) were team leaders and nine (6.7%) were systems analysts. There were 23 (17.2%) respondents that had *řotherř* roles, which were not specified in the questionnaire. These roles were user enterprise architects, QA specialists, IT operations manager, service management specialist, director, managing director, functional director, testers and business architects.

Table 4.27 Respondents primary role in systems development

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	IS Manager	15	11.2	11.2	11.2
	Project Manager	19	14.2	14.2	25.4
	Team Leader	10	7.5	7.5	32.8
	Systems Analyst	9	6.7	6.7	39.6
	Analyst/Programmer	25	18.7	18.7	58.2
	Developer	33	24.6	24.6	82.8
	Other	23	17.2	17.2	100.0
	Total	134	100.0	100.0	

The **highest qualification** of the individuals was also determined, as illustrated in Table 4.28. The largest number of the sample, 44 (33.1%), consisted of individuals who had University or Technicon degrees. Forty one (30.8%) of the individuals had Honours or Master's degrees. Only four (3%) had PhDs, six (4.5%) only had High School Certificates and 38 (28.6%) had certificates or diplomas.

Table 4.28 Highest Qualifications of Respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Senior Certificate (High School)	6	4.5	4.5	4.5
	Certificate or Diploma	38	28.4	28.6	33.1
	University or Technicon degree	44	32.8	33.1	66.2
	Honours or Master's degree	41	30.6	30.8	97.0
	PhD	4	3.0	3.0	100.0
Missing	System	1	.7		
Total		134	100.0		

In Table 4.29, the **personal experience** in SD of the respondents is shown. Most of the individuals, namely 54 (40.6%), had more than 10 years of experience and only one (0.8%) had no experience in systems development. Of the remainder of the responses, 29 (21.8%) had 5 - 10 years of experience, 26 (19.5%) had 3 - 5 years of experience, 13 (9.8%) had 1 - 2 years of experience and 10 (7.5%) had less than one year of experience.

Table 4.29 Respondents' personal experience in systems development

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	1	.7	.8	.8
	Less than 1 year	10	7.5	7.5	8.3
	1- 2 Years	13	9.7	9.8	18.0
	3 - 5 Years	26	19.4	19.5	37.6
	5 -10 Years	29	21.6	21.8	59.4
	More than 10 years	54	40.3	40.6	100.0
	Total	133	99.3	100.0	
Missing	System	1	.7		
Total		134	100.0		

4.5.7 Empirical Results of Research Objective 1

This section presents the empirical results of analysing the data collected with the questionnaire and then analysed in order to achieve the first research objective, namely to develop a Green approach towards systems development methodologies so that the development process, as well as the end product is greener. The results are presented in terms of the sub-objectives of the first research objective. In order to improve readability, each sub-objective is stated again. Only the results that were meaningful are presented.

The different sub-objectives will each be individually discussed.

4.5.7.1 Investigate different techniques or initiatives that can be used to reduce the negative impact of IT

Literature was reviewed to determine Green IT techniques. These techniques are discussed in section 2.2.1.

4.5.7.2 Determine the effectiveness of Green IT techniques or initiatives

In section 2.2.1 different Green IT techniques were identified. These techniques were then summarised in section 2.4.1 in ten Green IT categories. The perception of effectiveness of these techniques was then measured on a scale of 1 to 5 using the questionnaire.

Table 4.30 shows the number of people that indicated that they do use specific Green IT initiatives, as well as the mean and standard deviation of each Green IT initiative in terms of effectiveness.

Table 4.30 Effectiveness of Green IT initiatives

	N	Mean	Std. Deviation
Communication	132	3.82	1.090
Process Centric	130	3.71	1.144
Paper usage	134	3.20	1.200
Retirement of systems	129	3.03	1.262
Physical Infrastructure	131	2.76	1.352
IT infrastructure	130	2.59	1.322
Procurement/Sourcing	127	2.39	1.162
Green Software	130	2.34	1.255
Green Goals	131	2.30	1.305
Metrics	127	2.15	1.134
Valid N (list-wise)	121		

As seen in Table 4.30, Communication is perceived to be the most effective Green IT initiative, 3.82, and is implemented the second most, according to data. Process Centric (3.71), Paper usage (3.2) and retirement of system (3.03) are also regarded as effective, since they all have ratings of more than 3. The rest of the techniques are not considered to be effective, since all of them have values below 3. The Green IT technique that was implemented by most organisations (134) is Paper usage as opposed to Procurement/Sourcing and Metrics that were implemented by the least number of organisations with 127.

4.5.7.3 Evaluate different SDMs and determine if any existing systems development methodologies incorporate Green initiatives into the systems development methodology

This sub-objective was firstly investigated by doing a literature review of existing Green SDMs. These SDMs are discussed in section 2.4.2.

The questionnaire was then used to determine if Green initiatives are used in practice. The respondents were asked to indicate if their systems development process incorporates Green initiatives.

Table 4.31 shows that 79 (75.2%) of the respondents answered that their systems development process does support Green Initiatives, as opposed to 26 (24.8%) who said that their process did not.

Table 4.31 Green Initiative support of systems development processes

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	26	19.4	24.8	24.8
	1.00	79	59.0	75.2	100.0
	Total	105	78.4	100.0	
Missing	System	29	21.6		

4.5.7.4 Determine how different SDMs can be adapted to have greener development process and a greener end product

In order to determine how different SDMs can be adapted, literature was consulted to determine different Green IT techniques and initiatives, as explained in section 2.2.1. These techniques and initiatives were then summarised into ten categories in section 2.4.1. Implementing Green IT techniques in an SDM is important, since the core of any IS is IT. The evaluation of the different Green SDMs in section 2.4.3 also gives an indication of how current SDMs can be adapted.

In order to determine how SDMs are being adapted in practice, the questionnaire asked the respondents to indicate how they are adapting their SDMs to be Green. The results are shown in Table 4.32.

Table 4.32 **Considerations used when adapting SDMs**

Consideration	Techniques and Strategies
Green Goals	New products include environmental impact assessments in the feasibility study.
Paper Usage	Organisations are switching to a paperless environment with electronic document sharing via tools, such as SharePoint. This is to avoid paper usage, as well as to limit printing.
Green Software	Software is developed as efficiently as possible in order to use fewer resources. Interfaces are developed with dark colours because this uses fewer resources.
IT infrastructure	Ensuring that no hardware is running when it is not in use. Hardware is shared using virtual servers and energy-efficient hardware is used.
Physical Infrastructure	Organisations ensure that when the building where the software development takes place is not in use, the lights and air conditioning are turned off. Some organisations also use solar panels to power the physical infrastructure.
Retirement of System	Correctly disposing of old IT equipment when the cross-over to a new system is made. This also includes recycling of equipment, as well as refurbishment.
Communication	Telecommunication is used instead of travelling to different people.
Metrics	Metrics are used that could monitor resource consumption and performance of the IS(s).

An additional category was also found within the results, namely improving environmental awareness. Organisations are improving awareness regarding environmental impact. This is done by having a Green agenda item at all meetings and by including a footer in all e-mails, which asks the receiver to take the environment into consideration.

4.5.7.5 Determine how a Green SDM should be classified

In section 2.4.4 the framework of Iivari *et al.* (2000) is expanded in order to classify a Green SDM.

4.5.8 Empirical Results of Research Objective 2

This section presents the empirical results that were collected with the questionnaire and then analysed in order to achieve the second research objective, namely to determine the possible influences that could affect the adoption of Green IT and Green systems development. The results are presented in terms of the sub-objectives of this objective. In

order to improve readability, each sub-objective is stated again. Only the results that were meaningful are presented.

The empirical results of factors that motivate or inhibit organisations from adopting Green IT initiatives are presented first.

4.5.8.1 Determine the factors that motivate organisations into or inhibit organisations from adopting Green IT initiatives

In order to determine the factors that motivate organisations into or inhibit organisations from adopting Green IT initiatives, a literature review was undertaken in section 3.2.1 to identify possible factors. These factors were then included in the questionnaire in order to determine if they are also motivating or inhibiting organisations in practice. The predictions of the respondents for the adoption of Green IT/IS in the future were also determined using the questionnaire. The empirical results of motivating factors are discussed first.

As shown in the Figure 4.2, the main motivational factor for adopting Green IT initiatives is economic 46 (29.87%), followed closely by an ethical motivation 44 (28.57%). The regulatory factor received the least number of responses 22 (14.29%).

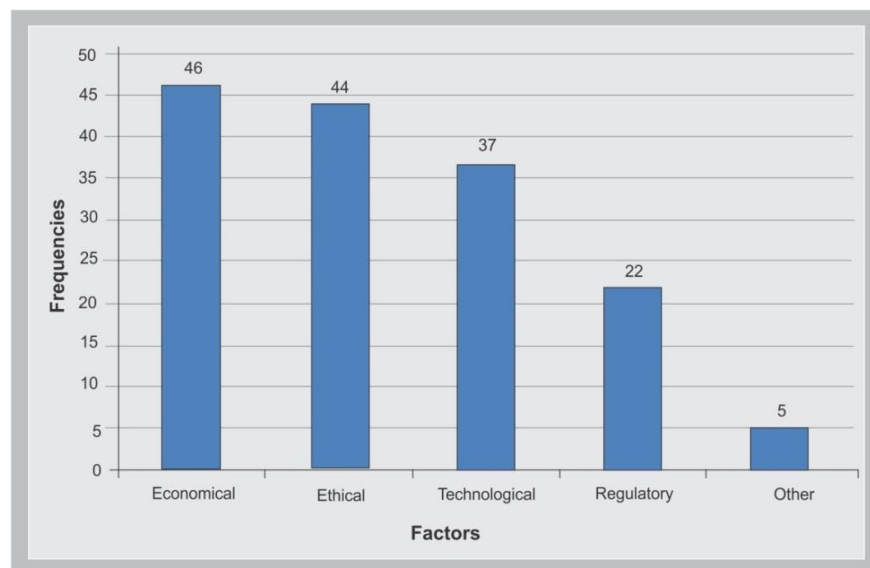


Figure 4.2 Factors that motivated the adoption of Green Initiatives

Respondents also indicated additional motivation was: "avoidance of an emerging threat", "overall organisation that focuses on sustainability", "part of the rules of this company" and "the ability to audit a paperless system".

The empirical results of the inhibiting factors are shown in the figure below. The number one factor that inhibits organisations from adopting Green IT initiatives is cost 33 (30.28%) followed by organisations not seeing the business value 22 (20.183%) and lack of business leadership 20 (18.35%). Lack of government incentives or regulations received the lowest value nine (8.26%).

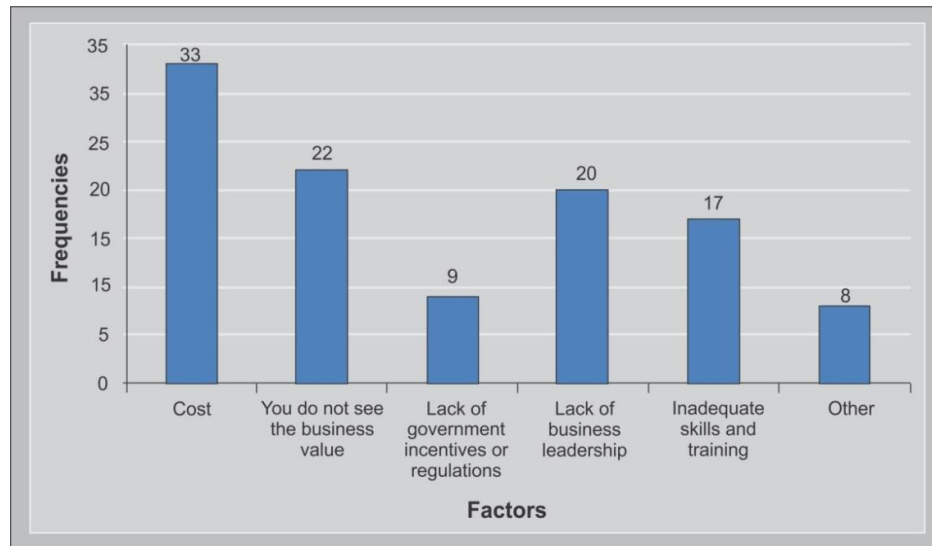


Figure 4.3 Factors that inhibit the adoption of Green Initiatives

Eight of the respondents included marked the "other" category. The respondents indicated that their inhibitory factors were: "Didn't ever think about it", "Limited application, efforts are electronic and runs off mainframe servers, unsure what the Green status of the mainframes are", "We have Green initiatives, but cost to implement for sake of Greening does not always stack up, e.g. the cost to add constant power-monitoring devices in a data centre is prohibitive. Rather, business will not invest if there is valid threat such as a legislative or mandatory change, or cost saving", "Unfortunately for a large company these decisions are made on an executive level and I cannot therefore pinpoint the reasons for it not being adopted effectively", "find it unnecessary in an IT development area", "client still wants paperwork", "there are more pressing concerns" and "they are unsure".

The future predictions were also determined so that the importance of Green IT initiatives can be better understood. By looking at Table 4.33, it is clear that most respondents, namely 63 (48.1%), are expecting that their organisations will use more Green IT initiatives in the future and 24 (18.3%) expected that their current Green IT initiatives will be supplemented with more Green IT initiatives. Of all the respondents, only one (0.8%) expected that they

would abandon the use of Green IT initiatives and another 39 (29.8%) expected that no change would occur. One respondent marked the 'other' option and said they are going to focus more on virtualisation.

Table 4.33 Predictions for Green IT initiatives for the future

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Use more Green IT initiatives	63	47.0	48.1	48.1
	Replace your current Green Initiatives	3	2.2	2.3	50.4
	Supplement current Green IT initiatives with more Green IT initiatives	24	17.9	18.3	68.7
	Abandon the use of Green IT initiatives	1	.7	.8	69.5
	No Change	39	29.1	29.8	99.2
	Other	1	.7	.8	100.0
	Total	131	97.8	100.0	
Missing	System	3	2.2		
Total		134	100.0		

4.5.8.2 Determine the impact that organisational characteristics has on the adoption of Green IT initiatives and the incorporation of Green IT techniques into systems development

The different organisational characteristics that were presented in section 4.5.5, were analysed using inferential statistics to determine if any relationships exist between them and the different Green initiative factors investigated in this study. The comparison that indicated that relationships exist was

- core business area of the organisation and the ratings of effectiveness of the different Green IT initiatives;
- sizes of organisations and ratings of effectiveness of the different Green IT initiatives;
- size of the organisations' IS Departments and the effectiveness of Green Initiatives;
- the core business area of the organisation and factors that motivate the adoption of green initiatives;

- the IS departments' tasks and factors that motivate the adoption of Green IT initiatives;
- the IS departments' tasks and factors that inhibit the adoption of Green IT initiatives; and
- the total number of people employed in the organisations' IS departments and if the SD process of the organisations supports Green Initiatives.

All these relationships will be presented next, but they will not be interpreted. The interpretation of the results will be done in Chapter 5. There were many other comparisons that were done that did not indicate any relationships. The comparisons will also be mentioned. The results of the relationship of the core business areas of the organisations with the effectiveness of each of the different Green IT initiatives are presented first.

Relationship between the core business area of the organisation and the ratings of the effectiveness of the different Green IT initiatives

T-tests were performed in order to analyse the relationship of the core business area of the organisations with the ratings of effectiveness of the different Green IT initiatives. The results are summarised in Table 4.36. Only the Green IT initiatives and core business areas that indicated a statistically significant relationship are presented, as mentioned in section 4.5.4. The mean value indicates the average rating of each Green IT initiative in terms of the core business area.

Table 4.34 Comparison between core business area and effectiveness of Green IT initiative

Core Business area		N	Mean	Std. Deviation	t	p-value	Effect size
Paper Usage	Finance etc.	21	4.00	.837	3.164	0.003	0.63
	Software House	69	3.28	1.149			
IT infrastructure	Finance, etc.	21	3.05	1.117	2.022	0.05	0.43
	Software House	67	2.45	1.385			
Process centric	Finance, etc.	1	4.05	.921	2.071	.044	0.41

Core Business area		N	Mean	Std. Deviation	t	p-value	Effect size
Procurement/ Sourcing	Software House	66	3.52	1.304			
	Finance, etc.	17	2.94	1.249	2.240	.035	0.60
	Software House	67	2.19	1.145			
	Finance, etc.	18	2.67	1.237	1.973	.060	0.51
	Software House	66	2.03	1.123			

The mean value of paper usage is 4.00 for the 21 respondents from organisations in Finance/Banking/Insurance and 3.28 for the 69 respondents from organisations in Software House/Software consulting. The effect size is 0.63 indicating a practical visible relationship.

The mean value of IT infrastructure is 3.05 for the 21 respondents from organisations in Finance/Banking/Insurance and 2.45 for organisations in Software House/Software consulting. The effect size is 0.43 indicating a practical visible relationship.

The mean value of Process Centric is 4.05 for the one respondent from organisations in Finance/Banking/Insurance and 3.52 for the 66 respondents from organisations in the Software House/Software consulting. The effect size is 0.41, indicating a practical visible relationship.

The mean value of Procurement/sourcing is 2.94 for the 17 respondents from organisations in Finance/Banking/Insurance and 2.19 for the 67 respondents from organisations in Software House/Software consulting. The effect size is 0.60, indicating a practical visible relationship.

The mean value of metrics is 2.67 the 18 respondents from organisations in Finance/Banking/Insurance and 2.03 for 66 respondents from organisations in Software House/Software consulting. The effect size is 0.51, indicating a practical visible relationship.

The relationship between the size of organisations and ratings of effectiveness of the different Green IT initiatives

This relationship was analysed using ANOVA tests. The results are summarised in Table 4.35. The *n* column indicates how many organisations of a specific size implemented the Green IT initiative. The mean indicates the average of how effective each of the different sizes of organisations rated the Green IT initiative. The ANOVA values are also presented.

Table 4.35: Comparison between size of an organisation and effectiveness of Green IT considerations

Green IT initiative	Size of Organisation	N	Mean	Std Deviation	ANOVA values
Green Goals	Small organisations	36	1.94	1.241	$F(2,128) = 10.048$ $p = 0.053$
	Medium organisations	26	1.62	0.941	
	Large organisations	69	2.74	1.302	
IT infrastructure	Small organisations	35	2.11	1.255	$F(2,127) = 5.434$, $p = 0.005$
	Medium organisations	25	2.32	1.145	
	Large organisations	70	2.93	1.333	
Physical Infrastructure	Small organisations	34	2.29	1.292	$F(2,28) = 3.878$, $p = 0.023$
	Medium organisations	26	2.62	1.203	
	Large organisations	71	3.04	1.378	
Retirement of Systems	Small organisations	34	2.32	1.364	$F(2,126) = 9.549$, $p = 0.000$
	Medium organisations	26	2.96	0.999	
	Large organisations	69	3.41	1.155	
Communication	Small organisations	34	3.38	1.303	$F(2,126) = 9.549$, $p = 0.000$
	Medium organisations	26	3.69	1.258	
	Large organisations	72	4.07	0.828	
Process Centric	Small organisations	34	3.35	1.535	$F(2,29) = 5.105$, $p = 0.007$
	Medium organisations	25	3.40	1.190	
	Large organisations	71	3.99	0.802	
Procurement/ Sourcing	Small organisations	33	1.94	1.088	$F(2,127) = 4.919$, $p = 0.009$
	Medium organisations	26	1.96	0.999	

Green IT initiative	Size of Organisation	N	Mean	Std Deviation	ANOVA values
	Large organisations	68	2.76	1.135	
Metrics	Small organisations	32	1.64	0.895	$F(2, 124) = 11.110, p = 0.000$
	Medium organisations	26	1.73	0.827	
	Large organisations	68	2.56	1.189	

When reporting the results of an ANOVA test, the effect size needs to be analysed. Only effect sizes of 0.5 or more are significant, as mentioned in section 4.5.4. For this study, effect size of between 0.46 and 0.5 are also reported. The Green IT initiatives that had a significant effect size between different groups are summarised in Table 4.36.

Table 4.36: Effect size of different sizes of organisations

Green IT initiative		Effect size of difference between the sizes of organisations.	
	Size of Organisation	Medium	Large
Green Goals	Small		0.61
	Medium		0.86
IT Infrastructure	Small		0.61
	Medium		0.46
Physical Infrastructure	Small		0.54
Retirement of Systems	Small	0.47	
	Medium		0.79
Communication	Small		0.79
Process Centric	Small	0.49	
Procurement/ Sourcing	Small		0.73
	Medium		0.71
Metrics	Small		0.78
	Medium		0.70

The results in Table 4.36 will be briefly discussed next.

Green Goals has two meaningful effect sizes. The effect size between the medium-sized organisations and large organisations is 0.86, which indicates a large practical difference. There is also a medium practical difference between the small organisations and the large organisations, based on the effect size of 0.61.

IT Infrastructure also has two meaningful effect sizes. The effect size between the medium-sized organisations and large organisations is 0.46, indicating a medium practical difference. There is also a medium practical difference between the small organisations and the large organisations, based on the effect size of 0.61.

Physical Infrastructure had only one meaningful effect size. There is a medium practical difference between the small organisations and large organisations, based on the effect size of 0.54.

For **Retirement of Systems**, two effect sizes can be reported. The effect size between the small organisations and the medium organisations is 0.47 and indicates a medium practical difference. There is also a large practical difference between medium organisations and large organisations, based on the effect size of 0.79.

There is a medium practical difference between the small organisations and the large organisations, based on the effect size of 0.79 for **Communication**.

Process Centric has a meaning effect size between the small organisations and the medium-sized organisations of 0.49, and this indicates a medium practical difference.

Procurement/Sourcing has two meaningful effect sizes. The effect size between the small organisations and the large organisations is 0.73 and it indicates a medium practical difference. There is also a medium practical difference between the medium-sized organisations and the large organisations, based on the effect size of 0.71.

Lastly, **Metrics** has two effect sizes which can be reported. The effect size between the small organisations and the large organisations is 0.78 and indicates a large practical difference. There is also a medium practical difference between medium-sized organisations and large organisations, based on the effect size of 0.70.

The next relationship that will be presented is the size of the organisations' IS departments and the rating of effectiveness of each Green IT initiative.

Relationship of the size of the organizations' IS Departments and the effectiveness of Green Initiatives

This relationship was also analysed using ANOVA tests. The results are summarised in Table 4.37. The first column indicates how many organisations of a specific size implemented the Green IT initiative. The mean indicates the average of how effective each of the different

sizes of organisations's IS departments rated the Green IT initiative. The ANOVA values are also presented.

Table 4.37: Comparison of the size of an IS department and effectiveness of Green IT initiatives

Green IT initiative	Size of IS department	N	Mean	Std Deviation	ANOVA values
Green Goals	Small IS department	27	2.22	1.396	$F(3,127) = 3.468$, $p = 0.018$
	Medium IS department	30	1.80	0.997	
	Large IS department	18	2.06	1.110	
	Very large IS department	56	2.68	1.377	
Retirement of Systems	Small IS department	26	2.65	1.413	$F(3,125) = 3.377$, $p = 0.021$
	Medium IS department	29	2.69	1.257	
	Large IS department	18	2.94	1.162	
	Very large IS department	56	3.41	1.141	
Communication	Small IS department	28	3.54	1.261	$F(3,128) = 4.571$, $p = 0.004$
	Medium IS department	29	3.34	1.317	
	Large IS department	18	4.17	0.857	
	Very large IS department	57	4.09	0.808	
Process Centric	Small IS department	27	3.70	1.436	$F(3,126) = 5.125$, $p = 0.002$
	Medium IS department	29	3.03	1.401	
	Large IS department	18	4.00	0.485	
	Very large IS department	56	3.96	0.830	
Procurement/ Sourcing	Small IS department	25	2.20	1.190	$F(3,123) = 5.323$, $p = 0.002$
	Medium IS department	29	1.83	0.928	
	Large IS department	18	2.28	0.958	
	Very large IS department	55	2.80	1.193	
Metrics	Small IS department	26	1.77	0.951	$F(3,123) = 9.127$, $p = 0.002$
	Medium IS department	28	1.54	0.793	
	Large IS department	18	2.06	0.873	
	Very large IS department	55	2.67	1.218	

In order to interpret the results in Table 4.38, the effect sizes are summarised in Table 4.38 below. Once again only the statistical significant effect sizes are reported. The Green IT initiatives that had a significant effect size between different groups are summarised in the next table:

Table 4.38: Effect size of difference between the sizes of IS departments

Green IT initiative	Effect size of difference between the sizes of IS departments			
	Size of IS department	Medium	Large	Very large
Green Goals	Medium			0.64
	Large			0.45
Retirement of Systems	Small			0.54
	Medium			0.57
Communication	Small		0.5	
	Medium		0.62	0.56
Process Centric	Small	0.47		
	Medium		0.69	0.66
Procurement/ Sourcing	Small			0.5
	Medium		0.47	0.82
	Large			0.44
Metrics	Small			0.74
	Medium		0.6	0.93
	Large			0.51

The effect sizes presented in Table 4.38 will now be briefly discussed.

For **Green goals** there is a medium practical difference between medium-sized IS departments and very large IS departments, based on the effect size of 0.64. There is also a medium practical difference between large IS departments and very large IS departments, based on the effect size of 0.45.

Retirement of systems indicates a medium practical difference between the small IS departments and very large IS departments, based on the effect size of 0.54. There is also a medium practical difference between the medium-sized IS departments and the very large IS departments, based on the effect size of 0.57.

For **Communication**, there is a medium practical difference between the small IS departments and the large IS departments, based on the effect size of 0.5. There is a medium practical difference between the medium-sized IS departments and large IS departments, based on the effect size of 0.62. There is also a medium practical difference between the group of medium-sized organisations and very large organisations, based on the effect size of 0.56.

The **Process centric initiative** indicates a medium practical difference between small IS departments and the medium-sized IS departments, based on the effect size of 0.47. There is a medium practical difference between medium-sized IS departments and the large IS departments, based on the effect size of 0.69. There is also a medium practical difference between the medium-sized IS departments and the very large IS departments, based on the effect size of 0.66.

For **Procurement**, there is a medium practical difference between the small IS departments and the very large IS departments, based on the effect size of 0.5. There is a medium practical difference between the medium-sized IS departments and the large IS departments, based on the effect size of 0.47. There is a medium practical difference between the large IS departments and the very large IS departments, based on the effect size of 0.44. There is also a large practical difference between the medium-sized IS departments and the very large IS departments, based on the effect size of 0.82.

Lastly, **Metrics** indicates a large practical difference between the small IS departments and the very large IS departments, based on the effect size of 0.74. There is a medium practical difference between the medium-sized IS departments and the large IS departments, based on the effect size of 0.60. There is a large practical difference between the medium-sized IS departments and the very large IS departments, based on the effect size of 0.93. There is also a medium practical difference between the large IS departments and the very large IS departments, based on the effect size of 0.51.

Relationship between tasks of the IS departments and the effectiveness of Green IT initiatives

The comparison between the tasks of IS departments and the effectiveness of Green IT initiatives was done using correlations. Only one Green IT initiative, namely Retirement of

Systems, produced a significant relationship. The results of the correlation are shown in Table 4.39.

Table 4.39: Comparison of tasks of the IS department with the effectiveness of Retirement of Systems

Task		Retirement of Systems
Development of new applications	Pearson Correlation	-.372**
	P-value. (2-tailed)	.000
	N	129
Systems maintenance and support	Pearson Correlation	.313**
	P-value. (2-tailed)	.000
	N	129

The *p*-value of retirement of systems and development of new applications is below 0.05, therefore there is a statistical significant relationship between the two variables. The correlation is also 0.372 indicating a medium-strength relationship.

The *p*-value of retirement of systems and systems maintenance and support is 0.000 therefore there is a statistical significant relationship between the two variables. The correlation is also 0.313 indicating a medium-strength relationship.

Relationship between the core business area of the organisation and factors that motivate the adoption of Green initiatives.

The comparison of the core business area of organisations and motivating factors for Green initiatives was done using Cross-tabs. Only the regulatory motivation factor indicated a statistic meaningful relationship between these two factors. The results of the Cross-tab performed on these two factors are summarised in Table 4.40 and Table 4.41.

Table 4.40: Comparison of Core Business Area and the Regulatory motivation factor

Core Business area		Regulatory		Total
		0	1	
Finance/ Banking/ Insurance	Count	11	10	21
	% within Core business area	52.4%	47.6%	100.0%
Software House/ Software consulting	Count	62	7	69
	% within Core Business area	89.9%	10.1%	100.0%
Total	Count	73	17	90
	% within Core business area	81.1%	18.9%	100.0%

Table 4.41: Phi values of the comparison of Core Business Area and the Regulatory motivation

		Value	P-value.
Nominal by Nominal	Phi	-.405	.000
Nominal by Nominal	Cramer's V	.405	.000
N of Valid Cases		90	

The p -value of 0.000 indicates that there is a statistical significant relationship between the core business area factor and the regulatory motivation factor. The phi value of 0.405 also indicates that there is a strong relationship between the two variables. As shown in Table 4.41 11 (52.4%) of respondents from organisations within the Finance/Banking/Insurance industry indicated that regulatory factors did not motivate them to adopt Green IT initiatives, as opposed to 62 (89.9%) of the respondents from Software house/Software Consulting. Of the organisations that did indicate regulatory influence as the factor that motivated them to adopt Green IT, 10 (47.6%) of the respondents were from organisations in the Finance/Banking/Insurance industry and seven (10.1%) of the respondents were from Software house/Software Consulting.

Relationship between the IS departments' tasks and factors that inhibit the adoption of Green IT initiatives

This comparison was done using T-tests. Only two statistic meaningful relationships between the tasks of an IS department and inhibitory factors were found. The first relationship is

between the no business value inhibitory factor and the systems maintenance and support task. The second relationship is between the lack of government incentives or regulations factor and the development of new applications task. The results of these comparisons are presented in Table 4.42

Table 4.42: Comparison of IS departments' tasks and inhibitory factors

Inhibitory Factor	Task		N	Mean	Std. Deviation	t	p-value	Effect Size
No business value	System maintenance & support	0	112	45.55	23.432	2.439	0.020	0.470
		1	22	34.55	18.446			
Lack of government incentives or regulations	Development of new applications	0	125	43.82	25.202	4.276	0.001	0.870
		1	9	22.00	13.730			

The no business value factor has a p -value of 0.02, indicating a statistical difference between the groups and the effect size is 0.47, indicating a medium-strength relationship between the variables. The mean value of systems maintenance and support is 45.55 for the 112 respondents who did not indicate that they do not see the business value and 34.55 for 22 respondents who indicated that that they do not see the business value.

The lack of government incentives or regulations factor has a p -value of 0.001, indicating a statistical difference between the groups and the effect size is 0.87, indicating a strong relationship between the variables. The mean value of development of new applications is 43.82 for the 125 respondents who did not indicate lack of government incentives or regulations and 22.00 for nine respondents who indicated that lack of government incentives or regulations inhibited them from adopting Green IT initiatives.

Relationship between size of the IS departments and if the SD process of the organisations supports Green Initiatives

The comparison of the size of the IS departments and if the SD process of the organisations supports Green Initiatives were analysed using Cross-Tabs. The results are displayed in Table 4.43.

Table 4.43: Comparison between the size of IS departments and support for Green Initiatives in the SD process

Size of IS department		Green systems development process		Total
		0	1	
Small	Count	8	17	25
	% within Employees in IS department	32.0%	68.0%	100.0%
Medium	Count	9	13	22
	% within employees in IS department	40.9%	59.1%	100.0%
Large	Count	5	5	10
	% within employees in IS department	50.0%	50.0%	100.0%
Very large	Count	4	44	48
	% within employees in IS department	8.3%	91.7%	100.0%
Total	Count	26	79	105
	% within O_3R	24.8%	75.2%	100.0%

Table 4.44: Phi values of comparison between the size of IS departments and support for Green Initiatives in the SD process

	Value	<i>p</i> -value
Nominal by Phi	.367	.003
Nominal		
Cramer's V	.367	.003
N of Valid Cases	105	

The *p*-value of 0.003 indicates that there is a statistical significant relationship between small IS departments and if the systems development process of the organisation supports Green initiatives. The phi value of -0.367 also indicates that there is a medium-strength relationship between the two variables. Table 4.43 shows that of the 26 respondents who said that their SD process did not support Green initiatives, eight of the organisations had small IS

departments, nine of the organisations had medium-sized IS departments, five had large IS departments and four respondents had very large IS departments in their organisations.

Table 4.43 also indicates that of the 79 respondents who said that their SD process did support Green initiatives, 17 of the organisations had small IS departments, 13 of the organisations had medium-sized IS departments, five had large IS departments and 44 respondents had very large IS departments in their organisations.

Comparisons that were analysed, but showed no relationships

There were many additional comparisons made in order to determine the effect of the characteristics of an organisation and Green IT initiatives and the incorporation of Green IT techniques into systems development. None of the following comparisons produced any relationships.

The size of the organisation and if the systems development process supports Green initiatives.

- The size of the organisation and the factors that motivated an organisation to adopt Green IT initiatives.
- The size of the organisation and the factors that inhibited an organisation from adopting Green IT initiatives.
- The size of the IS department and the factors that motivated an organisation to adopt Green IT initiatives.
- The size of the IS department and the factors that inhibited an organisation from adopting Green IT initiatives.
- The core business area of the organisation and if the systems development process supports Green IT initiatives.
- The core business area of the organisation and factors that inhibit the adoption of Green initiatives.
- The type of SD process and if the systems development process supports Green initiatives.
- The tasks of the IS department and if their systems development process supports Green IT initiatives.

- The tasks of the IS department and factors that motivate the adoption of Green IT initiatives.
- The tasks of the IS department and the factors that inhibit an organisation from adopting Green IT initiatives.

In the next section the results of comparisons made on the impact of an individual's characteristics in an organisation on the adoption of Green IT initiatives and the incorporation of Green IT techniques into systems development are presented.

4.5.8.3 Determine the impact of an individual's characteristics in an organisation on the adoption of Green IT initiatives and the incorporation of Green IT techniques into systems development

In order to determine the influence of an individual's characteristics and the adoption of Green IT initiatives and the incorporation of Green IT techniques into systems development, the following comparisons were done using Cross-Tabs:

- The primary role in systems development and the future expectations of Green IT initiatives.
- The primary role in systems development and motivational factors
- The primary role in systems development and inhibiting factors
- The highest qualification and motivational factors
- The highest qualification and inhibit factors
- The highest qualification and future expectations of Green IT initiatives
- Personal experience in systems development and motivational factors
- Personal experience in systems development and inhibiting factors
- Personal experience in systems development and future expectations of Green IT.

None of the comparisons produced any statistical meaningful results.

In the next section the results of the comparisons between organisational culture and the adoption of Green IT initiatives and the incorporation of Green IT techniques into systems development will be discussed.

4.5.8.4 Determine the impact that organisational culture has on the adoption of Green IT initiatives and the incorporation of Green IT techniques into systems development

The competing values framework discussed in section 3.3.1 was used in order to measure the OC in the survey. The CVF categorises OC into four types, namely Group, Developmental, Hierarchical and Rational Culture. The values of these types of OC for the participants are calculated using the different variables described in section 4.5.2. The average value for each of these types of OC is displayed in Table 4.45.

Table 4.45: Average calculated for the different types of OC of the survey

	Type of Organisational Culture			
	Group Culture	Developmental Culture	Hierarchical culture	Rational Culture
Mean	3.609	3.547	3.229	3.448

The types of OC of the participants were used to determine if the type of OC can influence the adoption of Green IT initiatives or the incorporation of Green IT techniques into systems development. The following comparisons produced statistical relevant relationships:

- The type of organisational culture and the effectiveness of Green IT initiatives.
- The type of organisational culture and the type of SD process.
- The type of organisational culture and factors that motivate the adoption of Green IT initiatives.
- The type of organizational culture and factors that inhibit the adoption of Green IT initiatives.

An additional comparison was also made, which did not produce any significant results. This comparison will also be mentioned. The first comparison that will be discussed is that the between the organisational culture and the effectiveness of Green IT initiatives.

Relationship between the organisational culture and the effectiveness of Green IT initiatives

The relationship between OC and the effectiveness of Green IT initiatives is analysed using correlations. Only the effectiveness of two Green IT initiatives, Process Centric and Communication, were affected by the type of OC of the organisations in the survey. The correlations of these two initiatives are summarised in Table 4.46.

Table 4.46: Comparison of OC and effectiveness of Green IT initiative

Type of Culture		Green IT initiative	
		Process Centric	Communication
Group culture	Pearson Correlation	.288	
	<i>p</i> -value (2-tailed)	.001	
	N	130	
Developmental Culture	Pearson Correlation	.303	.326
	<i>p</i> -value (2-tailed)	.000	.000
	N	130	132
Rational Culture	Pearson Correlation	.277	
	<i>p</i> -value (2-tailed)	.001	
	N	130	

The *p*-value of process centric and group culture is 0.001 therefore there is a statistical significant relationship between the two variables. The correlation is 0.288 indicating a medium-strength relationship.

The *p*-value of communication and developmental culture is 0.000 therefore there is a statistical significant relationship between the two variables. The correlation is 0.326 indicating a medium-strength relationship.

The *p*-value of process centric and developmental culture is 0.000 therefore there is a statistical significant relationship between the two variables. The effect size is 0.303 indicating a medium effect size.

The p -value of process centric and rational culture is 0.001 therefore there is a statistical significant relationship between the two variables. The correlation is 0.277 indicating a medium-strength relationship.

Relationship between the organizational culture and the type of SD process

The comparison between OC and the type of SD process was done using T-tests. The results of these tests are shown in Table 4.47.

Table 4.47: Comparison between OC and the type of SD process

Agile systems development		N	Mean	Std. Deviation	t	p-value	Effect Size
Developmental Culture	0	99	3.4343	.82266	-2.756	0.008	0.530
	1	35	3.8667	.78881			
Rational Culture	0	99	3.5404	.82893	-2.876	0.005	0.520
	1	35	3.9714	.73707			

The p -value is 0.008, indicating a statistical difference between the groups and the effect size is 0.530, indicating a practical visible relationship between the variables. The mean value Developmental Culture is 3.4343 for the 99 respondents who indicated that they do not use agile development and 3.8667 for the 35 respondents who indicated that they do use agile development.

The p -value is 0.005, indicating a statistical difference between the groups and the effect size is 0.530, indicating a practical visible relationship between the variables. The mean value Rational Culture is 3.5404 for the 99 respondents who indicated they do not use agile development and 3.9714 for the 35 respondents who indicated that they do use agile development.

Relationship between the organisational culture and factors that motivate the adoption of Green IT initiatives

This relationship was also determined using T-Tests and is presented in Table 4.48.

Table 4.48: Relationship between the organisational culture and factors that motivate the adoption of Green IT initiatives

Regulatory		N	Mean	Std. Deviation	t	p-value	Effect Size
Rational Culture	0	112	3.7321	.81354	2.623	0.013	0.590
	1	22	3.2500	.78300			

The p -value is 0.013, indicating a statistical difference between the groups and the effect size is 0.590, indicating a practical visible relationship between the variables. The mean value Rational Culture is 3.7321 for the 112 respondents who indicated regulatory factors do not motivate the adoption of Green IT and 3.2500 for the 35 respondents who indicated that regulatory factors motivated them to adopt Green IT initiatives.

Relationship between the organisational culture and factors that inhibit the adoption of Green IT initiatives

The last relationship that was identified in this section is between the type of OC and the factors that inhibit the adoption of Green IT initiatives. Only one factor, namely lack of government incentives or regulations, was influenced by the type of OC of organisations.

Table 4.49: Comparison of inhibitory factors and type of OC

Lack of government incentives or regulations		N	Mean	Std. Deviation	t	p-value	Effect Size
Developmental Culture	0	125	3.5840	.83135	2.189	0.054	0.660
	1	9	3.0370	.71578			
Hierarchical Culture	0	125	3.1840	.83865	-3.635	0.004	0.800
	1	9	3.8519	.50308			

The p -value is 0.054, indicating a statistical difference between the groups and the effect size is 0.660, indicating a practical visible relationship between the variables. The mean value Developmental Culture is 3.5840 for the 125 respondents who indicated lack of government incentives or regulations did not inhibit the adoption of Green IT initiatives and 3.0370 for the nine respondents who indicated that lack of government incentives or regulations did inhibit the adoption of Green IT initiatives.

The p -value is 0.004, indicating a statistical difference between the groups and the effect size is 0.8, indicating a strong relationship between the variables. The mean value Hierarchical Culture is 3.1840 for the 125 respondents who indicated lack of government incentives or regulations did not inhibit the adoption of Green IT initiatives and 3.8519 for the nine respondents who indicated that lack of government incentives or regulations does inhibit the adoption of Green IT initiatives.

Comparisons that indicated no relationships

T-tests were also used to investigate the type of OC and if the systems development process supports Green IT initiatives, as well as if OC influenced the rating of effectiveness of Green IT initiatives. However, no statistical significant relationship was found.

4.5.8.5 Determine the impact that national culture has on the adoption of Green IT

National culture was measured using the four dimensions of Hofstede (1983b), discussed in section 3.3.2. These dimensions are: Power Distance Index (PDI), Individualism Index (IDV), Masculinity Index (MAS) and Uncertainty Avoidance Index (UAI). The averages for these different dimensions were calculated using the different variables described in section 4.5.3.

Table 4.50: Averages of the different dimensions of NC

	Dimension of National Culture			
	PDI	IDV	MAS	UAI
Mean	3.851	4.175	4.278	3.013

Only IDV and MAS are for this study, because the data of the UAI and PDI dimensions are not reliable enough, as discussed in section 4.5.3. The data shows that the sample has a high IDV and MAS because both these indices had a value or more than four out of five. In this study 127 respondents were South Africans. Two respondents were from the USA, two from Canada, one from Germany, one from Britain, one from Romania and lastly, one from Fiji.

Several comparisons were made in order to determine if national culture has an influence on the adoption of Green IT. Only one statistical relationship was found and it is discussed first. The comparisons that did not produce any results are not discussed, but they are mentioned after this relationship.

Relationship between the National Culture and factors that motivate the adoption of Green IT initiatives:

The influence of NC on factors that motivate the adoption of Green IT initiatives was analysed using T-tests. Only one Green IT initiative had a statistical significant relationship with NC. The results are shown in Table 4.51.

Table 4.51: Comparison between the Regulatory motivational factor and the different dimensions of NC

Regulatory		N	Mean	Std. Deviation	t	p-value	Effect size
IDV	0	112	4.2411	.62053	2.989	.005	0.59
	1	22	3.8750	.50444			
MAS	0	112	4.3460	.67136	2.850	.008	0.62
	1	22	3.9318	.61326			

The p -value is 0.05, indicating a statistical difference between the groups and the effect size is 0.59, indicating a medium-strength relationship between the variables. The mean value of the Individualism Index is 4.2411 for the 112 respondents who indicated regulatory factors did not motivate them to adopt Green IT initiatives and 3.8750 for the 22 respondents who indicated that it did.

The p -value is 0.008, indicating a statistical difference between the groups and the effect size is 0.62, indicating a practical visible relationship between the variables. The mean value for Masculinity index is 4.3460 for the 112 respondents who indicated regulatory factors did not motivate them to adopt Green IT initiatives and 3.9318 for the 22 respondents who indicated that it did.

Comparisons that produced no relationships

The following comparisons were also made, but produced no noteworthy results:

- National culture and the type of systems development process
- National culture and if the systems development process incorporates Green IT initiatives.

- National culture and the factors that inhibit an organisation from adopting Green IT initiatives.
- National culture and effectiveness of Green IT initiatives.

4.6 Summary

This chapter described the research methodology that was used for this study. The positivistic paradigm was chosen as the philosophical paradigm and reasons for choosing this paradigm were given. The research method of this study was a survey, which is discussed fully in section 4.3, along with the implementation of the survey in this study. A questionnaire was used for the data collection method, which is discussed, along with the implementation of the questionnaire, in section 4.4.

The data analysis was explained next in section 4.5 and was divided into two sections. The first part used structural equation modelling to determine if the OC and NC models used in the questionnaire were valid. The second part explained the different statistical techniques that were used to evaluate the collected data namely: ANOVA tests, Cross-Tabs, T-test and Correlations.

The demographic data of the organisations and individuals were presented in the next two parts, using descriptive statistics. This is to identify the type of participants of the survey. The empirical results were then presented in sections 4.5.7 and 4.5.8 according to the research objectives stated in Chapter 1.

The next chapter concludes the study by interpreting all the data collected in this study.

CHAPTER 5

INTERPRETATION OF RESULTS AND CONCLUDING DISCUSSIONS

5.1 Introduction

This is the final chapter of the study and will present the knowledge gained from conducting this particular study. The results of the different research objectives will be presented and discussed.

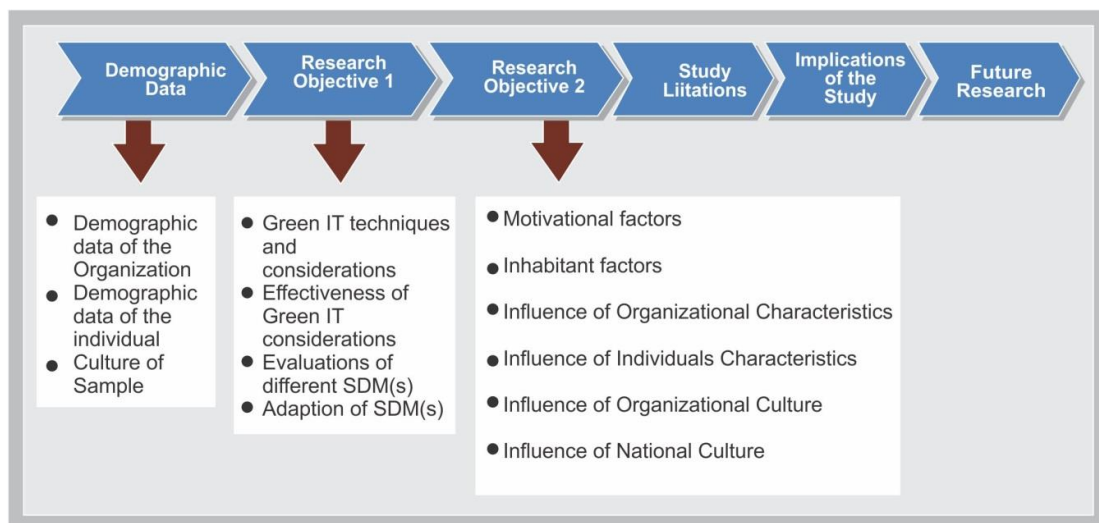


Figure 5.1: Flow of Chapter 5

As depicted in Figure 5.1, this chapter is divided into six different sections. Firstly, the demographic data of the sample will be discussed, both in terms of the organisations, as well as the individuals of the sample. The OC and NC of the sample will also be discussed. The next section will focus on the first research objective, namely to develop a Green approach towards systems development methodologies so that the development process, as well as the end product is greener. The different sub-objectives of this objective are all discussed in their own part in this section. The second research objective, which is to determine the possible influences that could affect the adoption of Green IT and Green system development, is discussed in the third section. Each of the sub-objectives are explained in its own part of this section. The possible limitations of the

study are presented in section four and in section five the implications, both practical and theoretical, of the study are outlined. Lastly, possible future research ideas are discussed.

5.2 Demographic data of the sample

The demographic data of the organisations and the individuals of the sample will be briefly discussed in the next two sub-sections.

5.2.1 Demographic data of the organisations

The organisational characteristics of the organisations that were part of the survey are summarised in Table 5.1 and the characteristics of the IS departments in Table 5.2.

Table 5.1: Organisational characteristics of the organisations in the survey

Business Area	Size of Organisation	Size of IS department
Administrative Services 1(0.7%)	Micro 3(2.2%)	Micro 16(11.9%)
Finance/Banking/Insurance 21(15.7%)	Small 33(24.6%)	Small 13(9.7%)
Software house/ Software Consulting 69(51.1%)	Medium 26(19.4%)	Medium 30(22.4%)
Manufacturing 7(5.2%)	Large 72(53.7%)	Large 18(13.4%)
Retail/Wholesale 1(0.7%)		Very Large 57(42.5%)
Education 6(4.5%)		
Other 29(21.6%)		

The respondents were mostly from Software houses/Software consulting organisations (51.5%). Most of the organisations in this study were large organisations and had very large IS departments.

Table 5.2: Characteristics of the IS departments of the organisations in the survey

Activities		Total	Time in Use		Total	Proportion of Projects		Total
Development		42.36%	Less than one year		1(0.8%)	None		7(5.3%)
Maintenance		43.75%	1 - 2 years		19(14.3%)	1-25%		6(4.5%)
Package Customisations		13.88%	3 - 5 years		36(27.1%)	26-50%		14(10.6%)
Type of SDM		Total	5 - 10 years		23(17.3%)	51-75%		37(28%)
Informal		59 (44 %)	Over 10 years		33(24.8%)	Over 75%		68(51.5%)
Traditional		46	I do not know		21(15.8%)			
Agile		35						
Support Green initiatives		Total						
Yes		79(75.2%)						
No		26(24.8%)						

The organisations spend an average of 42.36% of their time developing new applications, 43.75% on systems maintenance and support and 13.88% on package customisation. The horizontal usage results showed that the majority of the organisations, namely 68 (51.5%), applied the SD process to over 75% of the development projects. 75.2% of the respondents indicated that their systems development process does support Green Initiatives. Most of the organisations used their systems development process for between 3 and 5 years (27.1%).

The organisations mostly used formal SD processes (56%) of which 52.87% used traditional systems development processes. Traditional systems development processes are still used the most, but Agile systems development is not very far behind.

The characteristics of the individuals that were part of the survey are summarised in Table 5.3.

Table 5.3 **Characteristics of the individuals in the survey**

Primary Role	Total	Highest Qualification	Total	Experience in SD	Total
IS manager	15 (11.2%)	Senior Certificate	6 (4.5%)	None	1 (0.7%)
Project Manager	19 (14.2%)	Certificate or Diploma	38 (28.4%)	Less than 1 year	10 (7.5%)
Team Leader	10 (7.5%)	University or Technicon degree	44 (32.8%)	1- 2 Years	13 (9.7%)
Systems Analyst	9 (6.7%)	Honours or Master's degree	41 (30.6%)	3 - 5 Years	26 (19.5%)
Analyst/ Programmer	25 (18.7%)	PhD	4 (3%)	5 -10 Years	29 (21.8%)
Developer	33 (24.6%)			More than 10 years	54 (40.6%)
Other	23 (17.2%)				

The individuals of the sample consisted mainly of developers and analysts, namely 33 (24.6%). The largest number of individuals, 44 (33.1%), consisted of individuals who had University or Technicon degrees and had more than 10 years of experience in systems development (40.6%).

This data is a clear indication that the survey was conducted on individuals who are highly educated, since 67.4% of the sample has degrees. This data also shows that 62.4% of the respondents has 5 or more years' experience, indicating that they should be knowledgeable in the IS field.

5.2.2 National Culture and Organisational Culture of the Sample

Table 5.4: National and Organisational Culture of the Sample

Organisational Culture	Group Culture	Developmental Culture	Hierarchical culture	Rational Culture
	3.609	3.547	3.229	3.448
National Culture	PDI	IDV	MAS	UAI
	3.851	4.175	4.278	3.013

The literature review indicated that organisations are likely to have components of all the types of OC, but some are usually more dominant than others. In this study there is a good balance between the different types, with Group culture and Developmental Culture being the most dominant. A group culture focuses primarily on the development of individuals and working together as a team, as discussed in section 3.3.1. A Developmental culture is very powerful because it focuses on new innovations and adaptations.

The NC dimensions that are the most dominant are MAS and IDV.

The literature in section 3.3.2 suggests that a high MAS index means that the male role in a group is very important and being assertive and achieving play significant roles. This NC dimension also indicates a very rigid management style. A high IDV index shows that individuals prefer to work independently and they also value their personal life and time.

The study revealed that the nationalities of the sample are primarily South African, which is likely as the study was conducted in South Africa.

5.3 Results of research objective 1: Develop a Green approach towards systems development methodologies so that the development process, as well as the end product is greener

The first main objective of this study was to develop a Green systems development methodology. This entire development process of this SDM should be Green, as well as the IS that was developed. This Green SDM is given in article format in Appendix B. The

Green SDM is designed using the results of the different sub-objectives of objective one. Currently existing Green SDMs were investigated and evaluated to determine possible shortcomings, as explained in section 2.4.3. The techniques explained in section 2.2.1, were then incorporated together with the results of the evaluation in order to address the shortcomings. To ensure that current techniques that are used in practice are also incorporated into the SDM, the data collected with the questionnaire determined how organisations are currently adapting their SDM. These results were presented in section 4.5.7.

The Green SDM is based on the traditional systems development life cycle. It consists of six phases, namely feasibility study, systems investigation, systems analysis, systems design, implementation and review and maintenance. The systems development considerations and techniques of these phases are used to ensure that the systems development process will be effective and that the IS is correctly developed. Each of these phases is also adapted by including the different Green IT/IS considerations discussed in section 2.4.1. This is to ensure that the systems development process, as well as the IS will be as Green as possible.

Each of the phases is discussed in Appendix B.

The results of the different secondary objectives that were necessary to achieve this objective are discussed in the next sections.

5.3.1 Investigate different techniques or initiatives that can be used to reduce the negative impact of IT

The different Green IT techniques were identified in section 2.1.1 of this study. The techniques and initiatives were categorised according to the different phases of IT, namely design, manufacturing, operation and disposal. The rest of the techniques or initiatives that did not fit into any of these categories were classified into five other categories, namely process centric, communication, procurement/sourcing, Green software and metric.

5.3.2 Determine the effectiveness of Green IT techniques or initiatives

The different techniques and initiatives mentioned in section 2.1.1 were grouped into ten Green IT considerations:

- **Green Goals** ĩ Specifying environmental goals as part of the IS department or IS project.
- **Paper Usage** ĩ Initiatives to limit paper usage or printing.
- **Green Software** ĩ Considering the environmental effect of the software being used and developed.
- **IT infrastructure** ĩ Procedures and techniques that lower the negative environmental impact of IT infrastructure.
- **Physical Infrastructure** ĩ Initiatives, which improve the negative environmental impact of the physical infrastructure.
- **Retirement of System** ĩ Taking the retirement and disposal into account, when buying or developing IT or IS equipment.
- **Communication** ĩ Techniques, which eliminate the need for traveling.
- **Process Centric** ĩ Focusing on processes during systems development.
- **Procurement/Sourcing** ĩ Assessing how Green a vendor is before any products or services are obtained from him/her.
- **Metrics** ĩ Incorporating metrics into IS(s) or IT so that their environmental impact can be measured.

These ten considerations were then used in the questionnaire to determine how effective the respondents perceived each consideration.

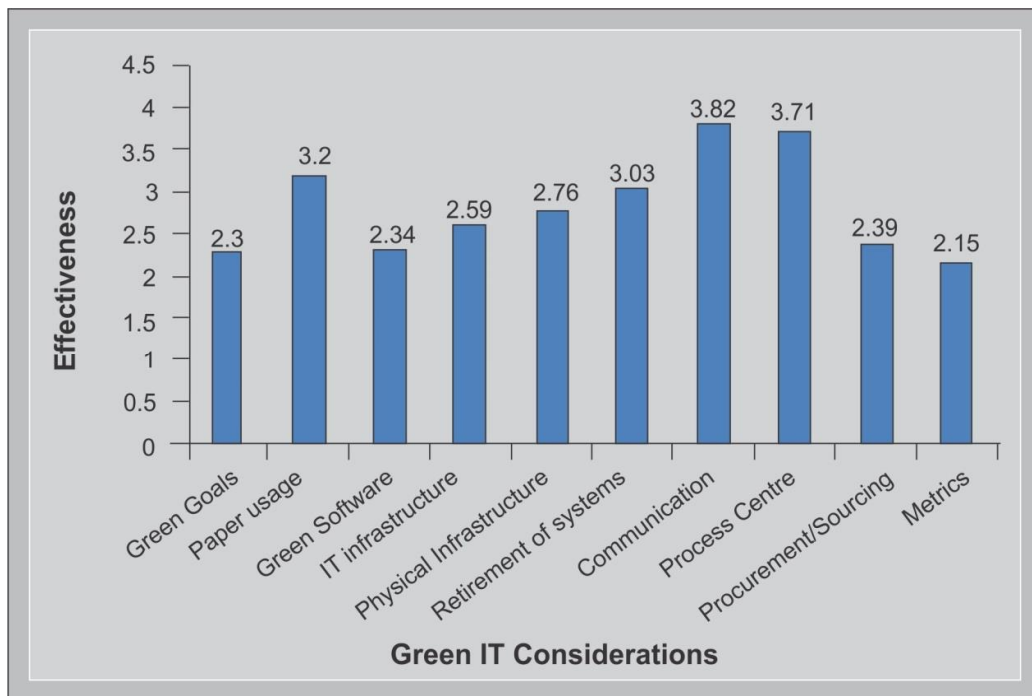


Figure 5.2 Effectiveness of the Green IT considerations

The perception of effectiveness of the considerations was measured on a scale of 1 to 5 and the considerations are ranked from the highest to the lowest score. The rankings were as follows:

1. Communication (3.82)
2. Process Centric (3.71)
3. Paper Usage (3.20)
4. Retirement of Systems (3.03)
5. Physical Infrastructure (2.76)
6. IT Infrastructure (2.59)
7. Procurement/Sourcing (2.39)
8. Green Software (2.34)
9. Green Goals (2.30)
10. Metrics (2.15)

It is clear that Green IT considerations are still not perceived as being effective. Only four of the considerations scored above average (3) and two of these considerations barely made it above average (paper usage and retirement of systems). The consideration that scored the highest was communication with 3.82 and even this score is not very high above average. Some of the organisations incorporated double-sided printing and recycled paper and printer cartridges. Only virtualisations and energy-efficient technology, such as laptops and thin clients were used in most of the organisations. Lastly, five of the organisations stated that they included power efficiency as a requirement in the procurement process.

Studies regarding the effectiveness of Green IT/IS considerations are very limited and therefore it is difficult to compare the results. Retirement of systems is ranked fourth in this study. In a similar study done in Australia and New Zealand, the retirement of systems was considered to be the most relevant Green IT consideration followed by a combination of IT and physical infrastructure (Capra & Merlo, 2009). This might be due to more emphasis being placed on recycling in these two countries.

Metrics is ranked the least effective. This might be because it is still very difficult to accurately measure metrics, such as the power usage of IT (Harmon *et al.*, 2010).

In a separate study on the adoption of Green IT/IS in South Africa (Petzer *et al.*, 2011), the following was found regarding the seven organisations being investigated: Only two organisations implemented power-saving software, three replaced older less power-efficient hardware and only three organisations focused on physical infrastructure. Lastly, five of the organisations stated that they included power efficiency as a requirement in the procurement process.

The evaluation of existing Green SDMs in section 2.4.3 indicated that in current literature Green Goals, Green Software, IT Infrastructure and Paper Usage are regarded as the most important Green IT considerations. The study indicates that in practice however, only one, Paper usage, is considered above average in terms of effectiveness. Green Goals, Green Software and IT infrastructure scored below 3, indicating that in practice they do not think these three considerations are important.

Physical infrastructure and Communication are seen as the least important in literature. However, in practice these two considerations are seen as the most effective of all the considerations.

5.3.3 Evaluate different SDMs and determine if any existing systems development methodologies incorporate Green objectives into the systems development methodology

Five articles could be found that included Green objectives during system development. The five articles were discussed in section 2.4.2 of this study. Each of these articles was also evaluated in section 2.4.3, based on the 10 Green IT considerations that were explained in section 2.4.1. The results of these comparisons indicated that even though there are methodologies that do incorporate Green objectives into their SDM, none of them are very thorough.

The highest percentage achieved by any of the SDMs was the SDM of Huang (2008), which was a mere 64%. The SDM developed in this study, therefore is a valuable practical contribution because it is truly a Green SDM and is much more thorough than any existing Green SDMs that were found in the literature.

5.3.4 Determine how different SDMs can be adapted to have greener development process and a greener end product

The specific techniques that were used by the organisations in the survey are listed in section 4.5.7.4. All of these techniques used for adapting their SDMs fit into the following of the ten Green Considerations, namely Green Goals, Paper Usage, Green Software, IT Infrastructure, Physical Infrastructure, Retirement of Systems Communication and Metrics.

The respondents did not indicate that any Process Centric or Procurement techniques are currently used specifically to adapt their SDM(s).

Only one technique was mentioned, which does not fit into any of the Green Considerations, namely improving overall environmental awareness in the IS department. The Green goals consideration should therefore be extended to include this technique.

5.3.5 Determine how a Green SDM should be classified

The model of Iivari *et al.* (2000) was investigated in section 2.3.3 in order to determine how a Green SDM should be classified. The model can be extended on one of four levels, including techniques, SDMs, SD Approaches and SD paradigms. The model was extended by adding a new approach called 'Green SDM' approach, as shown in section 2.4.4. The ten Green considerations are also added to the model on the last level under Green SDM techniques.

5.4 Results of research objective 2 – Determine possible influences on Green IT and Green Systems development

The second main objective was to determine possible influences on different aspects of Green IT and Green systems development.

The framework of Rogers (2003), discussed in section 3.2 is often used in the IT/IS field to better understand adoption processes. This framework was used to determine the adoption process of Green IT/IS as well. The model consists of five stages. This study focused on the third stage, namely the decision stage, where a person will either adopt or reject an innovation. This decision maker will already have developed a perception regarding the innovation by this stage. The study therefore investigates factors that could motivate or inhibit the adopting of Green IT/IS, since the factors will affect the decision made. The decision can be made on an organisational level or by individuals therefore the influence of organisational and individual characteristics is investigated. As mentioned in section 3.3.3 OC and NC can affect the adoption of IT, therefore the effect of OC and NC was also studied on Green IT/IS. Lastly, different influences on the perception of the decision maker are also investigated. These investigations were divided into five different sub-objectives of objective 2. The motivation and inhibiting factors of Green IT initiatives are presented first.

5.4.1.1 Determine the factors that motivate organisations to adopt or inhibit organisations from adopting Green IT initiatives

1. Factors that motivate organisations to adopt Green IT initiatives

The main motivational factor for adopting Green IT initiatives is economic (46 responses), followed closely by an ethical motivation (44 responses). Technological factors had 37 respondents and the regulatory factor received the least number of responses, namely 22. The literature discussed in section 3.2.1 can be used to compare the results.

This result is the same as in Molla (2009), which indicates that Green IT/IS adoption is motivated by economic factors and that the regulatory factor had little influence. The economic benefits in this study are mainly focused on cost saving. The motivation for Green IT/IS adoption in the study by Jenkin *et al.* (2011) was also mainly because of economic reasons and ethical factors were not considered to be important. The study by Erek (2011) yet again confirms the previous studies where economic factors, such as cost savings and improved reputation were considered the most important motivational factors.

One study done across Europe, North America and Asia indicated that 59%, 52% and 55% respectively of the respondents from these continents were concerned about climate change (Info~Tech, 2008), thereby indicating that the motivational factor of Green IT/IS might still be influenced by ethical reasons and organisations are just not aware of it.

In the study done by Molla *et al.* (2009) in New Zealand, Australia and North America the results were more balanced. The economic factor is once again the number one motivational factor of Green IT/IS, with 80% of the respondents agreeing to this. In this study, 77% of the respondents also indicated that ethical reasons are also influencing the adoption process. Fifty-seven percent of the respondents said that government regulations were also influencing the adoption process.

The study done in South Africa by Petzer *et al.* (2011) verifies the results, indicating once again that the economic factor is the most relevant factor influencing the adoption of Green IT/IS. Regulatory factors did not have an influence and the influence of ethical factors were present, but very limited.

This study did, however, indicate that Green IT/IS is not an important priority for organisations in South Africa. The only difference between this study and the study by Petzer *et al.* (2011) is that this study did find that the regulatory factor influenced the adoption of Green IT/IS in South Africa. A possible reason for this is that there is considerable speculation regarding different regulations and laws, which will shortly be implemented in this country (National Treasury of RSA, 2013). Therefore organisations might already be adopting Green IT/IS in order to be ready when the government implements regulations.

2. Factors that inhibit organisations from adopting Green IT initiatives

The number one factor that inhibits organisations from adopting Green IT initiatives is cost (33) followed by organisations not seeing the business value (22) and lack of business leadership (20). Lack of government incentives or regulations received the lowest value (9) and inadequate skills and training received 17 frequencies.

The study by Molla et al. (2009) also found that cost was the largest inhibitor of Green IT/IS, and that the second biggest inhibiting factor was unclear business value. Lack of government incentives was ranked in third place, followed by lack of business leadership. These first two results are exactly the same as in this study and the second and third results are also nearly the same. Lack of government incentives and regulations was ranked in the last place in all the studies.

The study by Molla (2009a) also supports this finding by suggesting that organisations will only adopt Green IT/IS if it is affordable and found that the largest inhibitor of Green IT/IS adoption is cost.

3. Predictions for adoption of Green IT/IS in the future

Almost half of the sample (48.1%) indicated that they expect their organisation to use more Green IT initiatives within the next two years and 18.3% indicated that they plan to supplement current Green IT initiatives with more new ones. Only 8% indicated that they will abandon their current initiatives and 29% said that they expect no change to occur.

5.4.1.2 The influence that the characteristics of organisations have on Green IT and Green Systems Development.

In section 3.2 it is mentioned that studies on technology adoption are usually focused on the different characteristics of an organisation such as sector, size and resources.

Several relationships were therefore investigated between the core business area, size, size of the IS, and the tasks of the IS department of the organisation. The result of the influence of the core business area of an organisation is discussed first.

5.3.1.2.1 The influence of the business area of the organisation

1. *Comparison of the core business area of the organisation and factors that inhibit the adoption of Green initiatives*

The core business area of the organisation did not influence the factors that inhibited the organisations from adopting Green IT initiatives.

2. *Comparison of the core business area of the organisation and factors that motivate the adoption of Green initiatives*

Molla and Ahmad (2011) suggest that different core business areas might respond differently to the adoption of Green initiatives. Only one relationship was identified in the comparison of core business areas and motivational factors of Green IT initiatives. Finance/Banking/Insurance organisations are more likely to adopt Green IT to regulatory factors, than Software Houses/Software Consulting organisations. This could be due to the fact the financial industry is subject to many strict regulations and that they are used to taking the precautionary measure of implementing solutions before the regulations are made mandatory. Carbon taxing and other environmental regulations are being discussed in parliament and could be implemented soon. The financial industry therefore could already be implementing Green Initiatives so that when new regulations are put in place they already adhere to them. The financial industry also needs to adhere to new regulations, in order to create a positive perception with the public and their clients.

3. *Comparison of the core business area of the organisation and the ratings of effectiveness of the different Green IT initiatives*

Several relationships were found during this comparison. The first is that Finance/Banking/Insurance organisations consider paper usage, IT Infrastructure, process centric, procurement and metrics to be more effective than Software Houses/Software consulting organisations.

5.3.1.2.2 The influence of the size of the organisation

Thong (1999) suggests that the most important characteristic that determines adoption of ISs, is the size of the organisations. He also stated that bigger organisations adopt more ISs than smaller organisations, due to more resources and greater needs. The

relationships that were identified between the size of organisations and different Green factors are discussed next.

1. *Comparison of the number of people employed in the organisation and if the systems development process supports Green initiatives*

The total number of people employed in the organisation did not have an influence on whether the systems development process supports Green initiatives or not.

2. *Comparison of the number of people employed in the organisation and the factors that motivated an organisation to adopt Green IT initiatives*

The total number of people employed in the organisation did not have an effect on the type of factors that motivated the organisation to adopt Green IT initiatives. This is in contrast to what was found in the literature, where it is suggested that small firms may be less likely to adopt Green initiatives (Molla & Ahmad, 2011). As mentioned in Chapter 1, everyone should be doing their part for the environment and it is no longer only the responsibility of large organisations. Therefore the size of an organisation should not have an impact on factors that motivate an organisation to adopt Green IT initiatives.

3. *Comparison of the number of people employed in the organisation and the factors that inhibit an organisation from adopting Green IT initiatives*

The total number of people employed in the organisation did not have an effect on the type of factors that inhibit an organisation from adopting Green IT initiatives.

4. *Comparison of the total number of people employed in the organisation and the effectiveness of Green Initiatives*

Large organisations rated Green goals, IT infrastructure, metrics and procurement as being more effective than small and medium-sized organisations.

Large organisations also rated physical infrastructure and retirement of systems as more effective than small organisations.

Medium-sized organisations rated retirement of system and process centric more effective than small organisations.

Medium organisations rated communication as more effective than small organisations.

Based on these results, it is clear that even though organisations of all sizes are implementing Green IT initiatives, the maturity of the process is different for the different sizes of the organisations. Larger organisations are more mature than medium and small organisations. They use metrics to evaluate and improve their Green IT initiatives and incorporate Green goals into their planning process. The reason why medium and small organisations are not as mature as large organisations might be due to financial constraints.

5.3.1.2.3 The influence of the size of the IS department

1. *Comparison of the number of people employed in the organisations' IS departments and the factors that motivated an organisation to adopt Green IT initiatives*

The number of people employed in the organisations' IS departments did not influence the factors that motivated the organisations to adopt Green IT initiatives.

2. *Comparison of the number of people employed in the organisations' IS departments and the factors that inhibit an organisation from adopting Green IT initiatives*

The number of people employed in the organisations' IS departments did not influence the factors that inhibited the organisations from adopting Green IT initiatives.

3. *Comparison of the total number of people employed in the organisations' IS departments and Green Initiatives*

Organisations with very large IS departments rated Green goals as more effective than organisations that had medium or large IS departments.

Organisations with very large IS departments rated retirement of systems as more effective than organisations that had small or medium-sized IS departments.

Organisations with very large IS departments rated communication as more effective than organisations that had medium-sized IS departments. Organisations with small and medium IS departments indicated that they think communication is less effective than organisations with large IS departments.

Organisations with very large IS departments rated process centric as more effective than organisations that had medium-sized IS departments. Organisations with small IS departments rated process centric more effective than organisations with medium-sized IS departments. Organisations with medium-sized IS departments rated process centric as less effective compared to organisations with large IS departments.

Organisations with very large IS departments rated procurement/sourcing as more effective than organisations that had medium-sized IS departments. Small IS departments indicated that they think procurement/sourcing is less effective than very large IS departments think it is. Medium IS departments indicated that they think procurement/sourcing is less effective than large IS departments think it is. Large IS departments indicated that they think procurement/sourcing is less effective than very large IS departments think it is.

Organisations with very large IS departments rated metrics as more effective than organisations that had small, medium and large IS departments. Small IS departments indicated that they think metrics is more effective than medium IS departments think it is. Lastly, organisations with medium IS departments rated metrics as more effective than organisations that had large IS departments.

The size of the IS department has the same effect as the size of the organisation itself. As discussed in section 5.3.1.2.2, the larger the organisation, the more mature the Green IT initiatives of the organisation tend to be. The same results are seen with larger IS departments, which are more mature than in smaller organisations.

4. *Comparison of the total number of people employed in the organisations' IS departments and if the SD process of the organisation supports Green Initiatives*

The SD process of organisations with very large IS departments supported Green initiatives the most, followed by organisations with small IS departments. The systems development process of organisations with medium and large IS departments supported Green IT initiatives the least.

5.3.1.2.4 The influence of the IS departments' development activities

- Comparison of the tasks of the IS departments and if their systems development process supports Green IT initiatives

The tasks of the IS departments did not influence whether their systems development process supported Green IT initiatives or not.

- Comparison of the tasks of the IS departments and the factors that inhibit an organisation from adopting Green IT initiatives

The tasks of the IS departments did not influence which factors inhibited the organisations from adopting Green IT initiatives.

- Comparison of the tasks of the IS departments and the effectiveness of Green IT initiatives

The data analysis revealed the following two relationships. Firstly, the more time that IS departments spent on developing new applications, the less effective they rated retirement of systems. Secondly, the more time organisations spent on systems maintenance and support, the more effective they rated retirement of systems. The reason why IS departments that spend more time on development do not rate retirement of systems as effective as organisations that spend more time on maintenance and support could be due to two reasons. The first reason might be that IS departments that are busy with new developments are too busy to consider the effects that the retirement of the system could have on the environment. The second reason could be because organisations that spend more time on maintenance and support more frequently have to retire systems and are therefore more aware of its importance.

- Comparison of the IS departments' tasks and factors that inhibit the adoption of Green IT initiatives

Organisations that indicated that no business value is an inhibiting factor, spent less time on maintenance and support than organisations that did not choose no business value. This could be because these organisations are focusing only on developing new systems and are therefore profit driven. Consequently they would not want to spend additional time on Green IT initiatives.

5.3.1.2.5 Comparison of the systems development process of the organisation and if the systems development process supports Green initiatives

The type of systems development process did not influence whether the systems development process of the organisation supported Green initiatives or not.

This finding supports the proposal made in section 2.4.4, where it is suggested that a Green SD approach should be an extension of other SDMs. It therefore does not matter which type of SD approach is used, as long as it is extended with the Green SD approach.

5.3.1.2.6 Comparison of the time that the systems development process of the organisation has been in use and if the systems development process supports Green initiatives

The maturity of the SD process did not have an influence on whether the systems development process of an organisation supported Green Initiatives.

5.3.1.2.6 Conclusion of the influence that the characteristics of organisations have on Green IT and Green Systems Development

The core business of the organisations had an influence on the motivation for the adoption of Green initiatives, as well as on the rating of effectiveness of the different Green IT initiatives. The size of the organisation only influenced the rating of effectiveness of Green IT initiatives. The size of the IS departments influenced the rating of effectiveness of Green IT initiatives, as well as if their SD process supports Green IT initiatives. The tasks of the IS departments influenced the effectiveness of Green IT initiatives and factors that inhibit the adoption of Green IT initiatives.

The influence that the characteristics of the individuals in an organisation has on Green IT and IS is discussed next.

5.4.1.3 The influence that the characteristics of individuals has on Green IT and Green Systems Development

In the next sections the results of the influence of the characteristics of individuals on the different aspects of Green IT and Green systems development will be discussed.

5.3.1.3.1 Comparison of the influence of the characteristics of individuals on different Green factors

1. *Comparison of the primary role of the individual during systems development and motivational factors, inhibitory factors and expectations of Green IT initiatives in the future*

The primary role in systems development did not influence the individuals' expectations of Green IT initiatives for the future.

2. *Comparison of the highest qualification of the individuals and motivational factors, inhibitory factors and expectations of Green IT initiatives for the future*

The level of education of the individuals did not influence their expectations of Green IT initiatives for the future.

3. *Comparison of the personal experience in systems development and motivational factors, inhibitory factors and expectations of Green IT initiatives for the future*

The number of years of experience in systems development of the individuals did not influence their predictions of Green IT initiatives for the future.

5.3.1.3.2 Conclusion of the influence of Individuals

The results indicate that the characteristics of the individuals did not significantly affect the adoption or rejection of Green IT/IS. This may be due to the fact that decisions regarding the adoption of Green IT/IS are made at a higher level and that the individual does not really have an input into the matter. It may also be because organisations do not communicate their environmental objectives and strategies to individuals (Jenkin *et al.*,

2011). The individuals therefore do not know that environmental considerations are important to the organisation.

5.4.1.4 The influence that organisational culture has on Green IT and Green Systems Development

In the next sections the results of the influence of the different types of OC and the different aspects of Green IT and Green systems development will be discussed.

5.4.1.4.1 Comparison of the influence of organisational culture and the different Green factors

1. Comparison of organisational culture and if the systems development process supports Green IT initiatives

The type of organisational culture did not influence whether organisations' systems development processes support Green IT initiatives or not.

2. Comparison of organisational Culture and the factors that motivated an organisation to adopt Green IT initiatives

Organisations that indicated that 'regulatory' was a factor that motivated them to adopt Green IT initiatives had a weaker rational culture than organisations that did not choose 'regulatory' as a factor that motivated them to adopt Green IT initiatives. Organisations with a high rational culture are more driven to follow their own rules, whereas organisations with lower rational culture tend to be influenced by external factors. Organisations with a low rational culture will therefore be more likely to adopt Green IT initiatives because of regulatory factors.

3. Comparison of organisational culture and the factors that inhibit an organisation from adopting Green IT initiatives

Organisations that indicated that lack of government incentives or regulations was an inhibiting factor had a weaker developmental culture and a stronger hierarchical culture than organisations that did not choose this factor. Organisations with a strong hierarchical factor are more inclined to follow strict regulations and laws. However, if no regulations or laws are already in place, they will not follow them merely as a precautionary step.

4. Comparison of organisational culture and effectiveness Green IT initiatives

Organisations with strong group culture or rational culture rate process centric as more effective than other types of OC. The stronger the development culture of an organisation is, the more effective an organisation will rate communication and process centric.

5.3.1.4.2 Conclusion of the influence that organisational culture has on Green IT and Green Systems Development

The OC of an organisation had an influence on the factors that motivate organisations to adopt Green IT initiatives, as well as on the factors that inhibit organisations from adopting Green IT initiatives. The OC of an organisation also had an impact on the rating of effectiveness of Green IT initiatives.

The influence of the NC of the organisations on Green IT and IS is discussed next.

5.4.1.5 The influence that national culture has on Green IT and Green Systems Development

In the next sections the results of the influence of the different NC dimensions and the different aspects of Green IT and Green systems development will be discussed.

5.4.1.5.1 Comparison of the influence of the national culture and the different Green factors

1. Comparison of national culture and the type of systems development process

National culture did not have an effect on the type of systems development processes being used by organisations.

2. Comparison of national culture and if the systems development process incorporates Green initiatives

National culture did not have an effect on whether the systems development process of an organisation supports Green initiatives or not.

3. Comparison of national culture and the factors that inhibit an organisation from adopting Green IT initiatives

National culture did not have an influence on which factors inhibited the organisation from adopting Green IT initiatives.

4. Comparison of national culture and factors that motivate the adoption of Green IT initiatives

Organisations that indicated that regulatory was a motivating factor had a lower IDV and MAS index than organisations that did not indicate this factor. In organisations with a low IDV, individuals have a low say. Regulations are therefore important to guide individuals and clearly indicate what procedures should be followed in the organisation.

5. Comparison of national culture and effectiveness of Green IT initiatives

National culture did not have an influence on how effective Green IT initiatives were perceived to be.

5.4.1.5.2 Conclusion of the influence of national culture and the different Green factors

The NC of organisations in this sample only had an impact on factors that motivate the adoption of Green IT.

Findings regarding the survey that was conducted are discussed next.

5.5 Findings regarding the Survey

SEM was performed on the organisational and national culture parts of the measurement instrument. This was done in order to ensure that the different models were reliable for this specific sample. The OC culture model had to be modified to ensure reliability. Rational culture was measured using only two variables (OC8 and OC12) instead of three. The variable OC4 measures the level of productiveness of the IS departments. The studies by Brits (2011) and Iivari and Huisman (2007), which were also done in South Africa and for an IS survey, also measured rational culture, using the same two variables and leaving out the same variable. This is a good indication that the reliability of variable

OC4 in South Africa should be investigated. Overall the OC measurement model was proved reliable for this study using SEM.

The reliability tests of national culture indicated that only two of the four fitted dimensions could be used. This meant that only two of these indexes could be used for the inferential statistics. No other study that used this measurement model in the IS industry could be found to compare the results. The unreliability of this measurement model could be due to the country in which this study was conducted (South Africa) or because it was an IS survey. Both these possible causes should be investigated so that the model can be used for future research.

5.6 Study Limitations

The study had the following limitations:

The first limitation is that this study was only conducted in South Africa, which means that the study is not generalisable to other countries. Therefore similar studies need to be performed in other countries. The next limitation is that due to the low response rate of 24.8%, the sample was relatively small.

The questionnaire was based on all the literature that the author could find, but it may be possible that additional literature regarding Green IT, Green IS and Green systems development exists, which the author did not find. It is therefore possible that the questionnaire did not include additional important factors.

Another possible limitation is that it has not been determined how the incorporation of the different Green techniques will affect the effectiveness of the SDM. SDMs are used to increase productivity and improve the quality of the developed system (Iivari *et al.*, 2000). If an organisation incorporates these techniques into their SDM, they might not be as productive as they used to be and this could lead to the techniques being discarded. If the organisations are less productive it could also lead to lower quality IS. This then means that two of the most important advantages of using a SDM are lost.

The Green IT techniques that were chosen for this study are based on different literary works. Green IT is still a relatively new field and therefore the different techniques may not

be as effective as they are described in the literature. Studies, such as that by Fuchs (2008) indicate that electronic communication might not be as effective as previously thought. The other techniques should be thoroughly investigated to determine the precise effectiveness of each technique.

Lastly, there is no formal Green SDM that is used in practise. All the Green SDMs that are evaluated in this study are theoretical.

5.7 Implications of the study

This study is unique in South Africa, since it is the first study to collect quantitative data regarding different influences on the adoption of Green IT. It is also unique in this country because the author could not find any studies regarding Green systems development currently being done in South Africa. This study contributes theoretically, as well as practically. The main reason for this study is to contribute towards helping our planet in the IT and IS field, by trying to reduce these industries' environmental impact.

The theoretical contributions of the study include:

Even though there are published articles regarding Green systems development, they are not based on any empirical data. Therefore this study makes a significant contribution because empirical data is presented in an area where the research is very limited. The study theoretically contributes by determining with empirical data the future predictions for Green IT initiatives in South Africa, by determining which Green IT techniques are perceived to be effective in the industry and if organisations are currently adapting their SDM for a Green development process. It also contributes by identifying which type of SDM is mostly used in South Africa, as well as which type of SDM is adapted the most to be Greener. The research also indicated that no thorough Green SDM could be found and therefore the Green SDM developed in this study is very significant.

The effect of organisational culture and national culture on Green IS/IT is also very significant, because very limited studies could be found that attempted to investigate these relationships. The findings of this study regarding the influence of these two types of culture on Green IT/IS should be investigated in other countries as well and compared with these results.

Lastly, the one variable of the OC measurement model was found not to be reliable. The reliability of this variable should be investigated in other studies done in South Africa. The NC culture model was also found to be very unreliable for an IT/IS survey and the reliability of the complete model should be tested in other studies within South Africa.

The practical contributions of the study include:

This study makes two main practical contributions. The first is that the adaption of the systems development process will allow IS professionals to develop systems in a manner that is environmentally friendly. The written article also give professionals guidelines on the type of Green IT initiatives that are available so that they can implement them in their organisations. The second contribution is that by identifying factors that influence the adoption of Green initiatives, it allows professionals to focus on these factors in order to help them adopt more Green initiatives.

5.8 Recommendations for Future Research

This study was only done South Africa therefore similar studies can be done in different countries to further investigate these different topics.

Studies should be done to determine how the incorporation of the different Green techniques would affect the effectiveness of the SDM. This is to ensure that the productivity of the development, as well as the quality of the SDM is not affected.

The different Green IT techniques should be further investigated to determine if each technique truly is Green and that it can effectively be incorporated into systems development.

This study established that most organisations are already adapting their systems development process to support Green Initiatives. Further studies are, however, required to determine the extent of the adaption in the industries of South Africa.

Additional studies should be done on the influence of organisational culture and national culture on Green IT/IS adoption. These studies should also be done using the questionnaires of Hofstede (1991), Hofstede (1983a) and Hofstede *et al.* (1990) in order

to determine if similar problems with reliability are encountered when they are used in South Africa.

The GLOBE culture framework can be used on a national level, as well as on an organisational level (House *et al.*, 2004). Even though the model of Hofstede (1980) has been widely used and validated, the GLOBE framework is based on newer data. It has also been validated and should therefore be considered for future studies.

Lastly, future research might focus on adapting agile SDMs because even though traditional SMDs are still predominantly used, agile SDMs are becoming more popular.

5.9 Conclusion

This study attempted to adapt a systems development methodology so that the entire systems development process, as well as the developed IS would be Green. It also attempted to provide insights regarding the different possible influences that could motivate organisations to adopt Green IT initiatives or inhibit organisations from adopting Green IT initiatives. In order to achieve these objectives a thorough literature study was conducted in order to create an accurate questionnaire. The questionnaire was then distributed to different organisations in South Africa. Once the data was collected, the reliability of the questionnaire was tested and different descriptive and inferential statistics were gathered using SPSS. The final part of this study interpreted the different statistics and these results were discussed. It is evident from the research that the characteristics of an organisation can have an effect on whether organisations adopt Green IT initiatives or not. It also has an impact on how effective the different Green IT considerations are perceived. The characteristics of individuals, however, had no effect on the adoption or use of Green IT and IS. The organisational culture of an organisation had an influence on factors that motivate and inhibit Green IT adoption, as well as on how effective Green IT initiatives were perceived. Lastly, national culture only had an influence on one factor that motivates organisations to adopt Green IT. This study provided significant theoretical contributions and practical contributions. Empirical knowledge was gained regarding the adoption of Green IT/IS, which currently is very limited. The influence of OC and NC on Green IT/IS has also not been investigated thoroughly and therefore these results are a good platform for further studies. A new Green SDM is also developed, which attempts to eliminate the limitations of existing Green SDMs. Possible problems with the use of the CVF model to measure OC in South Africa is identified, as well as problems with the reliability of Hofstede's NC model. This research can also provide valuable insight to

professions who can use it to adapt their SDM(s) to be Greener, as well as to help identify the factors inhibiting Green adoption within their organisation.

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APPENDIX A – QUESTIONNAIRE



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To the participant of this questionnaire:

Thank you very much for participating in this study. The goal of this questionnaire is to determine:

- If Information System(IS) departments uses Green IT initiatives in their system development process
- If IS departments feel that Green IT initiatives are effective.
- What inhibits or motivates the usage of Green IT initiatives within IS departments.
- If there is a relationship between the usages of Green IT initiatives and the culture of the organisation.

I promise that all the information gathered will be handled confidentially. Please inform me if you are interested in the result of this study and I will gladly send it to you once it has been processed.

If you have any question please feel free to contact myself or one of my supervisors.

Thank you once again.

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ORGANISATIONAL QUESTIONS

1. What is the core business area of your organisation?	
Administrative services	1
Finance/Banking/Insurance	2
Software house/Software consulting	3
Manufacturing	4
Retail/Wholesale	5
Education	6
Other, please specify IT Services Hardware	7

2. What is the total number of people employed in your organisation (at all locations)?	
1 ÷ 4	1
5 ÷ 50	2
51 ÷ 200	3
More than 200	4

3. What is the total number of people employed in your organisation's information system (IS) department (at all locations)?	
1 ÷ 5	1
6 ÷ 20	2
20 ÷ 50	3
50-100	4
More than 100	5

4. Please indicate what percentage of your IS department's efforts is devoted to the following activities:	
Development of new applications	%
Systems maintenance and support	%
Package customisation	%

100

5. Describe the systems development process (SDLC System development Life Cycle) used by your IS department. (The process can be described in terms of methodologies, approaches, tools and techniques)
Various methodologies but CMMI would be the most common

6. How long has your systems development process been in use in your IS department?	
Less than 1 year	1
1 - 2 years	2
3 - 5 years	3
5 - 10 years	4
Over 10 years	5
I do not know	6

7. What is the proportion of projects that is developed in your IS department by applying the systems development process knowledge?	
None	1
1 ÷ 25 %	2
26 ÷ 50 %	3
51 ÷ 75 %	4
Over 75 %	5

8. Please rate the effectiveness of Green IT Initiatives, if any, which are being applied within your organisation? <i>1= Not effective AND 5 = Very Effective</i>						
Green Goals	Do you specify environmental goals as part of your department or projects objectives?	1	2	3	4	5
Paper Usage	Do you have initiatives to limit paper usage or printing?	1	2	3	4	5
Green Software	Do you take into account the environmental effect of the software you developed?	1	2	3	4	5
IT Infrastructure	Do you apply any procedures or techniques to lower the negative environmental impact of IT infrastructure	1	2	3	4	5
Physical Infrastructure	Do you have any initiatives to improve the negative environmental impact of the physical infrastructure, such as example: better cooling techniques in server rooms, used by your IS department?	1	2	3	4	5
Retirement of Systems	Is the retirement and disposal of IT equipment taking into consideration when buying or developing it?	1	2	3	4	5
Communication	Are any communication techniques, such as video conferencing used to avoid travelling?	1	2	3	4	5
Process Centric	Does your development process, focus on the processes of the organization for whom it is developed?	1	2	3	4	5
Procurement/ Sourcing	Are the vendors that you procure from evaluated in terms of their environmental impact?	1	2	3	4	5
Metrics	Are metrics used for your information systems or information technology to monitor their environmental impacts?	1	2	3	4	5
Additional Green IT initiative that you use	Describe:	1	2	3	4	5
Additional Green IT initiative that you use	Describe:	1	2	3	4	5
Additional Green IT initiative that you use	Describe:	1	2	3	4	5

9. Does your systems development process support Green Initiatives? Green Initiatives include all attempts to lower the environmental impact of the Information Technology (IT) that is used. Examples include initiatives to use less paper, save electricity, use less hardware, correctly disposing of IT equipment or any of the examples in <i>QUESTION 8</i>.
If your answer is “Yes” please describe how Green initiatives are supported by the systems development process.
If your answer is “No” please describe how you would adjust your systems development process so that it supports Green initiatives.

INDIVIDUAL QUESTIONS

1. What is your primary role in systems development	
IS manager	1
Project manager	2
Team leader	3
Systems analyst	4
Analyst/Programmer	5
Developer	6
Other, please specify	7

2. Please indicate the highest qualification that you have obtained.

[illegible]

3. What is your personal experience in systems development?

None	1
Less than 1 year	2
1 - 2 years	3
3 - 5 years	4
5 - 10 years	5
More than 10 years	6

4. If you have Green IT initiatives in your organisation, which of the following factors motivated you to adopt them?

Economic	1
Ethical	2
Technological	3
Regulatory	4
All of the above	5

5. If you do not have Green IT initiatives in your organisation, which of the following factors inhibit you from adopting them?	
Cost	1
You do not see the business value	2
Lack of government incentives or regulations	3
Lack of business leadership	4
Inadequate skills and training	5
Other	6
.....	
.....	
.....	

6. What are your predictions regarding Green IT initiatives in your organisation within the next two years?	
Use more Green IT initiatives	1
Replace your current Green Initiatives	2
Supplement current Green IT initiatives with more Green IT initiatives	3
Abandon the use of Green IT initiatives	4
No Change	5
Other	6
.....	
.....	
.....	

ORGANISATIONAL CULTURE QUESTIONS

1= Totally disagree AND 5 = Totally Agree

7.1) The IS department I work in, is a very personal place. It is like an extended family and people seem to share a lot of themselves.	1	2	3	4	5
7.2) The IS department I work in, is a very dynamic and entrepreneurial place. People are willing to stick their necks out and take risks.	1	2	3	4	5
7.3) The IS department I work in, is a very formal and structured place. People pay attention to bureaucratic procedures to get things done.	1	2	3	4	5
7.4) The IS department I work in, is a very production-oriented place. People are concerned	1	2	3	4	5

with getting the job done and are not very personally involved.					
7.5) The glue that holds the IS department I work in together, is loyalty and tradition. Commitment to the IS department I work in runs high.	1	2	3	4	5
7.6) The glue that holds the IS department I work in together, is commitment to innovation and development. There is an emphasis on being first with products and services.	1	2	3	4	5
7.7) The glue that holds the IS department I work in together, is formal rules and policies. Following rules and maintaining a smooth-running institution are important.	1	2	3	4	5
7.8) The glue that holds the IS department I work in together, is an emphasis on tasks and goal accomplishment. A production and achievement orientation is commonly shared.	1	2	3	4	5
7.9) The IS department I work in, emphasises human resources. High morale in the IS department is important.	1	2	3	4	5
7.10) The IS department I work in, emphasises growth through acquiring new resources. Acquiring new products/services to meet new challenges is important.	1	2	3	4	5
7.11) The IS department I work in, emphasises permanence and stability. Efficient, smooth operations are important.	1	2	3	4	5
7.12) The IS department I work in, emphasises competitive actions, outcomes and achievement. Accomplishing measurable goals is important.	1	2	3	4	5
7.13) The IS department I work in, is under threat of being disbanded.	1	2	3	4	5
7.14) The future of the IS department in our organization is uncertain.	1	2	3	4	5

NATIONAL CULTURE QUESTIONS

8. Please think of an ideal job, disregarding your present job, if you have one. In choosing an ideal job, how important would it be to you to ... (please circle one answer in each line across):

1= very little or no importance AND 5= utmost importance

1) Have sufficient time for your personal or home life	1	2	3	4	5
2) Have a boss (direct superior) you can respect	1	2	3	4	5
3) Get recognition for good performance	1	2	3	4	5
4) Have security of employment	1	2	3	4	5
5) Have pleasant people to work with	1	2	3	4	5
6) Do work that is interesting	1	2	3	4	5
7) Be consulted by your boss in decisions involving your work	1	2	3	4	5
8) Live in a desirable area	1	2	3	4	5
9) Have a job respected by your family and friends	1	2	3	4	5
10) Have chances for promotion	1	2	3	4	5

9. In your private life, how important is each of the following to you: (please circle one answer in each line across):

1= very little or no importance AND 5= utmost importance

11) Keeping time free for fun	1	2	3	4	5
12) Moderation: having few desires	1	2	3	4	5
13) Being generous to other people	1	2	3	4	5
14) Modesty: looking small, not big	1	2	3	4	5

10. If there is something expensive you really want to buy but you do not have enough money, what do you do?	
Always save before buying	1
Usually save first	2
Sometimes save, sometimes borrow to buy	3
Usually borrow and pay off later	4
Always buy now, pay off later	5

11. How often do you feel nervous or tense?	
Always	1
Usually	2
Sometimes	3
Seldom	4
Never	5

12. Are you a happy person?	
Always	1
Usually	2
Sometimes	3
Seldom	4
Never	5

13. Are you the same person at work (or at school if you are a student) and at home?	
Quite the same	1
Mostly the same	2
Do not know	3
Mostly different	4
Quite different	5

14. Do other people or circumstances ever prevent you from doing what you really want to?	
Yes, always	1
Yes, usually	2
Sometimes	3
No, seldom	4
No, never	5

15. All in all, how would you describe your state of health these days?	
Very good	1
Good	2
Fair	3
Poor	4
Very poor	5

16. How important is religion in your life?	
Of utmost importance	1
Very important	2
Of moderate importance	3
Of little importance	4
Of no importance	5

17. How proud are you to be a citizen of your country?	
Not proud at all	1
Not very proud	2
Somewhat proud	3
Fairly proud	4
Very proud	5

18. How often, in your experience, are subordinates afraid to contradict their boss (or students their teacher?)	
Never	1
Seldom	2
Sometimes	3
Usually	4
Always	5

19. To what extent do you agree or disagree with each of the following statements? (please circle one answer in each line across):					
1= strongly disagree AND 5= strongly agree					
19.1) One can be a good manager without having a precise answer to every question that a subordinate may raise about his or her work	1	2	3	4	5
19.2) Persistent efforts are the surest way to results	1	2	3	4	5
19.3) An organisation structure in which certain subordinates have two bosses should be avoided at all cost	1	2	3	4	5
19.4) A company's or organisation's rules should not be broken - not even when the employee thinks breaking the rule would be in the organisation's best interests	1	2	3	4	5
19.5) We should honour our heroes from the past	1	2	3	4	5

20. Are you	
Male	1
Female	2

21. How old are you?	
Under 20	1
20-24	2
25-29	3
30-34	4
35-39	5
40-49	6
50-59	7
60 or over	8

22. How many years of formal school education (or their equivalent) did you complete (starting with primary school)?	
10 years or less	
11 years	
12 years	
13 years	
14 years	
15 years	
16 years	
17 years	
18 years or over	

23. If you have or have had a paid job, what kind of job is it / was it?	
No paid job (includes full-time students)	1
Unskilled or semi-skilled manual worker	2
Generally trained office worker or secretary	3
Vocationally trained craftsperson, technician, IT-specialist, nurse, artist or equivalent	4

Academically trained professional or equivalent (but not a manager of people)	5
Manager of one or more subordinates (non-managers)	
Manager of one or more managers	

24. What is your nationality?

25. What was your nationality at birth (if different)?

APPENDIX B

ARTICLE:

A GREEN APPROACH TOWARDS SYSTEMS DEVELOPMENT

This article will be submitted to the Information and Management journal and has been formatted according to their author guidelines.

Abstract

There are increasing concerns regarding climate change and the effect that the information technology (IT) and information systems (IS) industry has on the environment. The latest research focuses more on Green IS than Green IT. System development methodologies form an integral part of the IS field. This article aims to present a Green approach towards systems development, by presenting an SDM that can be used for the development of a Green IS. Different Green IT techniques were identified that can be incorporated into the system development process to reduce the negative environmental impact of the development process and of the information system that was developed. The perceived effectiveness of these techniques was verified with a survey. These techniques were then used to evaluate existing SDM(s), which proved that the current Green SDM(s) are not thorough enough. A new Green SDM was developed based on the results of the survey and the evaluation of the current Green SDM(s).

Keywords: Green IT, Green IS, Green system development, System development methodologies

1. Introduction

Global warming and climate change are currently of the most critical concerns and important issues globally [1,2,3,4]. Our planet is in danger and it is very frequently a topic in research and has a worldwide public interest [1,5,6,7]. Even though it has been debated that global warming is a natural process [8], it has been established that human activities are the main cause of global warming, especially through the release of greenhouse gas emissions, which increase the temperature of the earth [7,9,10]. It is critical that environmental sustainability is achieved [11]. Many organizations and industry sectors are aware that this is an urgent situation and that it is critical that they improve their environmental impact [12,13,14,15,16,17]. Governments are also implementing new regulations and legislation which forces organizations to lower their environmental impact [14,6]. Organizations are therefore under pressure to decrease their environmental impact and become greener [18,19].

Organizations who want to improve their environmental impact should also see it as a source of opportunity and innovation which can be used as a competitive advantage [20]. It can also reduce the costs of an organization by managing resources more effectively and helping to attract and keep skilled employees [21,22,23,24].

The growing concern for the environment has also led to the investigation of the environmental impact of IT [6]. It is estimated that the Information Technology (IT) industry is currently responsible for 2% off all global greenhouse emissions [25]. The direct negative impact that IT has on the environment is truly significant and will increase if it is not handled correctly, since the world is becoming more dependent on this industry [12,26,27]. IS researchers have not focused on Green IT until recently [28,29].

It is not just Green IT that needs to be further investigated, but also the role of IS in improving environmental sustainability should be better understood. IS can be successfully used to lower the negative environmental effects of an entity and it is very important to improve the sustainability of the planet [30,31,32,33,34,35,36,37,11,38]. Green IS(s) is a new term, sometimes also called "IT for Green" or "the second wave of Green IT" and it is not defined clearly [39,40,27].

The amount of research on Green IT and Green IS is limited [26,32,12] even though it is very important that the IS academic community contributes to environmental sustainability [41,4]. Green IS is considered to be a wider field than Green IT [42,6], but currently the most research is done on Green IT. The initial Green IT research focused on energy efficiency and reduction in different areas of IT, such as hardware and software [43,44,24]. Murugesan [45] contributed several principles and practices for Green IT. Molla *et al.* [28] determined different possible motivations for Green IT. Molla [12] developed a theoretical framework called GITAM, which is a Green IT Adoption Model.

The latest IS research focuses on how IS can be used for transformation towards a more sustainable way of doing things within organizations [46,47] and the reduction of resource consumption [4]. The study of Melville [38] suggests using the transformative influence of IS to help change the perception of the importance of improving environmental and economic performance of organizations. Ijab *et al.* [27] also did a comprehensive literature review in order to clarify the difference between Green IT and Green IS and to provide a better conceptualization of Green IS, which IS researchers can use as a theoretical basis.

Even though systems development will affect the direct environmental effect of the IS on the environment [48], very little research focuses on the systems development process for achieving a truly Green IS. A Green IS should not only help organizations to lower their overall environmental impact, but the development process, as well as the IS itself should be green. The design of most IS are not designed and developed in an environmentally friendly manner [49,50,27,24]. Therefore the environmental sustainability of an IS should also be addressed from a system development process perspective [48,11], so that that greenness can be incorporated into a system from the beginning [27].

The aim of this paper is therefore to investigate how to adapt a SDM so that the development process, as well as the end product are greener. In order to achieve this objective, the following secondary objectives must be achieved:

- Investigate different techniques or initiatives that can be used to reduce the negative impact of IT. IT is the basis used for developing and using IS(s) [51] and therefore the techniques used for green IT can be implemented in green IS(s) to ensure that the IT products used to reduce the organization's carbon footprint and has the smallest possible impact on the environment.

- Determine the effectiveness of Green IT techniques or initiatives. The effectiveness of different green initiatives should also be determined, so that only the effective initiatives are incorporated into the SDM.
- Evaluate different SDM(s) and determine if any existing systems development methodologies incorporate green objectives into the systems development methodology. In order to adapt an SDM to be Green, current Green SMD(s) should be thoroughly studied, so that possible activities, tasks or areas that can be improved in terms of their environmental impact are identified [50,48]. A Green IS, as well as normal IS(s) should be designed to be Green from the start of development [27]. This will ensure that each stage of the development process will be greener, as well as continuously working towards the goal of a greener end product [52].
- Determine how SDM(s) can be adapted to have a greener development process and a greener end product. The systems development process should be modified so that the entire process incorporates environmental sustainability [48,11].

Dedrick [6] suggests that IS researchers focus decisions regarding the entire system, such as selection of hardware, system architecture and in-sourcing versus outsourcing. This article attempts to do this. This research also satisfies several of the different research areas proposed by Elliot [30], Melville [38] and Ijab *et al.*[27], due to the fact that systems development will determine the environmental impact of the IS.

The research was conducted in two parts, namely a literature study and an empirical study. The literature review was done to gather as much theoretical knowledge on Green IT, Green IS and SDM(s) that were adapted to be greener. The literature was then used as a basis together with the research objectives to create a measurement model. The empirical study consisted of a survey that was done in different industry sectors of South Africa. A questionnaire was used as the measurement instrument and the data that was collected, was analysed in SPSS.

This article will consist of four sections. The first section is the literature review of Green IT and Green IS. Next is the comparison of the different existing Green SDM(s). The research approach is explained in section three and discusses the research method and

data collection method that was used. Lastly a Green Approach to systems development is presented.

2. Green IT

The term "Green IT" is used to refer to IT, which has the smallest possible negative impact on the environment. This term currently does not have a universally accepted definition [29] and is still not well defined [12]. Based on the articles by Wang [1], Elliot[30], Murugesan [18], Harmon *et al.*, [23], Molla [12], Hedwig *et al.*, [53] and Chen *et al.*, [54] the following definition will be used for this article:

Green IT is the use of IT, throughout the entire life cycle, in such a way that it has the smallest possible negative effect on the environment.

IT organizations no longer have a choice in determining whether they will implement Green IT, but rather should determine how to implement Green IT most effectively [29]. There are many different Green IT techniques that can reduce the negative effects of IT equipment and service during its entire life cycle [6,26,55,23], but they will be discussed later in this section.

Most of the Green IT approaches only try to improve specific problem areas of IT and do not see the possibilities, which IT can have on an organization [56]. It is important that the entire life cycle of IT equipment is taken into account, since each stage has the possibility of a negative effect on the environment. The different stages of IT equipment consist of: design, manufacturing, operation and disposal [26,23,55].

Each of the four phases has different techniques that can be applied in order to make the phase greener. The considerations of each phase are summarized in Table 1. The considerations of each phase are based on the following literature: Design [39,26,57,45], Manufacturing [26], Operation [58,59,60,36,6,23,45,12] and Disposal [18,59,58,12].

Table 2: Techniques used in different stages of IT equipment and services' life cycle

Stage of life cycle	Techniques or Initiatives
Design	Clear environmental objectives should be incorporated into the design of the product. The design should ensure that the following phases of the product or service also include the smallest negative impact on the environment.
Manufacturing	The product or service should be manufactured using resource-efficient practices and according to the environmental objectives specified in the design.
Operation	1. Minimize printing and paper usage 2. Use energy from a renewable energy source 3. Minimize the negative effect of physical infrastructure, such as cooling products and energy usage of infrastructure. 4. Minimize the negative effect of physical technical Infrastructure with techniques, such as virtualization, rightsizing IT equipment, data de-duplication, cloud computing and energy management.
Disposal	1. It should be disposed in an environmentally friendly manner. 2. Recycle IT consumable equipment 3. Choose vendors with a "take-back" option 4. Refurbish and re-use Equipment

The following are Green IT techniques that cannot be classified according to any of the stages mentioned above and are therefore classified as additional areas of Green IT. Table 2 summarizes the following additional areas: Processes [39,61,62], Communication [61,3,59,63,58,64,29,27,4], Procurement/Sourcing [29,59,44,45,12], Metrics [65,66,39,45,59,67,68] and Green Software [59,69,70,71,72].

Table 3: Additional Green IT techniques

Area	Techniques
Processes	Focus on making processes greener
Communication	Use electronic communication instead of traveling
Procurement/Sourcing	Only use vendors who are Green by checking for eco-labels, certification, their environmental track record and performing TFCO-Analysis.
Metrics	Use metrics so that the environmental impact of equipment or processes can be monitored.
Green software	Software applications should be programmed in such a manner that they consume fewer resources and have computational efficiency. The software should also have the longest possible life time in order to require less frequent hardware upgrades.

3. Green IS

Green IS refers to IS(s) that are used to lower the environmental impact of an organization. Green IS can be defined as [30,73,54,74,39,36,73,6,75,76]:

Information systems that are used in such a way that they reduce the entire organization's negative effects on the environment, while eliminating or reducing the negative effects of IT used in the system.

It is believed that Green ISs have many different practical implications and can significantly help many sectors of the industry improve their environmental sustainability [30,77,26,32,27,38]. Environmental management systems use Green IS(s) in order to monitor, evaluate, improve and report the environmental impact of an organization [38,36]. Green IS(s) can be used to increase the efficiency of energy consumption and therefore reduce the amount of energy consumed [4,56,78]. There are also buildings that incorporate Green IS(s) in order to adapt to different changes in the environment [78,3]. These buildings are managed by a Green IS that uses remote sensors to monitor and

analyse resource usage. This IS can also be used to adjust different features, such as temperature, of the building. Different Green IS(s) are used to increase the efficiency of transportation [56,78,11,36]. These systems can be used to manage a transportation fleet and dynamically choose the route in order to decrease traffic congestion, reduce travel time, as well as to reduce fuel usage. Airlines also use a IS to schedule the least number of flights and to utilize seats as effectively as possible, which ensures that no fuel is wasted unnecessarily. The possibilities for the use of Green IS(s) are endless and the extensiveness of their use will be determined by the organizations that implements them.

There is a clear distinction between Green IT and Green IS(s) [73,36] such as:

- Green IT tries to improve problems caused by IT, whereas Green IS tries to use IS to improve environmental issues. Green IS incorporates environmentally friendly practices into IS.
- Green IT is used to reduce the 2% of greenhouse emissions, Green IS could be used to help reduce the 98% of all the other industries [6].
- Green IT is the predecessor of Green IS and is included in it [75,76,4]. Green IS evolved out of Green IT.
- In 2008 Green IT was recognized by many CIOs as the most important strategic technology. A transition occurred in 2010 when the CIOs emphases shifted to Green IS(s) [79,40].
- Green IT is usually reactive to specific problems caused by the IT they use; Green IS(s) is a proactive approach that is used to redesign or optimize current processes of the organization [80].

A Green IS is not only used as an instrument in lowering an organization's environmental impact, but the IS itself is also Green. The environmental impact of the IS should also be addressed from a systems development process perspective. Systems development is that creation of an IS and it directly impacts how the system functions and the type of infrastructure used [48]. The design of most ISs are not designed and developed in an environmentally friendly manner [27]. In order to develop a Green SDM, current Green SMD(s) must be thoroughly studied, so that possible activities, tasks or areas that can be improved in terms of their environmental impact are identified [50,48].

Only a few researchers have published research on how systems development could be improved to become more environmentally friendly [52,50,11,24,48]. These five articles were the only articles that could be found regarding a Green systems development process. In each article the author explains which phases or activities of systems development can be adapted and how to adapt them. Some of the articles also include additional techniques and considerations which are not included in a specific phase, but can be used throughout the entire development process. The five different articles are discussed briefly below.

The methodology of [11] is called the "sustainable system development life cycle (SSDLC)". This SDM is adapted from the traditional systems development life cycle (SDLC) and consists of six phases, namely systems planning, systems analysis, systems design, system implementation, system maintenance and system disposal. Each of these stages has specific considerations that should be taken into account for a greener development process. The *systems planning* phase ensures that the environment is taken into account from the start of the development process. The environmental impact of all the possible solutions should be investigated to make sure that the solution will have the smallest possible negative impact on the environment. This phase also specifies that if outsourcing will be used for the development of the system, that the environmental records of the different vendors should be included in their assessments. The *systems analysis* phase of the traditional SDLC is used to determine the specific requirements for the project. In this adapted version any current environmental initiatives of the organization, as well as new initiatives should be included as a requirement. The *systems design* phase includes different recommendations to make sure that energy is conserved and that the amount of waste generated by the system is reduced. The recommendations include using energy-efficient equipment, using power-management software and choosing greener physical infrastructure. The *system implementation* of the system implements the requirements and designs of the previous stages. The implementation also needs to be done with the smallest possible negative impact on the environment. Huang [11] suggest that the environmental focus during this phase should be put on the way that coding, testing, installation, and migration are executed, as well as training the users to effectively use the system. The *system maintenance* phase is also considered to be very important for the SDLC. By properly maintaining the system it can extend the life time of the system, it ensures the system is working as efficiently as possible and inefficient equipment can be replaced and put off-line. The last phase of this greener SDM is the *system disposal* phase. All systems will eventually have to be retired. The goal of

this stage is to dispose of the system in the greenest possible manner. The author suggests either transferring the ownership of the system or disposing of the material in the correct manner.

The SDM of Begtsson [48] considers environmental, economic and social sustainability. Only the environmental sustainability factors will be explained, since that is the focus of the current study. Begtsson [48] identified four generic systems development phases, namely planning, construction, testing, and implementation. Only the first three stages include an environmental sustainability consideration and only one suggestion is made in each phase.

The GREESOFT model of Naumann et al ., [52] takes the entire life cycle of systems into account. This model includes considerations for the entire life cycle of software products and it considers all possible effects that the use of IT can have on the environment. The article considers the first-, second- and third-order effects of the system on the environment, but for this study only the first-order effects will be investigated. This model consists of six phases, namely development, distribution, usage, deactivation and disposal. The *development* phase focuses on the impacts of the systems development process on the environment. The systems development process is a sub-procedure of this phase. The systems development process used in this study consists of 4 phases, namely requirements, design, implementation and testing. The process includes four enhancements, which can be used for a greener development process, namely sustainability review and preview, process assessment, sustainability journal and sustainability retrospective. *Sustainability review and preview* assesses the outcomes of each phase and then determines which measures can be implemented until the next review in order to make the development process as environmentally friendly as possible. This enhancement also assesses the impact of the development process on the environment. The *process assessment* also monitors the development process throughout the entire development process, so that the systems development process can be adjusted to be as green as possible. The *sustainability* enhancement combines the data of the previous two enhancements so that the results can be analysed. These results can then be used in future projects in order to improve the overall impact of the systems development process on the environment. The *sustainability journal* is used in order to document all the data of the development process in terms of environmental impact. The *distribution* phase determines the impact of the distribution of the system and ways to make this phase greener. The *usage* phase accounts for the impact on the environment,

based on the implementation, usage and maintenance of the system. The *deactivation* phase is concerned with the storage of data once the system has been deactivated. The last phase, *disposal*, takes the impact of disposal and recycling of the system parts into account. This model also recommends a procedure for purchasing hardware and software, which includes several considerations as listed in the table.

The SDM of Sheenoy and Eerata [50] focuses specifically on software development including different considerations for a more environmentally friendly development process. It also includes additional supporting processes, which include considerations outside of the software development process. This SDM is also adapted from the traditional SDLC so that it can be greener. This SDM is called the 'green software development model' and consists of seven phases, namely requirement gathering, design, implementation, testing, deployment/installation, maintenance and retirement. Each phase includes several practices that should be included for a greener systems development process. *Requirement gathering* takes into account the shelf life of the system, the power consumption and the prototyping technique. The primary objective of the *design* phase is to design the system to be as simple as possible. The system should also be designed in such a manner that parts of it can be re-used and that it will not need frequent changes during the rest of the SDLC. During the *implementation* phase no hardware-specific application programming interfaces should be used and programming should be done without resource-intensive constructs. Sheenoy and Eerata [50] also recommends pair programming and the use of automated code-generation tools. The *testing* phase should be done with test automation. Fewer resources will be used because test cases can be re-used, it standardizes the testing process and it improves the accuracy of the testing. The performance and resource usage of the system should also be done to ensure that the least amount of resources is used. The *deployment/installation* phase considers the impact that the installation packet size can have and determines the most environmentally friendly medium for delivering the installation packet. All the previous phases have an impact on the *maintenance* phase. Sheenoy and Eerata [50] suggests that documentation should be electronic so that paper can be saved, members of the development team should do the maintenance in order to avoid software archaeology and disassembling and avoiding system migration, which might lead to the disposal of legacy hardware. During the last phase, *retirement*, the system should be retired as green as possible. The re-usable code should be stored for future use and the hardware can be donated. Sheenoy & Eerata [50] included additional considerations that should be taken into account. These considerations include physical infrastructure,

travelling, storage of data, the minimization of paper usage and adding metrics for measuring the environmental friendliness of systems, as well as the development process.

Lastly, the article by Argarwal *et al.* [24] does not include a complete SDM but rather suggests different practices that can be used to improve normal tasks done during system design and implementation. In this article the development process is divided into three activities of software development, namely Software Requirement Analysis and Specifications, Software Design, and Software Implementation and Testing. The article explains how the three activities can be made greener. The article also suggests that software should be developed to be as simple as possible by following several different recommendations.

4. Evaluation of Green SDM(s)

The five different Green SDM(s) cannot be evaluated according to their phases, because the phases are not the same in each article. Therefore they will be evaluated using feature comparison. This technique works by identifying specific features that an ideal SDM needs to have and then uses these features to compare the different SDMs [81,82]. IT is the basis of all IS(s), and the different Green IT techniques identified in section 2 can be implemented in IS(s) in order to reduce the negative environmental impact of all IT used in the IS. The different techniques listed in Table 1 and Table 2 can be grouped into ten considerations, which are used as the features for comparing the abovementioned Green SDM(s). These factors are summarized in Table 3.

Table 4: Considerations that should be taken into account for a Green Systems development process and end product

Consideration	Description
Green Goals	Green goals should be incorporated into the design stage of system development, because the design will have a large impact on all the other stages of development, as well as on the end product. Green goals or objectives should be regarded as a non-functional requirement. These goals include efforts to reduce the impact of the system and the system development process on the environment.
Paper Usage	There are several different initiatives to lower the amount of paper used, as well as the amount of printing, which should be incorporated throughout the entire development process. The amount of paper used for the entire life cycle of the system should be minimized.
Green Software	Better programming techniques, which use less resources. The system should be coded with energy-efficient constructs. Develop software with a longer life cycle, as well as software that can be re-used.
IT infrastructure	IT infrastructure has several considerations that need to be taken into account: It must be determined whether new IT equipment needs to be acquired or if the old IT equipment can be refurbished. When procuring IT infrastructure the entire life cycle of the equipment should be taken into account. Techniques should be chosen to use and manage the equipment so that it can be used as effectively as possible while using as little energy as possible.
Physical Infrastructure	Physical infrastructure has several considerations. Cooling concepts with the least negative environmental impact should be chosen Energy usage should be effectively managed and renewable energy sources should be considered. It includes all physical infrastructure used for the system, as well as during the development of the system, such as buildings.
Retirement of System	The shelf life of the IS should be determined in order to plan how the retirement and disposal of the system will happen.
Communication	Communication should be as effective as possible, while eliminating negative effects that it may have on the environment. Electronic communication can be used to eliminate the need for travelling.

Consideration	Description
Process Centric	The systems development should be focused on processes, which can be reengineered in order to make the organization more environmentally friendly. Appropriate notational methods should be used in order to indicate the environmental impact of each process
Procurement/ Sourcing	For procurement/sourcing the vendor or dealer and the products procured should be evaluated to determine their impact on the environment. The vendor should also be analysed in terms of effect on the environment.
Metrics	Different metrics should be incorporated into the IS so that the performance and different impacts on the environment could be continuously monitored and used for improvement.

Each of the Green SDM(s) was compared individually in several steps. In the first step each phase of the SDM is analysed in order to determine which techniques and considerations fulfil the Green Considerations. The second step then groups the techniques and considerations of all the phases of the SDM according to the Green Considerations. A percentage value will then be given for each Green Consideration, depending on how thoroughly the SDM satisfies it. The values were determined interpretively.

The results of all the Green SDM(s) are shown in Table 4.

Table 5: Results of the evaluation of the different Green SDM(s)

Green Considerations	Huang [11] Value (100)	Begtsonn [48] Value (100)	Sheenoy & Eerata [50] Value (100)	Naumann et al., [52] Value (100)	Argawal et al., [24] Value (100)	Total: (500)	Percentage:
Green Goals	90	0	70	100	80	340	68
Paper Usage	100	0	90	50	60	300	60
Green Software	80	0	100	50	100	330	66

Green Considerations	Huang [11] Value (100)	Begtsonn [48] Value (100)	Sheenoy & Eerata [50] Value (100)	Naumann et al., [52] Value (100)	Argawal et al., [24] Value (100)	Total: (500)	Percentage:
IT infrastructure	95	10	80	70	65	320	64
Physical Infrastructure	50	0	60	60	0	170	34
Retirement of System	100	0	85	60	0	245	49
Communication	0	70	50	0	0	120	24
Process Centric	0	0	0	0	0	0	0
Procurement/ Sourcing	80	0	0	85	60	225	45
Metrics	50	0	80	70	50	250	50
Total: (1000)	640	80	615	545	415		
Percentage:	64	8	61.5	54.5	41		

The SDM of each article is evaluated against the ten different considerations. The SDM is given a point out of hundred for each consideration. Each SDM is then given a point out of a thousand. The point is then also represented as a percentage.

The different Green considerations are also given points based on their inclusion in the five SDM(s) of the articles. Each Green consideration is then given a point out of 500. This point is also represented as a percentage.

Based on the evaluation, the SDM(s) can be ranked from most-thorough to least-thorough:

1. Huang [11]
2. Sheenoy & Eerata [50]
3. Naumann *et al.*, [52]
4. Argarwal *et al.*, [24]
5. Begtsson [48]

The SDM of Huang [11] scored the highest of the different SDM(s) with a score of 640 points and is therefore considered the most thorough. It thoroughly considered Green goals, paper usage, Green software, IT infrastructure, procurement/sourcing and retirement of the system. This SDM received a low score for physical infrastructure because the SDM only mentions that it should be considered, both buildings used and data centres, but does not include techniques to make it more environmentally friendly. Metrics were addressed but only in terms of energy usage and therefore also received low score. The SDM is not process centric and it did not consider environmentally friendly communication.

The SDM of Sheenoy & Eerata [50] scored 615 points and is the second most thorough. The SDM thoroughly considers paper usage, Green software, IT infrastructure, the retirement of the system and metrics. It also addresses Green goals, physical infrastructure and communication but not in detail. The SDM does not consider procurement/sourcing and is not process centric.

The SDM of Naumann *et al.*, [52] scored 545 points. It considered Green goals the most thoroughly of all the SDM(s), taking these goals into account during each phase and reviewing after each phase. It also thoroughly considered procurement/sourcing. The article does consider IT infrastructure, physical infrastructure, retirement of the system and metrics. The last-mentioned considerations, however, did not receive high marks because they were not thorough enough. The article did mention paper usage and Green software, but did not explain how they could be more environmentally friendly. This SDM is not process centric and does not include considerations for more environmentally friendly communication.

The SDM of Argarwal *et al.*, [24] scored 415. It thoroughly considered Green goals and green software. It addressed paper usage, IT infrastructure and procurement/sourcing but not in very great detail. The article also considers metrics, but only mentions it without any detail. The article is not process centric and does not consider communication, physical infrastructure or the retirement of the system.

The SDM of Begtsonn [48] scored the lowest with 80 points. This article only addresses communication and listed on technique for IT infrastructure. The other eight considerations were not included in this SDM.

By looking at the percentages, is clear that these SDM(s) do not sufficiently fulfil the different Green Considerations. The highest percentage is only 64%, the lowest is 8% and the average of the five articles is 45%.

The Green consideration that was included in the different SDM(s) can also be ranked from most considered to least considered:

1. Green Goals (340 points)
2. Green Software (330 points)
3. IT Infrastructure (320 points)
4. Paper Usage (300 points)
5. Metrics (250 points)
6. Retirement of the system (245 points)
7. Procurement/Sourcing (225 points)
8. Physical infrastructure (170 points)
9. Communication (120 points)
10. Process Centric (0 points)

Even though there are several process centric SDM(s), such as example [82], not one of the five different SDM(s) focuses on processes. Communication was also only considered in two articles. The only consideration that was included in all five of the articles was IT Infrastructure. Green goals, paper usage, Green Software and metrics were considered in all the SDM(s), except the article of [48].

Green goals, paper usage, Green software and IT infrastructure all have a percentage higher than or equal to 60%. Retirement of the system, procurement/sourcing and metrics have percentages of above 40%. The physical infrastructure, process centric and communication considerations have percentages below 40%. This means that only the first four considerations are addressed on a level, which is sufficient.

If the poorest SDM [48] is left out of the interpretation the results are better, but still not sufficient. Green goals, paper usage, Green software and IT infrastructure all have a percentage higher than or equal to 75%. This means that these four considerations were thoroughly fulfilled. Retirement of the system, procurement/sourcing and metrics have percentages above 50%. These considerations are addressed, but they should be further improved. The physical infrastructure, process centric and communication considerations have percentages below 50%. The last-named considerations are not addressed enough.

If the different SDM(s) were combined, all the criteria would be sufficiently addressed, except for communication, infrastructure and process centric.

5. Research Approach

The empirical study was then done in order to collect data from different industries within South Africa. The study was conducted in the positivistic paradigm, which underlies the scientific approach [83]. This paradigm is the most frequently used paradigm in IS research [84,85]. It was used for this particular study because it can effectively identify patterns and relationships in an objective manner. Several research methods can be used in the positivistic paradigm [83,86], however, for this study a survey was used in order to gather a large amount of data in a systematic way [87]. The results of the survey produced quantitative data which can be used to generalize, which is favourable to this particular study. A questionnaire was used as the measurement model.

The survey was done between 1 May 2012 and 31 August 2012 in different industries of South Africa. 134 questionnaires were collected from 54 different organizations. Four of the 138 questionnaires were not usable, leaving 134 questionnaires, which could be analysed. The response rate was 24.8%, which is satisfactory compared to other studies on the use of methodologies [88,89,90,91,92,93,94,95].

Once the data had been collected, it was analysed in SPSS.

5.2 Data analysis of the survey

The survey gathered data regarding Green IT and Green systems development. The data that was gathered were the type of SDM mostly used in South Africa, if SDM(s) are being adapted, the type of SDM which is mostly adapted to be Greener, the predictions of IT professionals for the use of Green IT in the next two years and lastly the perception of the effectiveness of Green IT initiatives, which are implemented in the organizations.

Which type of SDM is mostly used in South Africa?

The next research variable that was investigated was the SDM of the different organizations. The SD can be divided into two categories, formal SDM and informal SDM(s). The organizations mostly used formal SDM(s), 81(56%), with informal SDM(s) being used by 59 (44%) of the respondents. The formal SDM can also be further divided into traditional SD and agile systems development. The results indicate that 46 (52.87%) of the organizations that use formal SDM(s), use traditional SDM(s), 35 (40.22%) use agile SDM(s) and 6 (6.9%) of the organizations use both traditional and agile SDM(s), depending on the specific situation.

Table 6: Systems development process used by IS departments

		Frequency	Percent	Valid Percent	Cumulative Percent
Informal System Development	.00	75	56.0	56.0	56.0
	1.00	59	44.0	44.0	100.0
Traditional System Development	.00	88	65.7	65.7	65.7
	1.00	46	34.3	34.3	100.0
Agile System Development	.00	99	73.9	73.9	73.9
	1.00	35	26.1	26.1	100.0

Which type of SDM is mostly adapted to be Greener?

It can be seen from the Table 6 that 77.5% of the organizations that use traditional systems development adapt their SDM to support Green Initiatives, compared to only 57.7% in organizations that use an agile SDM.

Table 7: Type of SDM which is mostly adapted

			Green Initiatives used in the SDM		Total
			0	1	
Traditional Systems Development	0	Count	17	48	65
		% of total Traditional SDM users	26.2%	73.8%	100.0%
	1	Count	9	31	40
		% of total Traditional SDM users	22.5%	77.5%	100.0%
Total	Count		26	79	105
	% of total Traditional SDM users		24.8%	75.2%	100.0%
Agile Systems Development	0	Count	15	64	79
		% of total Agile SDM users	19.0%	81.0%	100.0%
	1	Count	11	15	26
		% of total Agile SDM users	42.3%	57.7%	100.0%
Total	Count		26	79	105
	% of total Agile SDM users		24.8%	75.2%	100.0%

Determine if SDM(s) are being adapted to be Greener

Table 7 shows that 79 (75.2%) of the respondents answered that their systems development methodology does support Green Initiatives, as opposed to 26 (24.8%) who said that their SDM did not.

Table 8: Green Initiative Support of Systems development processes

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	26	19.4	24.8	24.8
	1.00	79	59.0	75.2	100.0
	Total	105	78.4	100.0	
Missing	System	29	21.6		

How are systems being adapted to be Green in Practice?

In order to determine how SDM(s) are being adapted in practice, the questionnaire asked the respondents to indicate how they are adapting their SDM(s) to be Green. The data showed that the following is being done by the organizations in the survey.

- Organizations are switching to a paperless environment with electronic document sharing via tools, such as SharePoint. This is to avoid paper usage, as well as to limit printing.
- Organizations are improving awareness regarding environmental impact. This is done by having a Green agenda item in all meetings and by including a footer in all e-mails, which asks the receiver to take the environment into consideration.
- Organizations ensure that when the building where the software development takes place is not in use, the lights and air conditioning are turned off. Some organizations also use solar panels to power the physical infrastructure.
- Ensuring that no hardware is running when it is not in use.
- Correctly disposing of old IT equipment when the cross-over to a new system is made. This also includes recycling equipment, as well as refurbishment.
- Telecommunication is used instead of travelling to different people.
- Hardware is shared, using virtual servers and energy-efficient hardware.
- New products include environmental impact assessments in the feasibility study.

- Metrics are used that could monitor resource consumption and performance of the IS(s).
- Software is developed as efficiently as possible in order to use fewer resources.
- Interfaces are developed with dark colours because it uses fewer resources.

What are the predictions for Green IT initiatives over the next two years?

The questionnaire also determined what the respondents' future expectations regarding Green IT initiatives within their organization were. By looking at Table 8, it is clear that most respondents, namely 63 (48.1%), are expecting that their organizations will use more Green IT initiatives in the future and 24 (18.3%) expected that their current Green IT initiatives will be supplemented with more Green IT initiatives. Of all the respondents only 1 (0.8%) expected that they would abandon the use of Green IT initiatives and another 39 (29.8%) respondents expected that no change would occur.

Table 9: Future predictions for Green IT initiatives

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Use more Green IT initiatives	63	47.0	48.1	48.1
	Replace your current Green Initiatives	3	2.2	2.3	50.4
	Supplement current Green IT initiatives with more Green IT initiatives	24	17.9	18.3	68.7
	Abandon the use of Green IT initiatives	1	.7	.8	69.5
	No Change	39	29.1	29.8	99.2
	Other	1	.7	.8	100.0
	Total	131	97.8	100.0	
Missing	System	3	2.2		
Total		134	100.0		

What is the perception of the effectiveness of Green IT initiatives that are implemented in the organizations?

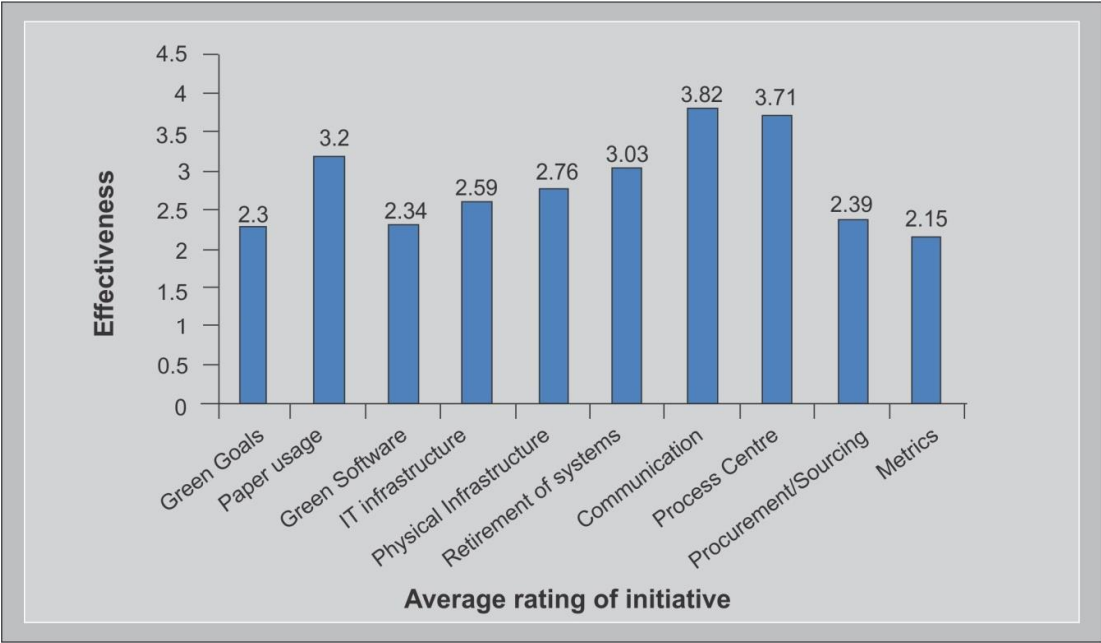


Figure 3: Effectiveness of Green IT initiatives

As seen in Figure 1 communication is considered to be the most effective Green IT initiative, 3.82, and is implemented the second most according to Figure 1. Process centric (3.71), paper usage (3.2) and retirement of system (3.03) are also regarded as effective, since they all have ratings of more than 3. The rest of the techniques are not considered to be effective, since all have values below 3. The Green IT technique that was implemented by most organizations (134) is paper usage as opposed to procurement/sourcing and metrics that were implemented by the least number of organizations with 127.

The most significant finding of this statistic is that even though process centric was the consideration that was the least implemented in the existing SDM(s), it is perceived as being one of the most effective techniques in practice.

5.3 Conclusion of empirical data

It is clear from the empirical data that the formal systems development methodologies are still used the most in South Africa, compared to informal methodologies. This article will focus on the traditional SD methodology, since it is used more than agile methodologies. The results also show that organizations that use traditional systems development adapt their SDM(s) to support Green Initiatives more compared to organizations that use agile SDM(s).

The survey revealed that many of the organizations are already adapting their SDM to be Greener. The problem is, however, that since the available literature to indicate how organizations should adapt their SDM is not very clear, the organizations do not know how to do this effectively. The results in Figure 1 support this because of the ten Green IT techniques, seven of them were rated below average. The highest score of the three techniques that scored above average was 3.82, indicating that these initiatives are also not truly perceived as effective.

The future predictions regarding Green IT show that almost half of the sample indicated that they plan to implement more Green IT initiatives in the future and that many organizations are planning to supplement their Green IT initiatives.

Based on the results of the survey, this article will focus on the adaption of the traditional SD methodology, since it is used more than agile methodologies and because more organizations that use traditional systems development adapt their SDM to support Green Initiatives compared to organizations that use agile SD. The survey indicates that many respondents predicted that more Green IT initiatives will be adopted over the next two years. It also shows that even though organizations are adapting their SD to be Greener, there perception of the effectiveness of Green IT techniques is very low. This adapted version of the Traditional SDM will give organizations a clear guideline on how to incorporate Green initiatives into their SDM, since many organizations are planning to adopt more Green IT initiatives. This will also help organizations to use the Green Initiatives effectively and to change their perception of the effectiveness of these initiatives.

6. The Green systems development life cycle

The Green SDM consists of six phases: feasibility study, system investigation, system analysis, system design, implementation and review and maintenance. There are many variants of the traditional SDLC, but these phases are based on the traditional SDLC as explained in Avison and Fitzgerald [82].

In this section each of the phases will be explained briefly, followed by techniques that can be implemented in order to make that specific phase Green.

6.1 Feasibility study

In this phase the current situation of the organization should be studied. If present information systems exist they should be investigated together with the requirements the system was created to meet in order to establish if the system truly satisfies these requirements. It should also determine if the system satisfies new requirements and if they do not, what possible solutions need to be considered.

The alternative solutions must be addressed from a technical, human, organizational and economic view point as well as what the benefits of a new information system would be. The new system should be legal, be socially acceptable to the organization, technically feasible and economically justifiable. A recommended solution should be given to management in order to establish whether the solution may proceed.

Green IT techniques that can be incorporated into this phase

Green goals should be seen as a new requirement when the present IS is being investigated. If this system is not Green, it is already a motivation why alternative solutions should be investigated. Green goals should also be used when the alternative solutions are being evaluated. The environmental impact of each solution should be thoroughly investigated in order to determine whether the solution will have a negative impact on the environment. When assessing the environmental impact of the current system as well as the alternative solutions, it can be very helpful to focus on the processes of both. Each process can be notated and analysed in order to establish the precise effect of that process on the environment.

During the assessment of the current system and the new system, paper usage and printing should be kept to a minimum. The documentation and communication thereof should be done electronically if possible [58]. If printing must be done print on double-sided paper [12], give employees a personal pin to start a print job [29] in order to monitor the amount of paper that they are using, share a large printer instead of personal printers [29], and use recycled paper [58].

6.2 System Investigation

Once a project has been approved, it will require an in-depth investigation, which will focus on factors such as requirements of the current system and if the degree to which these requirements are satisfied, new requirements and any existing constraints. This investigation can be done with interviews, questionnaires, studying existing documentation, as well as direct observations.

Green IT techniques that can be incorporated into this phase

Green goals should be seen as both a requirement and a constraint. It should be stated from the beginning that the development of the IS, as well as the IS itself, should be Green. This is very important because these goals will need to be implemented in the rest of the phases of development.

As mentioned in the feasibility stage, it is important to focus on each process of the IS and to determine the exact environmental impact of each phase using the correct notational methods [39,61,62].

The least amount of resources should be used when conducting the investigation. The interviews can be done electronically if the different parties are not located near each other [61,29,27,3,59,63,64,58]. It is important to mention that electronic communication, such as teleconferencing should be used throughout the SDLC in order to minimize travel.

The existing documentation that is being investigated should not be printed and when it must be printed, the guidelines mentioned earlier should be used. The questionnaire should also be distributed and collected electronically.

6.3 System analysis

During this phase the system analyst studies all the aspects of the current system, determines why it was developed as it was and how the new system can improve on current problems. The system analyst then determines the requirements of the new system and how it should be designed.

Green IT techniques that can be incorporated into this phase

Firstly the Green Goals identified in the first two phases of the life cycle should once again be used as a requirement and as a constraint during this phase.

It is important that the specification for the design includes Green software. Software should be programmed in such a manner that it consumes fewer resources and has computational efficiency [59,69,72]. The software should also be developed so that it will allow a longer life cycle for hardware [70].

Thereafter the design specification should include choosing Green IT infrastructure. There are several areas that organizations have to focus on when doing this. Data centres can be turned into Green Data centres, by buying new energy-efficient equipment or refurbishing the old equipment [39,59,45,60,12]. In order to reduce the quantity of IT equipment necessary, virtualization concepts can be used [29,39,59,58,12]. This can be done by using server consolidation and virtualization [45,63,12], desktop virtualization/thin clients [29,59,45,63,58,36], rightsizing IT equipment [12], storage tiering [12], cloud computing [29,39,59,60] and use of blade servers [58].

The organization should only buy energy-efficient IT equipment that complies with verified standards [29]. Organizations should also shift from desktops to laptops [39], use power-efficient monitors [59] and newer technologies, such as Green drives [58].

The physical infrastructure where the IT equipment will be kept should also be focused on, especially cooling and energy efficiency. There are many Green cooling options [29,39,58], such as airside/waterside economizer [12,58], liquid cooling for IT equipment [12], hot aisle/cool aisle data centre layout [58,12], water-cooled chillers with variable speed fans and pumps [12], free cooling in large scale data centres [12] and thermal load

management [39]. The energy consumption of the physical infrastructure can be lowered using high efficiency stand-by power systems [29,12], upgrades to more efficient transformers and UPS [12], DC-powered IT equipment [12], data centre airflow management [12], high voltage AC power [12], the usage of energy-efficient lights [12], grid computing [29], as well as the use of energy from a renewable energy source [58,45,12,36].

The retirement of old system, as well as the new system should also be determined in this step. Determine if some of the old equipment can be re-used for the new system [58] and how to dispose of the rest in an environmentally friendly manner [45,12].

Lastly, the design should include different metrics, which can be to monitor the different processes of the new system [65,66,39,45,59,67,68]. These processes can be used to measure energy efficiency, IT resource usage, job duration, identify where energy waste occurs in the system, effective decision making and monitor environmental considerations, such as carbon emissions.

6.4 System design

The design is based on the solutions identified during the feasibility study, but the new requirements identified by the system analyst are the most important. The computer and manual parts of the system are designed during this phase. The design includes the following aspects:

- The data that is necessary for the system and how it is to be captured;
- What outputs need to be created by the system;
- Processes for converting the inputs to the necessary outputs;
- Structure of the file systems;
- Security functions; and
- The testing and implementation recommendations.

Green IT techniques that can be incorporated into this phase

The design of the system should incorporate all the different considerations and techniques that were determined in the previous two phases.

6.5 Implementation

There are many tasks which need to be completed before the implementation of a new system. The new software should be developed and tested, new hardware and software might need to be procured and installed and the system should be proven to function correctly before cutover can occur. Quality control is very important during this phase. The system analysts should ensure that all requirements are satisfied by the new system and users should feel comfortable with it. The users should also be trained to use the system.

Documentation of the operation and user manuals are also created in this phase. Once all has been done, the cutover to the new system can be done. The new and old system are frequently run in parallel until the organization has enough confidence in the new system.

Green IT techniques that can be incorporated into this phase

New software that needs to be developed needs to be Green as specified in the previous stages.

When new hardware or software is procured it must be ensured that not only the hardware or software is Green but also that the vendor is an environmentally sustainable organization. This can be done by checking for Eco-labels [29,44,59,45], certification [29], by performing a TFCO-Analysis on the vendor [29] and by considering the Green track record of vendors [12].

In the quality control phase the analyst can use all the metrics designed into the system to determine if the Green goals that were specified in the first three phases are met.

Once the new system is implemented, the old system should be disposed of as specified in previous stages.

The documentation and the manuals should again be done according to the paper usage principles discussed in the first stage.

6.6 Review and maintenance

This phase is responsible for all changes to the system once it is operational. This is to ensure that the system is working as efficiently as possible. The changes can be due to errors of the system, the organization or its environment changing, new technology or additional requirements that might need to be incorporated into the system. Eventually the system will be retired and a new system will be developed to replace it.

Green IT techniques that can be incorporated into this phase

During this phase it is important that all the implemented metrics are continuously monitored. This should be done to ensure that the system is used effectively and that it is working efficiently. If the system stops to function according to all the specified requirements, it should be adapted as speedily as possible. Power and workload management software can be used to adjust the system to use the least amount of resources.

The last part of the system development cycle is the retirement of the IS. The retirement should be done according to the specification in the first three phases.

Figure 2 is a summary of the stages of the SDM. It includes all the considerations except for paper usage and communication, because these two considerations should be used in all the phases of the SDM.

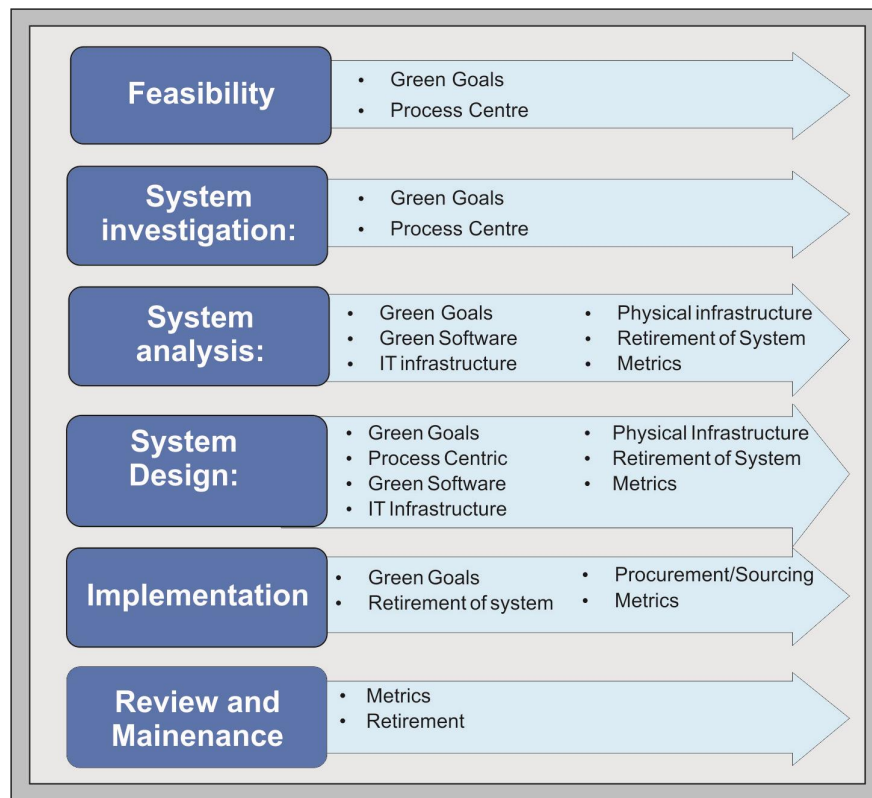


Figure 4: Summary of the different phases of the Green SDM

7. Conclusion

The main goal of this article was to adapt the traditional systems development life cycle so that the development process and developed IS would be Green. This is necessary because of the serious issue of global warming and climate change, as well as the fact that current research regarding Green systems development is very limited. The current examples of Green SDM(s) are also not very comprehensive. The empirical data that was collected shows that organizations are trying to adapt their SDM to be Greener, but they have a perception that the Green IT initiatives that could be used for the adaption are not effective. The result of this article is a Green SDLC, that shows which Green IT techniques can be implemented into systems development in order to ensure that the development process and the develop IS is Green.

8. Limitations, Contributions and Future research

The limitations of this study include that the survey sample was small and the study was only done in South Africa. Additional studies in different countries need to be done. Another possible limitation is that it has not been determined how the incorporation of the different Green techniques will affect the effectiveness of the SDM. If an organization incorporates these techniques into their SDM, they might not be as productive as they used to be and this could lead to the techniques being discarded.

Even though there are published articles regarding green systems development, they are not based on any empirical data. Therefore this article aims to contribute theoretically by determining with empirical data the future predictions for Green IT initiatives in South Africa, determining which Green IT techniques are perceived to be effective in the industry and if organizations are currently adapting their SDM for a green development process. It also contributes by identifying which type of SDM is mostly used in South Africa as well as which type of SDM is mostly adapted to be Greener.

This article also makes practical contributions. The adaption of the systems development process, will allow IS professionals to develop systems in a manner that is environmentally friendly. This article also provides professionals with guidelines on the type of Green IT initiatives that are available so that they can implement them in their organizations.

Future research might focus on adapting agile SDM(s) because even though traditional SMD(s) are still mostly used, agile SDM(s) are becoming more popular.

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