Modelling the Assimilation and Value of Sensor Information Systems in Data Centres

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DECLARATION

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

Signed

Adel Abdullah Alaraifi

22 Aug, 2012

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LIST OF PUBLICATIONS

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ABSTRACT

This research is concerned with studying the use and value of sensor information systems (SIS) in the context of data centres. It seeks to examine the nomological net of antecedent factors that explain variation in the assimilation of SIS and the impact of SIS use on data centre's performance.

Sensors are small electronic chips that can detect, identify, measure, and track their surrounding environments and/or objects within that environment. Thus, sensors can significantly enhance the three important roles of information systems (IS), that is, automation, informatisation, and transformation. Sensor Information Systems (SIS) refer to any IS that utilises sensor(s) that are directly or indirectly connected to other sensors or sensor networks in order to automate, inform and/or transform a given task or process or appliance. Such systems usually have advanced monitoring, analysing, reporting, recommending and controlling functionalities. SIS are promoted as one of the best practices to overcome critical data centres issues such as inefficiency of Information Technology (IT) infrastructure usage, rising cost of operations, and the consumption and efficiency of energy. These issues directly affect not only business continuity but also the environmental sustainability of IT operations. A review of the sensor, IS, and data centre literature shows that there is a dearth of theory driven empirical research on the utilisation of SIS in data centres, the factors that explain variations in applying SIS in data centres and the value of SIS use to data centres. The aim of this study is therefore to address the gap in the current literature and answer the following questions: (1) to what extent are SIS assimilated in data centres? (2) What is the nomological net of antecedent factors that explain the differences in the assimilation of SIS among data centres?, and (3) What are the operational and environmental values of SIS assimilation to data centres and what drives those values?.

The research was conducted through a mixed method approach consisting of a literature review, exploratory case studies (pilot study) and large scale survey. Drawing from several theories of innovation adoption and value, and the five exploratory case studies, an integrative theoretical framework, which we call as TOIN (Technology, Organisation, Institutional and Natural Environment), was proposed to investigate the factors that explain the variation in the assimilation of SIS and the impact of SIS use on data centre's

operational and environmental performance. A series of hypotheses are developed by linking the TOIN factors to SIS assimilation and value in a two order-based model. The TOIN framework is tested using Partial Least Squares (PLS) path modelling and data collected from a global survey of 205 data centres.

The findings indicate that SIS compatibility, perceived SIS risk, green IT orientation, and normative pressure directly influence the level of SIS usage among data centres. In addition, normative pressure, energy pressure, and natural environmental pressure indirectly affect the assimilation of SIS through influencing the organizational conditions (such as top management support, green IT/IS orientation, and data centre energy governance) for SIS use. These results are mostly sensitive to differences in data centre characteristics including age and type of data centre. Further, the test of the second order model show that the level of actual usage as well as the level of SIS mangers' knowledge affect the operational and environmental performance of data centre operations including the facility, cooling and power, and computing platforms. The differences in length of SIS use have significant effect on the linkage between SIS managers' knowledge and SIS value.

The research represents one of the first studies on the use and value of SIS in general and in the context of data centre environment in particular. It makes an original contribution by proposing and validating the TOIN framework which can be used as a theoretical foundation for future and related studies. It also contributes original knowledge regarding how data centres are using information systems that are integrated with sensors to tackle some of the operational, economic and environmental challenges. Thus, the research adds to the body of knowledge on intelligent systems, infrastructure management, green IS and energy informatics. Furthermore, the research extends the current innovation theories by incorporating the natural environment to study the technology use and value and shows the significance of natural environment and sustainability considerations on organizations' activities as well as on the extent of IS use and value. This adds to the body of knowledge on the role of natural environment and sustainability on technology innovation. Data centre and IT managers can benefit from the results of the study in identifying and nurturing the critical factors that facilitate successful assimilation and exploitation of SIS.

LIST OF ABBREVIATIONS

APC	American Power Conversion Corp.
BMS	Building Management Systems
CASE	Computer-Aided Software Engineering
CBD	Component-Based Software Development
CENS	Centre for Embedded Network Sensing
CFA	Confirmatory Factor Analysis
CIO	Chief Executive Officer
CIOS	Customer-Based Inter-Organisational Systems
CMB	Common Method Bias
CO^2	Carbon Dioxide
CPU	Central Processing Unit
CRAC	Computer Room Air Conditioners
CSSP	Critical Site Support Platform
DCiE	Data Centre Efficiency
DCP	Data Centre Productivity
DOI	Diffusion of Innovation
DPPE	Data Centre Performance per Energy
EDI	Electronic Data Interchange
EFA	Exploratory Factor Analysis
EPA	Environmental Protection Agency
EPI	Electronic Procurement Innovations
ERP	Enterprise Resource Planning
GoF	Goodness-Of-Fit
HVAC	Heating, Ventilation, and Air Conditioning
ICT	Information and Communication Technology
ICTP	Information and Communication Technology Platform
IPMI	Intelligent Platform Management Interface
IS	Information Systems
ISS	Initial Sample Size
IT	Information Technology
KMO	Kaiser-Meyer-Olkin
NRBV	Natural Resource-Based View

MAR	Missing At Random
MCAR	Missing At Completely Random
MRSS	Minimum Required Returned Sample Size
PCA	Principal Components Analysis
PDU	Power Distribution Units
PLS	Partial Least Square
PUE	Power Usage Effectiveness
RBV	Resource-Based View
RFID	Radio-frequency identification
RMIT	Royal Melbourne Institute of Technology
SCM	Supply Chain Management
SEM	Structural Equation Modelling
SIS	Sensor Information Systems
SRMS	Sensor Resource Management Systems
SRS	Simple Random Sample
SSL	Secure Sockets Layer
TOE	Technology Organisation and Environment
TOIN	Technology-Organisation-Institutional-Natural Environment
UPS	Uninterruptible Power Supply
WECD	World Commission on Environment and Development

Modelling the Assimilation and Value of Sensor Information Systems in Data Centres

CHAPTER 1

1. INTRODUCTION TO THE RESEARCH

1.1. Background

This research is concerned with studying the use and value of sensor information systems (SIS) in data centres. The aim of this study is to examine the nomological net of antecedent factors that explain variation in the assimilation of SIS and the value of SIS to data centres.

The role and impact of information technology (IT) on sustainability is attracting the attention of policy makers, practitioners and researchers alike (EPA, 2007; Lamb, 2009; Dedrick, 2010; Molla and Abrashie, 2012). One of the areas of IT where sustainability is becoming important is data centres (Schulz, 2009; Sioshansi, 2011). Data centres refer to the business facilities that contain large information and communication technology (ICT) platform (ICTP) and cooling and power delivery equipment (Critical Site Support Platform-CSSP) to store, process, and exchange digital data and information. A data centre represents an area with a large concentration of electronic equipment and power density within a limited space (Lefurgy et al., 2003). Thus data centres are one of the largest energy consumers, accounting for approximately 1.1% to 1.5% of total global energy use (Koomey, 2011). While the demand for and on data centres continues to increase, these digital ‘powerhouses’ are faced with several power, cooling, computing performance and space constraints associated with environmental, technological, and economic sustainability (Schulz, 2009; Smith, 2011). Improving the energy efficiency, operational and environmental performance of data centres is therefore at the forefront of organisations’ actions in ‘greening’ their IT (Daim et al., 2009; Dedrick, 2010).

A number of practices, methods and technologies can be employed to convert data centre operations into sustainable practices (Baird and Mohseni, 2008; Siddiqui and Fahringer 2010). Of these, Gartner has promoted ‘sensorisation’ as one of the 11 best practices for addressing the data centre’s efficiency related issues (Gartner, 2008). Sensorisation refers to the wide application of sensors (electronic devices that detect and observe their surrounding environment) (Meijer, 2008) and sensor information systems (SIS). SIS can be defined as any IS that utilises sensor(s) which are directly or indirectly connected to sensors or sensors networks in order to automate, inform and/or transform a given task or process or appliance. A number of vendors and laboratory experiments have introduced SIS and SIS enabled best practices for data centres (e.g. Sharma et al., 2005; Liu et al., 2008; Padala et al., 2007). These studies have explored the opportunities underlying the use of SIS for automating, informating, and transforming the processes and tasks of CSSP and ICTP.

The use of stand-alone sensors devices or building management systems to monitor the temperature, humidity, smoke and security of data centres is an old practice (Davis et al., 2006). Nevertheless, it is only recently that these sensors have been considered for integration into information systems (IS) to automate data centre management functions, inform decision making, and transform data centres for improving their operational, economic and environmental sustainability in an intelligent manner (Watson et al., 2009; Wang et al., 2011). Such SIS can be considered as an example of green IS (Watson et al., 2010) as they can provide data centres with effective solutions in improving their operational performance and environmental impact (Alaraifi et al., 2011). A review of the IS research (e.g. Melville 2010; Dedrick 2010; Watson et al., 2010; Elliot 2011) shows that there is a dearth of theory-driven empirical research on the utilisation of SIS in data centres, the factors that explain the variations in applying SIS in data centres and the value of SIS to data centres. Understanding the factors that facilitate or inhibit the utilisation and value of SIS is very important to help data centres leverage the advantages of assimilating SIS into their daily operations.

1.2. Research Motivation and Research Questions

The rationale for this research stems from the knowledge gaps identified in three areas of IS research and practice.

First, data centres typically encompass two platforms: ICTP and CSSP (Uptime Institute, 2000; Brill, 2007). ICTP includes the dense IT zone comprising computing hardware and telecommunication equipment such as servers, network equipment and storage devices. CSSP includes equipment that supplies cooling and power to the core IT equipment. The inefficiency of ICTP and CSSP operations of data centres is becoming a non-negligible risk to business performance because of the rise of operation costs, the consumption and availability of energy, and inefficiency of resource utilisation which could directly impact the business continuity and the environmental responsibility of IT departments (Velte et al., 2008). As business and other institutions' demand for large volume of data processing and storage capacity is increasing (Lefurgy et al., 2003; Kant, 2009), the increase is usually associated with an increase in operational cost, energy consumption, resource usage, and environmental footprint of data centre operations (e.g. CO_2 emissions) (EPA, 2007; Schulz, 2009; Zheng and Cai, 2011). Therefore improving operational, economic and environmental sustainability of data centres is very important to ensure the business continuity of data centres (Daim et al., 2009; Smith, 2011). Several consultants, regulatory institutions and researchers have proposed various best practices to help data centres enhance both their operational efficiency and environmental footprint (Greenberg et al., 2006; EPA, 2007; Gartner, 2008; Tschudi et al., 2004). Out of which the use of sensors and SIS was promoted as an effective solution for automating the ICTP and CSSP operations of data centres and improving the operational and energy performance and environmental footprint of data centres (Gartner, 2008; Kant, 2009; European Commission, 2010). The use of sensors and SIS can transform data centres to more economically sound and environmentally friendly facilities.

SIS utilises sensor to automate, inform and/or transform a given task or process or appliance. A number of vendors and laboratory experiments have introduced SIS and SIS enabled best practices for data centres (e.g. Sharma et al., 2005; Liu et al., 2008; Padala et al., 2007; Watson et al., 2009; Liu, and Terzis. 2012).

Despite the opportunities of SIS discussed by these studies for improving the performance of data centre operations which can directly impact the economic and environmental performance, these studies do not inform the extent of actual use of SIS in data centres. This implies that there is a dearth of empirical research about the actual use in data centres. This leads to the following research question:

Research Question 1: *To what extent are SIS assimilated in data centres?*

Second, assimilation as opposed to adoption of technology refers to the acquisition, fruition, full utilisation, and institutionalisation of a technology (Meyer and Goes, 1988). While the adoption of innovation implies the implementation and initial success of a system through using a new ICT (Damanpour, 1991; Agarwal et al., 1997), the assimilation of technologies implies the absorption of a technology into the routines of an organisation or individual. It reflects the 'how' and 'to what extent' a technology is utilised within organisational frameworks. Assimilation therefore helps organisations to leverage the advantages of using information technologies in their business activities and strategies (Armstrong and Sambamurthy, 1999). Previous research on the use of technology has identified a number of antecedents that could influence IS use. These factors have been researched from a technological perspective, organisational perspective (e.g. Roger, 1983), environmental perspective (usually defined in terms of external force) (e.g. Tornatzky and Fleischer, 1990) and institutional perspective (mimetic, coercive and normative forces) (e.g. DiMaggio and Powel, 1983). Empirical IS research has sufficient evidence that shows the influence of one (or more) of these factors on the use and assimilation of IS (e.g. Agarwal et al., 1997; Armstrong and Sambamurthy, 1999; Chatterjee et al., 2002; Hsu et al., 2006; Kouki et al., 2010; Bharati, and Chaudhury, 2012).

Although previous theories and other extended theoretical models (based in grounded theories) can help in studying the antecedent factors that explain the assimilation of SIS in data centres, they might not be adequate to cover emerging issues such as environmental sustainability or to address specific issues particular to data centres. First, there is a lack for a unifying framework in the IS assimilation literature (Aladwani, 2002). Therefore, some argue that future IS research on IT innovation should not merely rely on a single model or theory, rather combining multiple theoretical lenses into a more integrated view (Fichman, 2000).

Second, most of the existing empirical IS research reviewed in Chapter 2 (e.g. Karahanna et al., 1999; Cho and Kim, 2002; Raymond et al., 2005; Liang et al., 2007; Saraf et al., 2012) has employed different innovation theories, such as diffusion of innovation theory (DOI) (Roger, 1983), technology-organisation-environment framework (TOE) (Tornatzky and Fleischer, 1990) and institutional theory (DiMaggio et al., 1983), to study IS assimilation. Furthermore, researchers have extended and redefined the technological, organisational, institutional and environmental factors to account for other factors relevant to their specific research context.

Third, none of the previous studies in IS literature identified in Chapter 2 have specifically investigated SIS assimilation and value in the context of data centres. Because SIS have different features from other IT innovations, it is expected that the conditions of this research context differ from other research contexts. The unique characteristics of data centres and their associated issues are another area that has not been captured in a theoretical sense. In addition, the importance and significance of data centre particulars to IS assimilation has not been validated in IS literature. Therefore, it is important to explore different theoretical lenses from major theories on technology innovation use and value as well as factors relevant to the context of the research in order to identify the factors that influence the assimilation and value of SIS in the context of data centres.

Fourth, the growing importance of environmental sustainability implies that environmental considerations are likely to influence the use or misuse of technology (Hart, 1995; Sharma, 2000; Aragón-Correa, 2000). Therefore, including the dimension of natural environment to understand both the inhibiters and drivers for innovation is required (Chen et al., 2008). Although previous models of IS research on the use of technology refer to 'environmental' contexts (e.g. Tornatzky and Fleischer, 1990), the term was used in a narrow sense to refer to the dynamics of market forces and regulatory pressures rather than the natural environment (Hart, 1997).

Despite the importance of natural environment dimension, this factor has hardly been recognised in IS research (Chen et al., 2008). Due to the shortage for IT innovation theory to investigate the effect of environmental sustainability, the natural resource based view (NRBV) (Hart, 1995) can be a good starting point to study the relationship between environmental sustainability and IS (Chen et al., 2011). Therefore, this study borrows insights from the strategies of NRBV in order to redefine the organisational and environmental context of the research by including the natural environment considerations to study SIS assimilation and value. Thus, neither a single theory nor previous theoretical models of the use of technology adequately informs the use and value of emerging technologies and issues such as SIS in data centres. This needs to be extended.

To the best of our knowledge, there has been neither a model nor empirical research that incorporates the technological, organisational, institutional, and natural environments, and data centre particulars perspectives to study the use of SIS in data centres in Australia and elsewhere. This leads us to the following questions:

Research Question 2: *What is the nomological net of antecedent factors that explain the differences in the assimilation of SIS among data centres?*

Third, data centres can leverage SIS capabilities to improve their operational performance, economic performance and environmental performance. The SIS functionalities within a data centre platform can be classified into ICTP functionalities and CSSP functionalities. Traditionally, data centres have been using sensors for computing thermal management (Baird and Mohseni, 2008), and air-flow and thermal management at facility level (Tschudi et al., 2004). However, the full realisation of SIS functionalities requires SIS use beyond this limited scope. For instance, in order for data centre operators to improve their energy consumption, they would need to go beyond the traditional use of SIS to an extended level of infusion and utilisation such as optimising air performance and management based on change in conditions (Sharma et al., 2004; Liu et al., 2009), and management of computing resources (Padala et al., 2007; Wang et al., 2011). Existing vendor and experimental research shows that wider use of SIS capabilities and functionalities can bring potential value to data centres in operational, economic and environmental terms (e.g. Larkin, 2007; Watson et al., 2009; Liu et al., 2009; Liu and Terzis. 2012). These functionalities can help data centres to improve the visibility of data centres' vast operations, improve workload placement, improve energy efficiency, reduce the cost of running data centres, and CO_2 emissions, and improve compliance to regulatory requirements. Previous IS research on IT value also shows that the conditions by which organisations can observe and harvest business IT value are positively associated with the extent of use and utilisation in actual circumstances (Bharadwaj, 2000; Santhanam and Hartono, 2003; Zhu and Kraemer, 2005; Rai et al., 2009; Setia et al., 2011). Nevertheless, there is a lack of empirical research that has tested the connection between SIS assimilation and its value to data centres. This leads to the following research question:

Research Question 3: *What are the operational and environmental values of SIS assimilation to data centres and what drives those values?*

To answer these questions, the current PhD research proposes and empirically tests an integrated model of SIS assimilation and value.

1.3. Objective of the Study

The aim of this study is to address the gaps in the current literature and address the proposed research questions. In particular, the objectives are to:

1- Explore the current state of SIS applications in the data centres industry.

2- Explore and identify the factors that could influence the SIS assimilation and value.

3- Explicate the features and role of SIS in attaining operational and environmental advantages in data centres context.

4- Extend existing research on IS assimilation and value by integrating different theoretical lens to investigate the IS assimilation and value within the context of data centres.

5- Develop and conceptualise a theoretical model that informs the SIS assimilation and value.

6- Examine, communicate and discuss the theoretical and practical utility of the research model.

1.4. Overview of the Research Methods

The current research is intended to understand both the factors that explain the assimilation of SIS and the operational and environmental value of assimilating SIS in data centres. For this purpose, the study draws from theories that explain technology assimilation including diffusion of innovation theory (DOI) (Roger, 1983), technology-organisation-environment framework (TOE) (Tornatzky and Fleischer, 1990) and institutional theory (DiMaggio et al., 1983) as well as insights from natural environment-based theories such as the natural resource based view (NRBV) model (Hart, 1995). It also draws from theories that help to understand the value of technology in order to link the extent of use with assimilation impact on operational and environmental performance including the resource based view theory (RBV) (Barney, 1991; Peteraf, 1993; Penrose, 1995). Drawing from these theories, an integrative theoretical framework, which we call as TOIN (Technology, Organisation, Institutional and Natural Environment), was proposed to investigate the factors that explain the variation in the assimilation of SIS and the impact of SIS use on data centre's operational and environmental performance. A series of hypotheses are developed by linking the TOIN factors to SIS assimilation and value in a two order-based model.

This study was grounded in the positivistic research paradigm (Orlikowski and Baroudi, 1991). In light of this, the deductive strategy is adopted (Collin and Hussey, 2003) and served as the basis of the research strategy. This strategy requires the development of research hypotheses based on general observations derived from published literature and precedent theoretical frameworks, and then designing a method to test them. Due to the lack of knowledge in the area of research context, the research was conducted in two phases; an exploratory pilot study (qualitative) and a main study (quantitative) (Creswell, 1994).

The objective of the pilot study was to enhance the researcher's understanding about the current state of SIS application in data centres, what shape the use of SIS, and how data centre context would influence SIS assimilation. The pilot study followed an exploratory strategy using case study approach (Yin, 2003). It focused on conducting in-depth semi-structured interviews with five data centre managers from Australia. In the event where there is little much known about a particular phenomenon, the case study approach is advocated as one of the preferred methods to gather evidence and to obtain adequate understanding about the phenomenon (Eisenhardt 1989; Yin, 2003).

The main study used an online survey as its main strategy. A global sample of data centres was drawn from a reputable professional online database (www.LinkedIn.com). The targeted population comprised of data centre managers. Data were collected from the managers of 243 different data centres. The quantitative data (survey) was analysed to investigate and validate the research questions and empirically test the research model (Harrison and Tamaschke, 1993). Descriptive and analytic statistical methods (Exploratory Factor Analysis and Partial Least Square Path modelling) and statistical software packages (SPSS, SmartPLS) were used for data analysis. The results were interpreted and research conclusions made. Figure 1.1. shows the major phases followed in the current study based on the adopted research methodology.

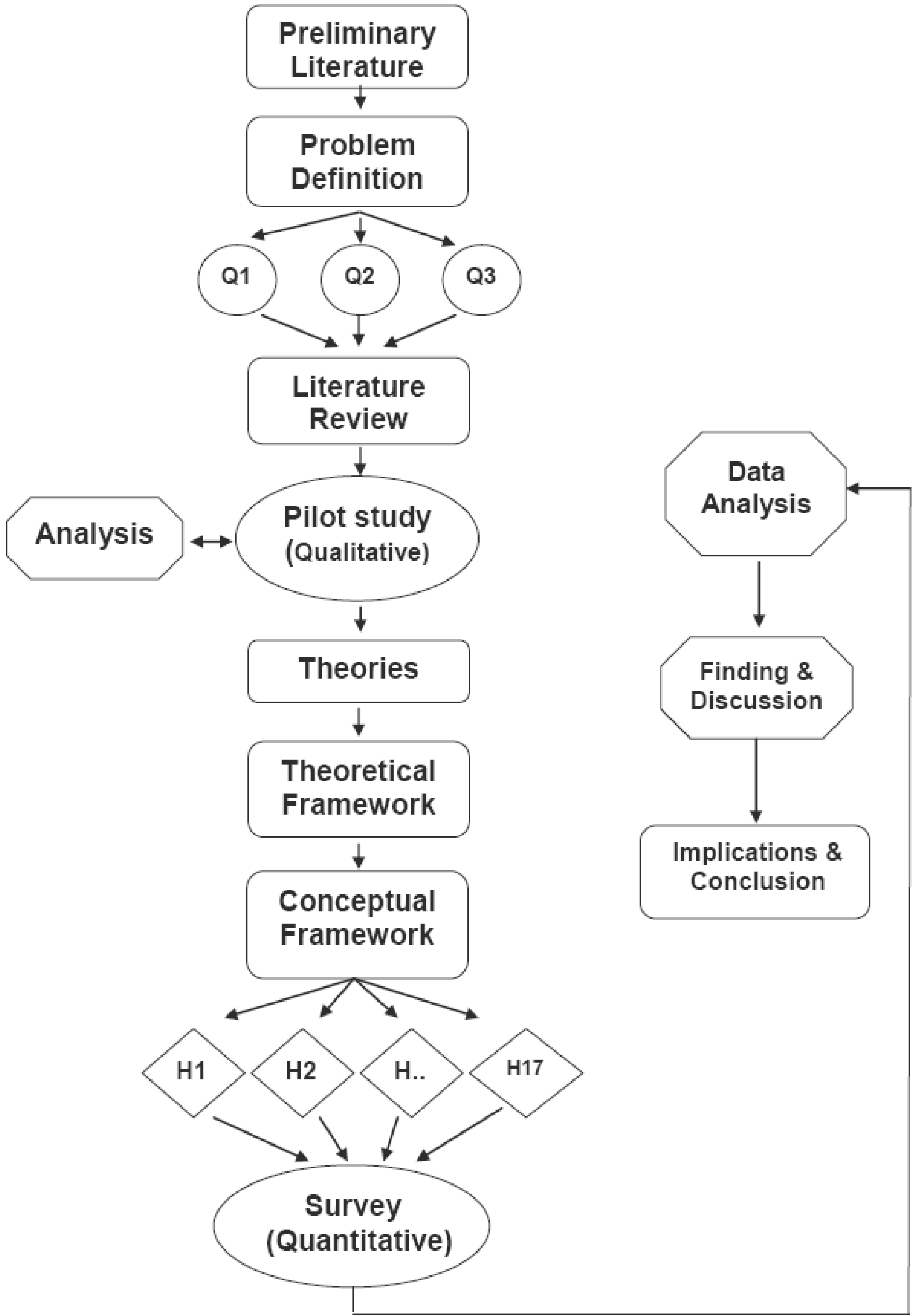

Figure 1.1: Research diagram

1.5. Contribution

The main contribution of this study lies in bridging the research gaps found in the literature by exploring, developing and testing an integrative model of SIS assimilation and value that measures the extent of SIS usage as well as the how SIS usage impact the operational and environmental performance of data centres.

The current research represents one of the first studies on the use and value of SIS in general and in the context of data centre environment in particular. It makes an original contribution by proposing and validating the TOIN framework which can be used as a theoretical foundation for future and related studies. It also contributes original knowledge regarding how data centres are using information systems that are integrated with sensors to tackle some of the operational, economic and environmental challenges. Thus, the research adds to the body of knowledge on intelligent systems, infrastructure management and automation, green IS and energy informatics. In addition, most of the existing research on SIS application in data centres focuses on developing and testing SIS designs in an experimental or simulated environment. Thus, the study extends those works by exploring the actual usage and highlighting some of the factors that influence the use of innovation in data centres using an empirical sample. Moreover, the research extends the current innovation theories by incorporating the natural environment to study the technology use and value and shows the significance of natural environment and sustainability considerations on organisations' activities as well as on the extent of IS use and value. This adds to the body of knowledge on the role of natural environment and sustainability on technology innovation.

Data centre and IT managers can benefit from the results of the study in identifying and nurturing the critical factors that facilitate successful assimilation and exploitation of SIS. Furthermore, the finding of the study can be used by designers and developers to improve some of the engineering aspects of data centres in respect to issues regarding sensors integration as well as hardware/software compatibility.

1.6. Organisation of the Thesis

The organisation and structure of this research is depicted in Figure 1.2. The current PhD thesis consists of ten chapters, including this chapter. The remaining chapters are as follows. Firstly, as the study investigates the assimilation and value of SIS within the context of data centres, chapter 2 begins the discussion by providing background and literature covering four areas: IT and sustainability, data centres, sensors technology, and technology assimilation and value. Due to the lack of knowledge about the research phenomenon, chapter 3 reports the findings of an exploratory case study of five Australian data centres. This is followed by chapter 4 that consists of three sections: theoretical foundation, theoretical framework of SIS assimilation and value, and hypothesis development. The research utilises a rigorous research methodology that is being discussed in chapter 5. Chapter 6 consists of two sections: the preparation of data for statistical evaluation and the descriptive statistics. The validation and assessment of measurement model is presented in chapter 7. This is followed by chapter 8 where the research employs a number of measures to analyse the structural model and test the research hypotheses. Finally, the research findings are discussed in chapter 9 and followed by theoretical and practical contribution, limitation, future research and conclusion remarks in the last chapter.

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Chapter 10: SUMMARY AND CONCLUSION

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Figure 1.2: Overview of thesis structure

1.7. Summary

The introduction chapter provided a starting point to understand the background, questions, objective and the motivation behind the questions of this study. In short, while the use of SIS can help data centres to overcome some contemporary issues regarding operation and environmental performance, the actual role of SIS in this regard is still an under-researched phenomenon. This study employs different techniques to answer the questions raised in the current research. The study builds on traditional innovation use models, innovation value models and natural environment models to understand the antecedent factors to the SIS assimilation and value. The study also uses findings from five case studies to further understand the specific factors relating to the research phenomenon. Finally, the chapter concludes with an outline of the thesis sections.

CHAPTER 2

2. LITERATURE REVIEW

2.1. Introduction

This chapter provides a literature review of the areas relevant to the research context. The literature review is organised as follows. Firstly, sustainability and its relationship with information technology are discussed (2.2), with a focus on demonstrating how the two areas of data centres and sensor information systems can reflect the negative and positive side effects of IT on sustainability. Secondly, the nature of data centre operation and their environmental and economic impact are also discussed (2.3), to review current and future considerations relevant to data centre businesses in a global context. This is followed by a review of the fundamental features, roles and capabilities of sensors (2.4) and sensor information systems, to illustrate the many advantages of SIS, and how they can be used to resolve most of today's organisational needs. Next (2.5), a review of the literature on the applications and utilisation of sensor information systems and on the current research within the context of data centres is presented (2.6). The aim is to demonstrate how SIS can be used to enhance data centre performance and sustainability. Finally, technology assimilation and assimilation value are reviewed (2.7) to address the gap identified in the literature; that is, the need for a theoretical framework to understand the extent of SIS use in data centres and the impact of SIS on data centre performance. Figure 2.1 illustrates the structure of the review.

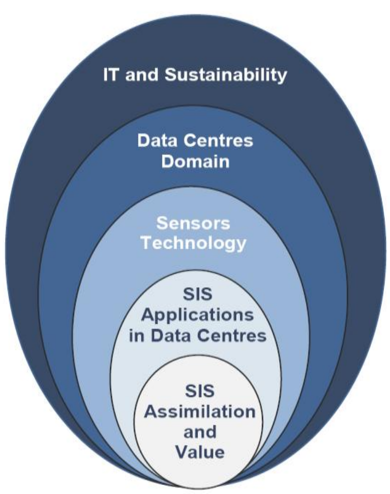


Figure 2.1: The flow of the literature discussion

2.2. Information Technology and Sustainability

The purpose of this section is to provide an introduction to sustainability and its interaction with information technology and information systems. This is relevant because the dual effects (negative and positive) of IT on sustainability can be observed in the two main areas of focus for this thesis; that is, sensor information systems and data centres. This section also establishes the position of the current study is relation to the emerging research on IT and IS and sustainability.

Sustainability is a broad concept. In its 1987 report (the Brundtland report), the World Commission on Environment and Development (WECD) defined sustainability as something 'that meets the needs of the present generation without compromising the ability of future generations to meet their own needs' (Brundtland, 1987: p. 43). In other words, the present generations have an obligation to pay more attention to how they meet their needs, to allow future generations an equal right to satisfy their needs (Pearce et al., 1989). Hamm and Mutagi (1998: p. 2) further explain sustainability as 'a capacity of human beings to continuously adapt to their non-human environments by means of social organization'.

This implies that sustainability can be approached from the economic, environmental and social dimensions (Elkington, 1997; Searcy et al., 2008). In the business context, economic sustainability refers to the capability of an organisation to secure its long-term economic performance through maximising shareholder's returns. Environmental sustainability is about the ability of an organisation to use natural resources to meet its current needs without compromising its future needs and the needs of other organisations. Social sustainability refers to an organisation's responsibility and commitment with respect to its obligations to communities and society. These three dimensions are interlinked and improving one will have a direct impact on the others. For example, in the Cosmic Interdependence model of sustainable development, economic and social systems are seen as part of the natural universe (Mebratu, 1998). Therefore, the model postulates that these systems provide an integrative view of sustainability. Another framework, Daly's Triangle, has reordered the three elements of sustainability and their interrelationship (Daly, 1973), placing the environment at the foundation of the triangle. This model implies that society's survival is determined by the environment's health. Moreover, it defines economy and technology as serving as a vehicle or intermediate means to achieve the ultimate end—the health of the natural environment.

Within the three dimensions of sustainability, the current study, and this section primarily, focuses on environmental sustainability and its relationship with information technology. Information technology can have a considerable impact on the natural environmental and sustainability (Lamb, 2009). Nevertheless, since environmental sustainability is inseparable from economic sustainability (Schulz, 2009), especially in the context of data centres, the research will also consider the economic dimension of sustainability. Thus, most of the embedded thoughts found in the discussion of this study regarding the role of SIS within the data centre context are inspired by economic and environmental sustainability drivers. In the remainder of this section, a review of the literature on information systems and technologies and sustainability is presented.

The role of information systems and information technology for improving the sustainability of business operations is in attracting the attention of policy makers, practitioners and researchers (Melville, 2010; Dedrick, 2010). In general, IT and IS have multifaceted effects upon sustainability. The use of IS and IT lead to positive economic, environmental and social gains. These include profit maximisation, automation, dematerialisation and virtualisation, and social responsibility enhancement (Berkhout and Hertin, 2004). However, IT and IS also lead to some unintended side effects, including large operation costs, energy consumption, electronic waste and social value degradation (Köhler and Erdmann, 2004; Searcy et al., 2008; Lamb, 2009). The negative side effects of IT, coupled with business's increased dependency on IT and IS, have elevated the importance of sustainable IT and IS management in modern organisations. Sustainable IT and IS management is regarded as one of the strategies that offers opportunities to develop IT and IS solutions that are economically, environmentally and socially sustainable (Berkhout and Hertin, 2004; Lamb, 2009; Schulz, 2009).

In the literature on the role of IS and IT and sustainability, two streams of research have emerged: Green IT (Murugesan, 2008; Molla et al., 2008; Dedrick, 2010) and Green IS (Melville, 2010; Dedrick, 2010; Chen et al., 2011; Bengtsson and Agerfalk, 2011). Murugesan (2008: p. 25) defines Green IT as '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'. Green IS is defined as the use of information systems to help organisations to develop ecological sustainability through automating, informating and transforming products, business processes, business relationships and practices (Chen et al., 2008). In short, Green IT is concerned more with the reduction of environmental impacts of the use of IT (Dedrick, 2010). Conversely, Green IS is concerned with the use of IS to achieve environmental objectives and economic performance (Melville, 2010).

Table 2.1: A synthesis of the Green IT and Green IS literature

Authors	**Green IT**	**Green IS**	**Review and research direction**	**Adoption and use**	**Value**	**Method**
Bengtsson and Agerfalk, 2011		X		X		Case study
Bose and Luo, 2011	X			X		Conceptual
Butler, 2011		X		X		Case study
Capra et al., 2012	X			X		Metadata analysis
Chen et al 2011	X	X		X		Survey
Corbett, 2010	X				X	Literature review
Dao et al, 2011	X				X	Conceptual
Dedrick 2010		X	X			Review
Elliot, 2011	X	X	X			Conceptual
Jenkin et al., 2011		X	X			Conceptual
Karanasios et al., 2010	X			X		Case study
Loock et al., 2011		X		X		Survey
Melville , 2010	X	X	X			Review
Mithas et al., 2010	X			X	X	Survey
Molla and Abrashie, 2012	X			X		Survey
Molla et al 2008	X			X		Conceptual
Molla et al. 2009	X			X		Survey
Murugesan 2008	X		X			Review
Nishant et al., 2011	X				X	Panel data
Schmidt et l., 2011					X	Survey
Watson et al. 2010		X	X			Review

The Green IT and Green IS streams are rooted in the perceived difference between the definitions of IT and IS (Molla and Abreshie, 2012; Dedrick, 2010, Chen et al., 2011). Generally, IT is a broad concept that refers to hardware and software such as servers, networks, hard drives, monitors and the associated operating systems. IS refers to systems or computer software used to create, collect, store, manipulate or distribute information, and their output can be termed as information. A number of Green IT and Green IS practices and technologies have been investigated. For example, in terms of Green IT, some have studied the adoption of Green IT (Molla and Abreshie, 2012), the adoption of data centre green practice (Karanasios et al., 2010) and the contribution of Green IT to firms' performance (Schmidt et al., 2011). In terms of Green IS, research has focused on the use of IS for sustainability (Jenkin et al., 2011), IS as energy informatics (Watson et al., 2010) and IS investment and impact on carbon productivity (Dedrick, 2010).

A review of both the Green IT and Green IS literature identified that three major themes dominate the research: (a) review and research direction; (b) adoption and use; and (c) value of Green IS and Green IT. Table 2.1 provides a summary synthesis of the literature, to be followed by detailed discussion.

2.2.1. Review and Research Directions

Green IT and Green IS are emerging areas of research in the contemporary IS literature (Watson et al., 2010; Melville, 2010). As a result, a number of researchers have proposed frameworks that define agenda and questions to guide the research in these emerging areas. Chief among them are energy informatics (Watson et al., 2010); carbon productivity (Dedrick, 2010); Belief–Action–Outcome (Melville, 2010); IT-enabled transformation (Elliot, 2011) and a multi-level framework for IS and sustainability (Jenkin et al., 2011). The focus of these studies is on encouraging research to enable transformation to sustainable processes and practices in organisations, with the ultimate objective of improving organisations' technological, economic and/or environmental performance.

The energy informatics framework helps to answer questions regarding sensor networks, flow networks, information systems and sensitised objects that can drive research concerning reducing the energy consumption of societies (Watson et al., 2010). The carbon productivity framework helps researchers to understand questions regarding the potential impacts or the role of IT in increasing carbon productivity (Dedrick, 2010). The Belief–Action–Outcome framework offers questions for future research about the philosophical perspective, theory, research methodology and data sources and questions on belief formation, action and outcome (Melville, 2010).

Another framework for IT-enabled business transformation was developed to address key issues and questions about the role of environmental sustainability and its major challenges (Elliot, 2011). The multi-level framework for environmentally sustainable IT and IS provides several theoretical propositions and suggestions for future research in the area of Green IT and Green IS, including environmental sustainability motivating forces, environmental sustainability initiatives, environmental orientation and environmental impacts (Jenkin et al., 2011).

The above studies have proposed a number of valuable questions that need to be answered. The current study is concerned with how and to what extent SIS use (which is an IS that is based on sensor technology) can improve the operational and environmental performance of data centres. Therefore, it is related to the potential role of sensor technology and energy informatics (for example, SIS) in sustainability (Watson et al., 2010), and the role of IS in improving sustainability (Melville, 2010). Since the focus of the current study is on the antecedents and consequences of SIS use, the next section reviews the literature on Green IT and Green IS adoption and use.

2.2.2. Green IS and Green IT Adoption and Use

Adoption and use studies are very common in the IS literature. Likewise, Green IT and Green IS adoption and use studies are receiving a great deal of attention. Some researchers have suggested conceptual frameworks to study the factors that affect the adoption and use of Green IT and Green IS (Molla, 2008; Karanasios et al., 2010; Bose and Luo, 2011). Others have reported either case or survey evidence on what influences the adoption of Green IS and Green IT (Chen et al., 2011; Molla and Abrashie, 2012). These studies explain either theoretically or empirically, or both, the variations in adoption and use and the relationships between adoption and use and other technological, organisational, environmental and institutional antecedent factors. Different methods were employed to serve the purposes of these studies including systematic literature (Bose and Luo, 2011), cases studies (for example, Karanasios et al., 2010; Bengtsson and Agerfalk, 2011) and survey (for example, Schmidt et al., 2010; Chen et al., 2011; Molla and Abrashie, 2012).

In respect to those that have developed theoretical frameworks, Molla (2008) proposed a Green IT Acceptance Model to predict the intention and the breadth and depth of Green IT adoption (Molla, 2008). Karanasios et al. (2010) suggested a case study-derived conceptual framework and set of propositions to investigate the adoption of green data centre best practices. Yet other studies have identified criteria for a firm's readiness to go green (Bose and Luo, 2011), and explored the use of Green IS in supporting sense making, decision making and knowledge creation around environmental sustainability (Butler, 2011).

A number of researchers have empirically investigated the antecedents to Green IT and Green IS adoption and use, including Green IT readiness (Molla et al., 2009); institutional factors that influence the adoption of Green IS (Chen et al., 2011); Green IT implementation in organisations and impact on energy conservation and profit (Mithas et al., 2010); motivational factors that influence Green IT and IT for Green adoption (Molla and Abrashie, 2012); and the use of application software within the energy efficiency context (Capra et al., 2012). The findings of these studies indicate that using virtualisation and green data centre best practices and policies to improve the energy performance of data centres is an important dimension of Green IT (Karanasios et al., 2010; Molla and Abrashie, 2012). Some key reasons for undertaking a Green IT initiative include the rising cost of energy and waste disposal, the importance of corporate image and public perceptions, and the enactment of environmental legislation (Molla et al., 2009). Corporate environmental responsibility, cost cutting, energy conservation and pressure from market forces are also important motivators (Molla and Abrashie, 2012). The size of an information management system or application and its functionality range can affect its level of energy efficiency (Capra et al., 2012). Within an organisation, top management commitment influences the perceived importance of Green IT, while, in turn, the perceived importance of Green IT influences the portion of overall IT spending invested in Green IT (Mithas et al., 2010). In addition, coercive and normative institutional forces and their interaction have influenced the adoption of policies to install software for pollution prevention, product stewardship and sustainable development (Chen et al., 2011).

In terms of theoretical foundation, most of the adoption and use theoretical and empirical studies borrow insights from Green IT and Green IS frameworks and from the Technology Organisation and Environment (TOE) framework (Molla, 2008), institutional theory (Chen et al., 2011; Butler, 2011), Belief–Action–Outcome theory (Mithas et al., 2010) and motivation theory (Molla and Abrashie, 2012). Further, some have developed integrative frameworks based on different theoretical lenses, including TOE, Diffusion of Innovation (DOI) and process-virtualisation, to investigate the antecedents to the assessment of a firm's readiness to go green (Bose and Luo, 2011) and the motivation, ability and expectancy to investigate green data centre best practice adoption (Karanasios et al., 2010).

The above literature regarding the adoption and use of Green IT and Green IS shows that both the case study approach and the survey-based approach have been employed successfully to develop and test the adoption and use models. In addition, different theoretical lenses such as those of DOI, TOE and institutional theory have been used, either individually or as an integrative framework, in studying the factors that influence the adoption and use of Green IT and Green IS. This suggests that the use of the case study approach to build a theoretical model relating to the adoption and use of Green IT and Green IS, and testing the same through a survey, can be applied to studies of emerging systems relating to Green IS; for example, SIS. Further, such a study needs to be approached from a theoretically eclectic vantage point. To gain a better understanding about the actual impact of Green IT and Green IS, researchers have also explored the value of Green IT and Green IS investments. The development of conceptual frameworks to model the Green IT and Green IS value and allow empirical tests of Green IT and Green IS impact is as important as adoption and use. Therefore, the next section reports the review of the literature on the benefits of Green IT and Green IS.

2.2.3. Value of Green IS and Green IT

Green IT and Green IS can potentially improve technological, economic and environmental performance (Melville, 2010; Dedrick, 2010). The opportunities underlying Green IT and Green IS have attracted organisations due to their capabilities to create sustainable values for stakeholders and help them gain competitive advantage (Molla and Abrashie, 2012). Green IT and Green IS can also have a positive impact on the productivity and economic growth of an organisation through IT-enabled management practices (Dedrick, 2010). To uncover these benefits, a few studies have explored and discussed the potential value of Green IS (Corbett, 2010), developed a model for value creation (Dao et al., 2011), and investigated the value empirically (Mithas et al., 2010; Nishant et al., 2011; Schmidt et al., 2011).

Concerning the potential value of Green IS and Green IT, Corbett (2010) explored the concept of Green IT value by reviewing the practical literature on Green IT and drawing on the Natural Resources-Based View (NRBV) and environmental embeddedness to develop several theoretical propositions. Conversely, Bengtsson and Agerfalk (2011) used the case study approach to explore the role of IS as a tool for improving sustainability indicators and routines. Dao et al. (2011) developed a framework that highlights how the integration of human resources, supply chain resources and IT resources allows organisations to develop sustainability capabilities.

In respect to those studies that have tested the value of Green IS empirically, it was observed that Green IT contributes to efficient internal operations, reputational management and market competitiveness (Schmidt et al., 2011). These factors play a major role in Green IT and provide more understanding about the implementation of Green IT along the value chain of IT departments. Other studies have shown how Green IT announcements affect firms' stock price performance (Nishant et al., 2011). In this way, it has been shown that Green IT initiatives can positively enhance the financial performance of a firm.

The value of Green IT and Green IS was studied based on the Resource-Based View (RBV), to investigate the financial impact of the announcement of Green IT initiatives by a firm on that firm's market value (Nishant et al., 2011) and show how organisations develop sustainability capabilities (Dao et al., 2011). In addition, the NRBV was used to understand a firm's reasoning behind the choice of Green IT, and how investments in Green IT can realise value (Corbett, 2010). For example, Corbett (2010) found that the use of information to support decision making as one of the four identified green IT types was associated with all the three environmental strategies proposed under the NRBV. Two green IT types were associated with pollution prevention strategies and one was linked to product stewardship.

As such, she contended that an organisation's decision to invest in green IT that supports product stewardship would likely be determined by the organisation's previous investment in green IT in an effort to reduce pollution. As to the value realisation, she argues that achieving greater value from green IT investments is closely linked to the firm's ability to reconcile multiple stakeholders' diverse interests and its willingness to demonstrate a shared vision. The Green IT and Green IS value literature implies that several potential, and unexplored, advantages may underlie the application of Green IS for improving the sustainability of IT. Further, the literature also shows that the RBV and NRBV are useful theoretical frameworks to study and investigate the value of Green IT and Green IS.

The review of the literature on IT and IS and sustainability has identified two emerging streams of research: Green IT and Green IS. In both Green IT and Green IS areas, researchers have defined several research agendas. They have also explored the technological, organisational, motivational, institutional and ecological factors that affect organisations in their adoption and use of Green IS and Green IT. A number of technologies, policies and practices have been defined as Green IS and Green IT, and their operational, market and environmental values explored. Further, most studies have investigated either Green IT or Green IS in isolation; few, if any, have studied the impact of Green IS on Green IT. To fill this gap, the current research endeavours to show how Green IS can be used to achieve Green IT.

The review also shows that while a number of studies have touched on data centre-related issues as part of the wider Green IT and Green IS discussion, only a few have specifically focused on data centres and SIS. Data centres and SIS are areas in which the role of IS for sustainability can be observed, and this is of particular interest in this research. SIS and data centres are good examples through which to explore the positive impact of IS on making IT sustainable. In the following sections, the literature on data centres will be reviewed, which will be followed by a review of the sensor and SIS literature.

2.3. Data Centres

The demand for computing resources, data processing and information systems by businesses and institutions is increasing (Lefurgy et al., 2003). This has led to the need for larger fault-tolerant systems, capable of meeting the growing demand and handling large volumes of data processing and storage (Loper and Parr, 2007). This increasing demand for IT support has resulted in the growth of data centres in terms of volume and size. A typical data centre houses the ICT infrastructure of an organisation; supplies the informational needs of either its own or client institutions; provides digital data processing, storage and exchange services; and needs to ensure reliable power, trustworthy security and continuous connectivity via a high-capacity backbone (Tschudi et al., 2004; Brill, 2007; Schulz, 2009).

Data centres typically comprise two major platforms: the Information and Communication Technology Platform (ICTP) and the Critical Site Support Platform (CSSP) (Uptime Institute, 2000; Brill, 2007). The ICTP is a dense IT zone that includes servers (for example, servers, blade servers), network equipment (for example, routers, mainframe, switches), storage devices (for example, tapes, NAS) and other auxiliary equipment (Fan et al., 2007). Therefore, allotting ICTP elements within a data centre in regards to physical layout requirements and the ICT systems' performance and efficiency is very important.

The CSSP comprises equipment that supplies cooling and power to the core ICT equipment and the facility equipment (for example, lighting, security). The CSSP includes diverse equipment and systems that provide electric power, lighting, cooling and heat management and other requirements that facilitate the work of data centre professionals and technicians. The CSSP is very important for safeguarding the operations of the ICTP (Schulz, 2009). For instance, critical power equipment, uninterruptible power supply (UPS) systems and batteries, power transformers and load distribution panels work in a consistent manner to control, manage and supply electric power to the ICTP infrastructure during ordinary and emergency working situations. Cooling systems, such as Computer Room Air Conditioner (CRAC) units and water-chillers, are also essential to control and manage the data centre work environment (Greenberg et al., 2006). These systems help to maintain appropriate temperature and humidity levels for the ICTP infrastructure operation.

Table 2.2: A synthesis of research on data centres

Authors	Stream		Research Category				Method
	CSSP	ICTP	Operational	Environmental	Innovations	Factors	
Abts, and Felderman, 2012		X	X				Review
Almoli et al., 2012	X		X		X		Experimental
Beloglazov et al., 2012		X		X	X		Experimental
Brill 2007	X	X	X	X		X	Review
Chase et al , 2001		X	X		X		Experimental
Chen and Wang, 2009	X	X	X				Case study
Chen et al., 2005		X	X		X		Experimental
Chu, et al., 2004	X	X	X			X	Review
Daim et al., 2009	X	X		X	X		Case study
Femal and Freeh, 2005		X	X		X		Experimental
Garbin and Chang, 2009	X	X		X			Review
Greenberg et al., 2006	X		X				Review
Kant, 2009	X	X	X				Review
Krauter et al. 2002		X	X		X		Review
Lefurgy et al., 2003		X	X	X		X	Review
Loper and Parr, 2007	X	X		X		X	Review
Mukherjee, et al., 2010	X	X	X		X	X	Experimental
Nguyen et al., 2012		X	X	X			Experimental
Pan et al., 2008	X			X			Experimental
Raghavendra et al 2008		X	X		X	X	Experimental
Shah and Krishnan, 2008		X	X	X			Case study
Sharma et al., 2005	X	X	X		X	X	Experimental
Shi and Srivastava, 2011		X	X		X		Experimental
Smith, 2011	X	X		X			Case study
Sun and Lee, 2006	X	X		X			Case study
Tschudi et al.,, 2004	X	X	X			X	Review
Yoshino, et al., 2011		X	X	X	X		Experimental
Zheng and Cai, 2011		X	X		X	X	Experimental
Zimmermann et al., 2012	X	X		X	X		Experimental

The increase in the global demand on data centres poses some challenges for data centre owners and managers (Schulz, 2009; Kant, 2009; Smith, 2011). The operations of the ICTP are at the heart of data centre inefficiency (Shah and Krishnan, 2008; Kant, 2009;

Beloglazov et al., 2012). The performance of ICTP infrastructure directly accounts for roughly 50 per cent of data centre energy inefficiency (servers 36 per cent, network 4 per cent and storage 10 per cent of total energy consumption) and IT resource use inefficiency (Rasmussen, 2009). ICTP infrastructure performance also accounts indirectly for at least part of the remaining 50 per cent of CSSP operation, which is designed to provide support for ICTP operations (Schulz, 2009). Therefore, improving the operational and environmental performance of both the ICTP and the CSSP is at the forefront of the agenda of data centre managers, industry institutions, regulators, developers and researchers.

A number of practices, methods and technologies can be employed to improve the operational and environmental performance of data centres (Baird and Mohseni, 2008; Siddiqui and Fahringer, 2010). However, understanding how new technologies, techniques or designs can help to improve the performance of data centres and the factors that could affect the ability of data centres to adopt and use these innovations is relevant to the current study. Therefore, this section reviews the data centre literature. The review focuses on (a) operational performance; (b) environmental performance; (c) innovations used to improve operational and environmental performance; and (d) factors that could affect the adoption and use of these innovations. Table 2.2 provides a summary of the literature reviewed across these four areas.

2.3.1. Data Centre Operational Performance

The operational performance of data centres was of high interest to the majority of researchers in the data centre literature. The operational performance of data centres includes the cooling and thermal performance (for example, Almoli et al., 2012), and power and energy performance (for example, Raghavendra et al., 2008) of the CSSP, and the information processing performance of the ICTP (for example, Chen et al., 2005). Energy in the context of data centres has two sides: the operational side of energy, which covers cost of energy usage; and the environmental side, which covers energy consumption and related issues.

Cooling and thermal performance reflects how much energy a data centre is consuming to maintain a desired room temperature, the cost of operating cooling systems, and whether the cooling capacity is in line with real cooling needs. Effective cooling and air distribution systems are vital for improving energy efficiency and equipment reliability in data centres (Yoshino et al., 2011; Almoli et al., 2012). Some areas of a data centre generate more heat than do others; and some areas can tolerate heat more than others can because of the nature of their workload and resources (Sharma et al., 2005; Almoli et al., 2012). Cooling and thermal performance is therefore concerned with temperature, air distribution and circulation matching the heat loads of data centres, as well as with thermal mapping (Sharma et al., 2005; Loper and Parr, 2007).

Power and energy performance reflects how much power is consumed by data centres, the consumption per devise or application, and the total cost of energy consumed. Power and energy is an essential resource without which data centres cannot operate. Effective power management requires the establishment of procedures to ensure consistent delivery of power to the data centre infrastructure at a steady load, as well as methods for power measurement (Raghavendra et al., 2008; Kant, 2009). To ensure consistent delivery, UPS units are adopted in every data centre (positioned between IT equipment and the main power supply) for the purpose of power conversion (AC to DC), providing a temporary power source (in case of power blockage, to prevent costly business interruptions), and protecting sensitive loads (for example, servers and critical electronic equipment) from power disturbances and turbulence that may affect their operation or service life (Tschudi et al., 2004; Kant, 2009). The process of electric power conversion (from AC to DC and back) at UPS systems results in large energy losses (Greenberg et al., 2006). This can cause power inefficiency. Power and energy performance is therefore concerned with the effective distribution of the power grid within the data centres, and with reducing energy loss during power delivery and the power conversion process (Greenberg et al., 2006; Kant, 2009).

Information processing performance is concerned with achieving the objectives of availability, agility and scalability, while also using IT equipment and server capacity effectively (Krauter et al., 2002; Kant, 2009; DCUG, 2010; Nguyen et al., 2012). This can be approached through effective computing management, virtualisation and cloud computing. However, the increased rate of information exchange in modern societies has resulted in an increased demand for data processing, sharing and storage by governments, businesses and institutions to support their core or logistic operations (Lefurgy et al., 2003;

Zheng and Cai, 2011). For the sustainability of their business, data centres demand scalable and available infrastructure on a 24-hour basis, agile and flexible systems, and better resource utilisation (Kant, 2009; Shi and Srivastava, 2011; Nguyen et al., 2012). For example, data centres aim to hold surplus capacity to maintain their availability, agility and scalability; to increase their computing performance; to meet future demands; and to demonstrate their capabilities to their customers. This leads to the inefficient utilisation of computing capacity and a waste of energy. For instance, a study conducted by the Hewlett-Packard Lab of six corporate data centres revealed that most of the 1,000 servers investigated were operating at only 10 to 25 per cent of their capacity (Andrzejak et al., 2002).

Operational performance is measured through various metrics that consider energy. Such metrics, as proposed by researchers and institutions, include Power Usage Effectiveness (PUE), Data Centre Efficiency (DCiE), Data Centre Productivity (DCP) (Schulz, 2009), and Data Centre Performance Per Energy (DPPE) (Shiino, 2009). For example, PUE measures the facility's efficiency via total facility energy consumption divided by the total IT equipment energy consumption. However, such a method ignores the efficiency of the remaining part of the data centre platform, such as Heating, Ventilation and Air Conditioning (HVAC). DCiE addresses this limitation by including HVAC efficiency. Meanwhile, while DCP measures the energy per active or useful work, DPPE incorporates IT equipment usage, IT equipment energy efficiency, facility energy efficiency and a green energy coefficient (Shiino, 2009). All of these metrics contribute to the overall effort made to measure the operational performance of data centres.

Data centre operational performance has implications for their environmental performance. This is the subject taken up in the following subsection.

2.3.2. Data Centre Environmental Performance

A data centre's environmental performance includes the efficiency of its energy consumption and associated carbon emission (EPA, 2007; Loper and Parr, 2007), its water efficiency (Chu et al., 2004; Koulos, 2010) and the amount of e-waste it generates (Köhler and Erdmann, 2004; Garbin and Chang, 2009). Despite the wide coverage of data centre literature on energy and carbon, water consumption and e-waste have received less research attention (Chu et al., 2004; Cockrell, 2012; Garbin and Chang, 2009).

Increased energy consumption is one of the challenges faced by data centre businesses (Daim et al., 2009). The large amounts of energy used in data centres are due to the high electricity requirements of the ICTP (which roughly accounts for 55 per cent of total energy consumption), and the CSSP (which roughly accounts for 45 per cent of total energy consumption) (Uptime Institute, 2000). As a result of both data centre growth and the inefficiencies in data centres, the amount of electricity they consume has attracted the attention of global regulatory institutions (for example, EPA, 2007). For instance, global reports show that data centres account for approximately 1.1 to 1.5 per cent of total global energy use, with this figure estimated to double in the next 10 years (Koomey, 2011). The source of energy also adds another dimension to the energy problem (Velte et al., 2008). For example, a 2007/08 report shows that 95 per cent of energy consumption in Australia comes from non-renewable resources (Schultz, 2009). This means that the higher the energy consumption in data centres, the greater the exhaustion of non-renewable natural resources.

While the economic aspect, such as the cost of energy in running data centres and the rise in energy prices, attracts the attention of most data centre studies (for example, Zheng and Cai, 2011; Smith, 2011), regulatory institutions and other researchers place more emphasis on the environmental aspect (for example, EPA, 2007; Loper and Parr, 2007; Nguyen et al., 2012). This latter focus centres on the issue of emission of CO_2 into the atmosphere, which causes Green House Gas (GHG)—a major climate change problem (Velte et al., 2008). The growing concern about data centre energy consumption has resulted in some green initiatives (for example, the US Environmental Protection Agency's [EPA] initiative regarding the energy consumption in data centres, and the European Code of Conduct on Data Centres Energy Efficiency) (Mullins, 2006; European Commission, 2010). These initiatives and industry codes aim to regulate and improve the environmental footprint of data centres.

Few researchers have focused their attention on the water consumption of data centres (see, as exceptions, Chu et al., 2004, Koulos, 2010; Cockrell, 2012). The concern about potential water consumption problems in data centres is associated with their employment of new cooling techniques such as liquid cooling and free cooling (Chu et al., 2004). For instance, although direct fresh air cooling is considered the most energy efficient of the cooling systems, it still consumes considerable amounts of water (Koulos, 2010). This is therefore a matter of considerable importance, warranting further study.

As large computing farms, data centres also produce significant quantities of electronic waste (Garbin and Chang, 2009), which comprises hazardous substances. However, despite this, e-waste is another dimension of the environmental problems of data centres that has attracted little interest from researchers investigating the environmental impact of data centres (Köhler and Erdmann, 2004; Garbin and Chang, 2009). Thus, this is another issue that requires further investigation, as well as risk assessment to gain a better understanding of the actual impact of data centre e-waste on the natural environment (Garbin and Chang, 2009).

In response to the operational and environmental performance issues, data centres are adopting innovations. Likewise, IS and other researchers have shown growing interest in studies that focus on the adoption and use of innovations in data centres. The following section offers a review of this area of the literature.

2.3.3. Innovations to Improve Data Centre Operational and Environmental Performance

To improve the performance of data centres, several consultants, regulatory institutions and researchers have proposed various practices, some labelled as ‘best practices’, to help data centres enhance both the operational efficiency and environmental footprint of data centre business functions (Beck, 2001; Tschudi et al., 2004; Greenberg et al., 2006; EPA, 2007; Gartner, 2008; Brill and Stanley, 2008; European Commission, 2010). These best practices are designed to improve the efficiency of ICTP and CSSP operations and to ensure the availability/uptime, security, agility, scalability and sustainability of data centres (DCUG, 2010; Tschudi et al., 2004; Greenberg et al., 2006; Brill and Stanley, 2008) (see Appendix 2a for a list of data centre best practices).

The best practices are sometimes related to applying new architectures and techniques for improving the management of business functions; at other times, best practice involves installing and using information systems, energy efficient hardware and software applications. Some of these practices include the development of an adaptive resource provisioning architecture for resource management (Chase et al., 2001), resource management information system architectures (Krauter et al., 2002), policies for workload placement (Sharma et al., 2005), frameworks for boosting throughput utilisation under a set of operating constraints (Femal and Freeh, 2005), online power management solutions based on the control-theoretic approach (Chen et al., 2005), a management solution that coordinates different individual approaches (Raghavendra et al., 2008), energy metric credit-based systems (Daim et al., 2009), model-driven coordinated management architecture (Mukherjee et al., 2010), a method for calculating the energy consumption of an information system (Yoshino et al., 2011), a unified approach for data centre power optimisation (Shi and Srivastava, 2011), and concepts of economic value of heat discharge utilisation for reuse in cooling (Zimmermann et al., 2012).

The above innovations are aimed at improving operational performance dimensions, such as computing resource utilisation through IT resource management (Krauter et al., 2002), the visibility of data centre operations through visual mapping and single display observations (Sharma et al., 2005; Yoshino et al., 2011), operational costs reduction through the effective management of energy (Chen et al., 2005), evaluation and measurement accuracy through reading from and integrating operational outputs (Sharma et al., 2005; Daim et al., 2009), the stability and efficiency of power systems (Femal and Freeh, 2005; Raghavendra et al., 2008), and workload synchronisation through integration between platforms (Raghavendra et al., 2008; Mukherjee et al., 2010). Other innovations include those that have sought to improve the energy performance of computing systems (Chase et al., 2001; Yoshino et al., 2011), power systems (Femal and Freeh, 2005) and cooling systems (Shi and Srivastava, 2011) through load balancing and integration and reducing the carbon emission (Nguyen et al., 2012; Zimmermann et al., 2012).

Of particular interest to this PhD research is the, albeit scant, literature that indicates how data centres can leverage the power of IS to solve various data centre problems through the effective management of operations, energy and resource use (Krauter et al., 2002; Kant, 2009; Siddiqui and Fahringer, 2010; Alaraifi et al., 2011). Such studies show that IS are used for monitoring hardware sensors, booting up and shutting down the servers, managing hardware and software alerts, maintaining configuration data of devices and drivers, and offering remote management (Kant, 2009). As such, the use of IS can improve resource on-demand provisioning, share balancing, resource efficiency, optimisation, infrastructure monitoring and security, capacity planning, lifecycle management and quality of service (Krauter et al., 2002; Siddiqui and Fahringer, 2010).

Further, one review study that synthesised practitioner literature found that IS has a diverse role, including as a tool for management accessibility support, facility site management, cooling and thermal management, energy management, physical computing management, virtual computing management, data management, workflow management and applications and service level management (Alaraifi et al., 2011). This suggests that using IS to improve the performance of data centres holds great potential. Thus, if it is accepted that implementing IS innovations is a valid choice for data centres, it becomes worthwhile to investigate the factors influencing adoption of these innovations.

2.3.4. Factors Influencing Adoption of Innovations in Data Centres

The data centre literature has identified factors and issues that could foster or slowdown the adoption of best practices and innovations. These include technological (for example, complexity, compatibility) (Raghavendra et al., 2008; Kant, 2009; Mukherjee et al., 2010), organisational (for example, facility design constraints, lack of planning) (Chu et al., 2004; Loper and Parr, 2007), managerial (for example, lack of coordination, lack of knowledge and awareness by professional and managers) (Brill, 2007; Loper and Parr, 2007; Raghavendra et al., 2008), economic (for example, cost of investment, price of energy) (Brill and Ratio, 2007; Loper and Parr, 2007; Brill, 2007; Zheng and Cai, 2011) and institutional (for example, adoption by peer data centres) (Loper and Parr, 2007) factors.

In terms of compatibility and complexity issues, the heterogeneity of hardware and software creates barriers to the integration of the different platforms that operate in data centres (Mukherjee et al., 2010; Kant, 2009). This reduces how effective resource management information systems (Krauter et al., 2002) and management solutions that coordinate different platforms can be (Raghavendra et al., 2008; Mukherjee et al., 2010).

Typically, data centre infrastructure (the ICTP and the CSSP) is manufactured based on different equipment or manufacturer standards (Ciampa, 2003). Difficulties arise when two systems or technologies that are based on different technical standards need to be synced or integrated.

Facility design constraints affect the suitability of adopting innovations. For example, data centre facilities that are not purpose-built have faced limitations in accommodating different cooling techniques, such as Non-Raised Floor Rooms (where cooling is supplied from the ceilings and exhausters located near the walls) or Raised Floor Rooms (where the chilled air is circulated under the raised floor) (Chu et al., 2004). In respect to planning, data centre design schemes often lack a detailed understanding of the nature of airflow physics and heat transfer (Sharma et al., 2005). Therefore, most data centres tend to overcool their facilities rather than have the correct temperature and humidity level required for maintaining the equipment’s health (Loper and Parr, 2007). Omitting planning for efficiency in the early stages of facility design makes the achievement of efficiency very difficult in operation. As such, consultations with architects, financial managers, IT professionals and data centre operators in the process of planning are important, to adopt better design innovations that allow the correct selection of equipment, applications, cooling equipment, lighting and/or power supplies (Loper and Parr, 2007).

Researchers argue that interdependencies between IT decisions and physical layer facility operations are ignored or poorly understood (Brill, 2007). For example, organisations might address the power and cooling problems in isolation from other influencing factors. In such cases, the lack of coordination leads to problems of correctness, stability and efficiency (Raghavendra et al., 2008). Further, a lack of detailed understanding and consideration by IT professionals regarding the energy efficiency aspect as compared to their understanding and consideration of the reliability and availability aspects can affect the electrical power consumption and demand in a data centre (Tschudi et al., 2004). Moreover, increasing awareness levels among data centre owners and operators about energy efficiency opportunities can motivate them to adopt and extend the use of a particular practice or innovation (Loper and Parr, 2007; Brill, 2007).

As to the cost of investment, although computing manufacturers are continuously working on the production of more efficient hardware and environmentally friendly systems, adoption of these new technologies by data centres has been slow (Ciampa, 2003; Kant, 2009). This is because a data centre infrastructure is a long-term and costly investment, usually intended for use for more than 10 years (Brill and Ratio, 2007). Thus, data centre owners are often reluctant to update their infrastructure to keep pace with technology, especially if they do not expect a return on their investment. Further, the price of electricity depends on the global oil market, which is prone to fluctuation (Schultz, 2009; Koomey, 2011; Zheng and Cai, 2011). Concerns regarding current and future energy prices and energy availability affect the steadiness of data centre business and can act as a driver for adoption.

Institutional forces also influence the adoption of best practice and innovations. The adoption of innovative technologies by peer data centres, for example, prompts other data centre operators and owners to move towards adoption (Loper and Parr, 2007).

Despite the large volume of innovations and best practice in the area of data centres, researchers are still developing innovations and testing many facets of data centre areas. The adoption and use of these innovations and best practices in data centres appears to be influenced by a number of technological, organisational, managerial, economic and institutional factors. These issues provide a good starting point to enhance this researcher's understanding about data centre efficiency problems, the role of IS in solving these problems, and the factors that are expected to influence the use of IS in data centres and that serve as input for the research model.

Out of the innovations proposed, the use of SIS is promoted as one of the best practices to overcome data centre issues (Gartner, 2008; Kant, 2009; European Commission, 2010). This implies that, for systems dedicated to transforming data centres into sustainable businesses, SIS (which is an IS based on sensors) holds the greatest potential to improve both the operational performance and environmental footprint of data centres. Therefore, in the following section, the literature on sensors, SIS applications in data centres, SIS adoption and use, and how SIS can improve the performance of data centres will be reviewed.

2.4. Sensor Technology: Definition and Review of Literature

In its simplest form, a sensor is a small electronic chip that is capable of converting a physical phenomenon such as heat, light, sound or motion into an electrical or other signal and communicating that information to other systems for further manipulation (Zhao and Guibas, 2004; Meijer, 2008). Sensors capture and process different analogue or digital signals (for example, thermal, optical) by detecting and identifying their surrounding environments (physical property) and/or objects within that environment (to a certain degree of accuracy) (Fraden, 2010). There are many different types of sensors, such as optical (radiant) sensors, magnetic sensors, thermal sensors, mechanical sensors, chemical (biochemical) sensors and acoustic sensors (Middelhoek and Audet, 1989). Each sensor type has a different role and unique features (see Appendix 2b). The integration of different sensor types (at either chip level or instrumentation level) can increase the capacity, potential use and value of sensors (Middelhoek and Audet, 1989). For instance, the integration of radiant sensors and thermal sensors will create a radiant heating signal.

Sensor technology was invented for use in military projects and laboratories (Chong and Kumar, 2003). Following the commercialisation of sensors, several research centres and institutions were established, including the Center for Embedded Network Sensing (CENS) at the University of California; and the National Centre for Sensor Research at Dublin City University). These institutions worked to advance the refinement, innovation and wider application of sensors in different domains (Chong and Kumar, 2003). Consequent to these developments, sensors have become embedded in daily life. The driving forces behind the rapid development in sensor technologies are multifaceted and include:

- developments in the field of microelectronics, where the sensor's ongoing technological evolution furthers Moore's law that 'the number of active devices we can place on a given area of silicon doubles every 18 months' (Roussos, 2006)
- the development of electronic circuits manufacturing, microchip components and miniaturisation, which together allow for the fabrication of sensors and wireless transceivers on circuit boards of less than one square inch (Lyytinen and Yoo, 2002)
- increased chip capacity and processor production capabilities (Lyytinen and Yoo, 2002)

- the massive reduction in production and operation costs, making sensors commercially and economically viable (Mattern, 2001)
- advances in the field of wireless communications and autonomous systems that facilitate sensor networking (Roussos, 2006)
- efforts made towards realising the vision of ubiquitous computing and ambient intelligence due to the fact that these technologies are fundamentally based on sensing technology (Weiser, 1991; Mattern, 2001).

The advances in sensor technology and its application is the product of research efforts in various disciplines including computer science, electrical engineering and other applied and physical sciences. Despite sensor technologies having a long history of use in different domains, making the field of research an apparently mature one, this field continues to attract considerable research attention in three areas: developing new inventions, improving existing designs and exploring new applications of sensors in various domains (see Table 2.3). Of these three areas, the literature on the application of sensors, and the value of and the factors that influence these applications is relevant for the current study because it aims to investigate the application and utilisation of sensor information systems for improving data centre performance. In the following sections, after briefly reviewing the invention and improvement literature, the review shall focus more on the application research.

2.4.1. Sensor Inventions and Improvements

The sensor literature is dominated by research that reports the introduction of innovative ideas, algorithms and architectures (Intille et al., 2003; Holmquist et al., 2004; Ge et al., 2008; Beloglazov et al., 2012; Wen-Ding et al., 2012) and that suggests improvements of innovative ideas in terms of fundamental, technical and performance issues (Garg and Bansal, 2000; Åstrand and Baerveldt, 2005; Runde and Fay, 2011; Hu et al., 2012). The majority of these studies are laboratory experiments and simulations.

Table 2.3: A synthesis of research on sensor technology

Authors	Research Categories			Field of Literature	Method
	Invention	Improvement	Application		
Åstrand and Baerveldt, 2005		X		Computer science	Field test
Beloglazov et al., 2012	X			Computer science	Simulation
Bogue, 2006			X	Electric Engineering	Review
Chong and Kumar, 2003			X	Computer science	Review
Diamond, and Ceruti, 2007			X	Computer science	Design and Survey
Edan and Nof, 2000		X		Electric Engineering	Case study
Fengzhong et al., 2010	X		X	Computer science	Design
Fleming, 2008			X	Electric Engineering	Review
Garg and Bansal, 2000		X		Applied science	Laboratory
Ge et al., 2008	X		X	Electric Engineering	Experimental
He et al, 2004	X			Computer science	Simulation
Holmquist et al., 2004	X			Computer science	Simulation
Hsieh, 2004			X	Computer science	Simulation
Hu et al., 2012		X	X	Computer science	Experimental
Intille et al., 2003	X			Computer science	Simulation
Lam and Srivastava, 2005		X		Applied science	Simulation
Lowry, 2002				Applied science	Survey
Moyne and Tilbury, 2007		X		Computer science	Review
Olguín et al., 2009	X			Computer science	Human Trial
Pantelopoulos, 2010		X		Computer science	Review and Survey
Reynolds and Wren, 2006		X		Electric Engineering	Simulation
Runde and Fay, 2011		X	X	Computer science	Design
Shabha, 2006		X		Applied science	Review
Terry et al., 2005			X	Physical science	Review
Wang et al., 2006			X	Physical science	Review
Wen-Ding et al., 2012	X		X	Computer science	Experimental
Wong and Li, 2006				Applied science	Survey
Yao et al., 2011			X	BioScience and Tech	Review

Among the sensor inventions are those that include designs of wearable sensing devices (Olguín et al., 2009), stick-on sensing devices (Holmquist et al., 2004), stealth and energy efficient surveillance systems (He et al., 2004), wireless product quality management and monitoring systems (Wen-Ding et al., 2012) and sensing tools to analyse sensor data (Intille et al., 2003). While some of these inventions are foundational with wider applicability, others are domain specific. For example, Holmquist et al.'s (2004) stick-on sensing device allows sensors to be attached to any object to transmit information, including details of weight, location, temperature and the movement of that object. Olguín et al. (2009) designed a wearable computing platform for measuring and analysing human behaviour. Ge et al.'s (2008) intelligent learning algorithms suit modelling manufacturing operations for automation. Further, others have proposed an architectural framework and principles designed for energy efficiency in cloud computing (Beloglazov et al., 2012).

The improvement of sensor inventions in terms of structure, design, method and performance is a key prerequisite to incorporate sensors into our daily lives (He et al., 2004). Therefore, it serves as a transition mechanism between inventions and application. A number of researchers have conducted literature reviews to outline the fundamental and technical issues that need to be considered for improvement. Suggestions include increasing the productivity of sensing in the workplace (Shabha, 2006), improving the operation of industrial control systems (Moyne and Tilbury, 2007) and identifying technical challenges to sensing deployment in the health domain (Pantelopoulos, 2010). Other researchers have developed improved system structures to help in the building of automation systems (Lam and Srivastava, 2005; Runde and Fay, 2011), and yet others have introduced new system designs to enhance the operational performance and accuracy of plant rows (Åstrand and Baerveldt, 2005) and to optimise the monitoring method of ambient temperature (Hu et al., 2012). These researchers have enhanced understandings about both design and the technical and operational challenges that could affect the deployment of sensors, either as stand-alone devices or as part of a wider information systems network. The following section reports the review of the sensor application literature.

2.4.2. The Application of Sensors

The application research focuses on applying sensor technology in particular areas and the utilisation of the advantages of sensors to solve problems or support different business processes. A number of researchers have investigated the applications of sensors for military surveillance (Diamond, and Ceruti, 2007); monitoring and diagnosing manufacturing automation (Ge et al., 2008); safety, efficiency and sustainability of vehicles, traffic and transportation (Fengzhong et al., 2010); automation of food and agricultural production (Wang et al., 2006); health monitoring and the safety of patients (Pantelopoulos, 2010); monitoring of IT heat dissipation (Hu et al., 2012); and surveillance, control and fault diagnosing of building operations (Lam and Srivastava, 2005).

Sensors are used for different purposes in several industries, including in the military, automotive, manufacturing, transportation, building and IT sectors. These purposes include automation of operation and business functions, enhancement of performance, augmentation of human effort, supporting decision making and offering real-time monitoring. The wide application of sensors, also known as sensorisation, would likely form the third wave of the automation revolution, extending the mechanisation and information technology revolutions (Meijer, 2008). Sensors can transform organisations into sensible bodies that can see, hear, smell and feel their surrounding environment (Olguín et al., 2009). To illustrate the linkage between sensorisation and the automation revolution, the example of an airplane flight-management system can be used. The on-board sensors continuously monitor the flight conditions (such as air pressure, altitude, temperature, directions and equipment performance) and communicate that information in the form of a signal that carries important information to the airplane computer (sensorisation). The computer of the airplane then processes and analyses this data and compares it with set values to send the appropriate commands to the relevant airplane systems (informatisation). The airplane systems that control the movement of the airplane's equipment (such as engines, rudders, flaps) and manage the flight respond to the command given by the airplane computer (mechanisation).

However, it is important to identify the challenges and obstacles to the deployment of sensors (Wang et al., 2006; Terry et al., 2005). A number of potential obstacles for applying sensors in different domains exist. These include the lack of standardisation of wireless sensors, incompatibility with existing IT infrastructure, incompatibility with legacy systems, security issues, complexity, lack of reliability, power supply issues and lack of experienced staff (Wang et al., 2006). These aspects play important roles in the ability of an organisation to apply sensor systems for particular objectives; as such, researchers are encouraged to explore these areas.

The application research has shown that to obtain the most advantages from sensor applications, they need to be deployed as part of a sensor network and to be integrated with information systems (Meijer, 2008; Watson et al., 2010). The product of this integration is SIS. The next section reviews the pertinent literature to (a) introduce and define SIS; (b) discuss the potential role of SIS; and (c) identify the factors that affect SIS use and value.

2.5. Sensor Information Systems: Definition and Review of the Literature

The main concept of SIS is to utilise sensor data to provide decision support based on information content (Zhao and Guibas, 2004). To define SIS, it is important to recognise the role of information systems and the role of sensors. The role played by IS within the organisational context has three aspects: to automate, informate and transform (Zuboff, 1988). According to Cash et al. (1994), ‘When information technology substitutes for human effort, it automates a task or process. When information technology augments human effort, it informs a task or process. When information technology restructures, it transforms a set of tasks or processes’. Conversely, the basic role of sensors includes monitoring, identifying, quantifying, measuring and locating any object within a detection range (Ohba, 1992). Signals transmitted from sensors carry the desired information (which represents the actual behaviour of the objects and environment) to devices or systems that can utilise the information (Fraden, 2010). Thus, sensors can significantly enhance the three generic functions of IS: automation, informatisation and transformation (Zuboff, 1988).

SIS can be defined as any information system that utilises sensors that are either directly or indirectly connected to one or more sensors or to a sensor network for the purpose of automating, informating and/or transforming a given task, process or appliance. Examples of SIS are Building Management Systems (BMS), Sensor Resource Management Systems (SRMS), Congestion Management Systems and Environmental Monitoring IS. For example, BMS are intelligent SIS that utilise the intercommunication and interaction between a building’s structure and services to monitor, control and manage the entire building in a productive, optimised and cost-effective manner (Levermore, 2000). SRMS predict the network traffic, power load and thermal load of computing systems using real-time monitoring hardware activity via sensor nodes throughout the ICT infrastructure (Sharma et al., 2005). The convergence between sensors and IS can result in an enhanced sense-aware IS platform referred to as SIS (see Figure 2.2).

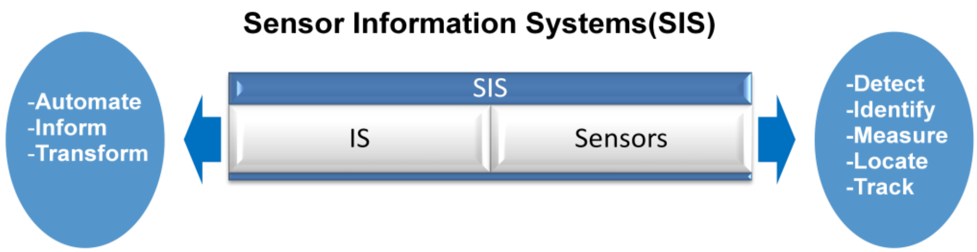


Figure 2.2: The fundamentals of SIS

2.5.1. The Potential Role of SIS

The ultimate goal of SIS are to exploit the many features of existing sensors or sensor networks, either to assist the decision maker or to perform an automated task. In doing so, SIS acquire and communicate extensive and detailed information about an unknown object or the status of a particular environment in consistently changing conditions (Meijer, 2008). Table 2.4 provides a sample summary of SIS research from different domains.

The variety of roles played by SIS in these industries, and the various advantages that can be observed, reveals that there are many features and opportunities underlying SIS. Chief among the advantages relevant to the data centre domain, and thus of particular interest in this research, is the benefit brought by sensors to infrastructure management and energy efficiency. The successful application and utilisation of SIS in various domains implies that data centres, as business facilities that contain large IT infrastructures and that are significant energy consumers, can benefit from the use of SIS in operational and environmental terms. However, before exploring the opportunities of SIS for data centres, the next section reviews the SIS research devoted to the study of the factors that inhibit or facilitate the adoption, use and value of SIS. Understanding these factors is important for achieving successful assimilation of SIS in general, and for developing the model of SIS assimilation and value presented in the current study in particular.

Table 2.4: A sample summary of SIS role

Industry	Class of SIS	Application domain	Advantages	Reference
Military	Military Information Integration Systems	missile targeting, aircraft assistance, surveillance, object tracking and detection	improve targeting accuracy, provide various readings for aircraft, enhance security and provide consistent observation of surroundings	e.g. Diamond, and Ceruti, 2007; Chong and Kumar, 2003
Buildings	Building Automation Systems	management of cooling, lighting, power distribution, access control, safety and security	optimise operating efficiency, , reduce energy u, reduce operations cost, enhance safety and security, provide early failure diagnosing	e.g. Runde and Fay, 2011; Garg and Bansal, 2000; Shabha, 2006
Transportation	Intelligent Transportation Systems	managing traffic lights, speed detection, road surveillance, toll points	enhance traffic congestion, enhance road compliance and safety, reduce accidents, toll collection automation	e.g. Fengzhong et al., 2010; Hsieh, 2004
Agriculture	Phytomonitoring Systems	managing crop and irrigation, monitoring soil, weather and environment	increase productivity, reduce labour, ,automation and precision irrigation, soil analysing	e.g. Åstrand and Baerveldt, 2005;Wang et al., 2006
Manufacturing	Manufacturing Monitoring & Diagnostic System	monitoring and automating production lines, controlling robotic arms, product and quality inspection	enhance quality control, increase productivity, provide early failure diagnosing, reduce labour, reduce operations cost	e.g. Ge et al., 2008; Agogino et al., 1988; Moyne and Tilbury, 2007
Food	Food-Quality Monitoring	monitoring and automating production lines, monitoring food condition, detecting food temperature and bacterial concentration	enhance production, enhance food quality, reduce labour, reduce operations cost	e.g. Wen-Ding et al., 2012; Terry et al., 2005; Wang et al., 2006
health	Health care monitoring systems	health management, monitoring patient's health, access management to and tracking of medical data, asset tracking, patient identification	ubiquitous monitoring, proactive personal health management, reducing healthcare costs, real-time decision making, protecting medical data and assets.	Pantelopoulos, 2010;Yao et al., 2011
IT Infrastructure	IT thermal monitoing systems	thermal monitoring and management, cooling systems management, energy efficiency	accurate detection of physical position of hot spots, utilisation of output by other MIS, cost savings, improvement of energy efficiency	Hu et al., 2012; Beloglazov et al., 2012

2.5.2. Factors that Influence the Adoption, Use and Value of SIS

This section reviews the adoption and use studies on SIS. To the best of the researcher's knowledge, no prior studies or theoretical frameworks have explained the adoption and use of SIS in data centres specifically. Therefore, the literature review was extended to include studies on adoption and use of SIS from domains other than data centres. However, it appears that SIS is an emerging phenomenon; thus, limited literature was found to have investigated the adoption and use of SIS in general.

The studies of SIS adoption and use were scattered among the domains of building automation (Lowry, 2002; Wang et al., 2006), supply chain management (Barbosa et al., 2010; Wamba, 2012) and healthcare management (Fensli et al., 2008; Hafeez-Baig and Gururajan, 2009). The acceptance of wireless handheld devices that provide hospital departments with updated information about their patients has been explored (Fensli et al., 2008; Hafeez-Baig and Gururajan, 2009; Huang, 2010). Others have investigated the adoption of radio-frequency identification (RFID)-based logistics information systems (RFID integrated with logistic IS) in manufacturing firms (Barbosa et al., 2010). Further, the role of an integrated RFID supply chain management system (RFID integrated with supply chain IS), as an enabler of supply chain integration, was explored through both longitudinal case study and laboratory experiments (Wamba, 2012).

Studies of SIS adoption and use have been conducted at the user level (for example, Huang, 2010) and at the organisational level (for example, Barbosa et al., 2010). In general, these studies explored the role of SIS and identified the antecedents to SIS adoption. Methods such as literature review, case study and survey were used to develop and test the framework of adoption models.

Regarding the specific focus of these studies, Lowry (2002) developed and tested an adoption model to investigate the factors that affect the user's acceptance of BMS. Wong and Li (2006) examined the factors that influence the selection of intelligent building systems. The adoption of RFID-based logistics information systems in manufacturing firms and the influenced of organisational characteristics on adoption was explored by Barbosa et al. (2010). Multiple researchers have worked to develop and test a conceptual model for the adoption of wireless handheld devices that provide hospital departments with updated information about their patients (Fensli et al., 2008; Hafeez-Baig and Gururajan, 2009; Huang, 2010).

The literature on SIS adoption and use shows that researchers have borrowed from the Technology Acceptance Model (Hafeez-Baig and Gururajan, 2009; Huang, 2010) and the Unified Theory of Acceptance and Use of Technology (Fensli et al., 2008) to model individual acceptance. Further, DOI was used by Wamba (2012) to explain variation in the adoption of SIS at the organisational level. Preliminary case studies have also been used to theorise on the important factors underpinning adoption (Hafeez-Baig and Gururajan, 2009).

The above researchers identified a number of factors that can facilitate or inhibit the adoption of SIS, including user characteristics, technological and organisational factors and other factors specific to the context under investigation. They also explored the role that can be played by SIS in the adopting organisations.

User characteristics factors that were found to influence adoption and use included perceived ease of use, perceived usefulness, benefits (Huang, 2010) and user comfort (Wong and Li, 2006). Technological factors included technical readiness (Hafeez-Baig and Gururajan, 2009), compatibility of new hardware with existing system (Hafeez-Baig and Gururajan, 2009; Lowry, 2002) and system technological issues (Wong and Li, 2006). The organisational factors comprised organisational readiness (Hafeez-Baig and Gururajan, 2009), the nature of companies' operations and their size (Barbosa et al., 2010), internal environment issues, work efficiency and cost effectiveness (Wong and Li, 2006). The other context-specific factors that were found to affect SIS adoption and use included perceived disease threat, perceived barriers to taking action and external cues to action (Huang, 2010); hygienic aspects, anxiety and medical equipment (Fensli et al., 2008); clinical practice; social aspects (Hafeez-Baig and Gururajan, 2009) and safety issues (Wong and Li, 2006). Together, these factors suggest that characteristics of adopters, organisational and technological factors and considerations of factors that arise from the nature of the research context were of high importance, especially when studying firms with different business classifications.

However, to facilitate the success of SIS applications in a particular area, SIS need to be capable of yielding a return on organisation investment through ease of use, ease of management and productivity (Conner et al., 2004). Therefore, in terms of the role of SIS, Wamba's (2012) study explored the role of RFID as integrated with a supply chain management system and showed their ability to enable timeliness, business process optimisation through automation, enhanced inter- and intra-organisational business processes, more accurate data flows into IS, and enhanced system-to-system communication and integration.

In sum, the above literature implies that organisational adoption and use of SIS could be influenced by technological and organisational factors that can be studied through DOI and through external factors and industry-specific information that can be identified through empirical preliminary studies. In addition, it suggests that using a mixed-methods approach to study the adoption and use of SIS can provide insight into some of the antecedents behind the choice to adopt and use SIS. Further, SIS was found to provide operational and economic benefits that could allow an organisation to develop sustainable advantages. These findings contribute to the development of the current research model. Due to the shortage of organisational adoption and use studies in the field of SIS, the researcher decided to expand the literature review to include studies on relevant IS. Next, because SIS assimilation and value in data centres is the focus of the current research, the following section will review the literature on SIS applications in data centres.

2.6. Applications of SIS in Data Centres

This section provides a review of the literature on SIS applications in the data centre domain. The review starts with a very brief introduction to the types of sensors used in data centres, the use of sensors in data centres and the potential for using SIS in automating, informating and transforming data centre activities.

The sensor types used in data centres include built-in CPUs, servers (Qinghui et al., 2006), facility management systems (for example, smoke detectors, occupancy sensors) and those sensors attached to various data centre equipment (Qinghui et al., 2006; Loper and Parr, 2007; Moore et al., 2004). The built-in sensors are embedded by computing manufacturers to monitor the temperature and humidity of server components, such as CPUs (Qinghui et al., 2006; Baird and Mohseni, 2008). Facility management sensors are used by BMS to monitor and control the temperature, lighting and humidity of a facility, and to support its security and safety (Tschudi et al., 2004; Loper and Parr, 2007). Equipment-based sensors represent an advanced method of use, whereby sensors are placed on the most critical areas of the equipment for better or more efficient monitoring (Moore et al., 2004). These sensors independently support both ICTP and CSSP operations but are rarely integrated into comprehensive SIS, except in the case of building automation and server management systems (Watson et al., 2009).

In general, most data centre or facility managers use BMS for managing limited CSSP operational processes. This includes monitoring the occupancy of a data centre facility, its temperature and airflow, and the water flow of cooling systems (Tang et al., 2006; Loper and Parr, 2007). BMS automate cooling, lighting and security operations. Within the ICTP, the server management systems use is limited to monitoring CPU performance (Baird and Mohseni, 2008). The server management system relies on the built-in sensors of the motherboard and allows operators to observe the status of the CPU and to manually control and execute some tasks (for example, turning off overheated servers).

Nevertheless, the full realisation of SIS's functionalities requires the application of SIS beyond the narrow traditional use (Liu et al., 2008). For instance, for data centre operators to improve their energy consumption, they should extend their application of SIS, such as by using it to optimise air flow management through the smart integration of sensors within computing resources (Sharma et al., 2005; Watson et al., 2009). In addition, SIS can be used to enhance power management (for example, through integration with smart metering) (Raghavendra et al., 2008) or computing management (for example, through smart load migration) (Padala et al., 2007). Table 2.5 provides a summary of the SIS application opportunities for use in data centres.

The opportunities underlying the use of SIS can be explored based on the three roles of SIS that were discussed earlier; that is, (a) automation, (b) informatisation and (c) transformation of the processes and tasks of the CSSP and the ICTP. Each of these categories is discussed in more detail in the following sections.

Table 2.5: Analysis of SIS capability to support the CSSP and the ICTP

Authors	Categories based on SIS role			Method
	Automate	Informate	Transform	
Bash 2006	X			Experimental
Bash and Forman 2007		X		Experimental
Berl et al., 2010		X		Review
Chen et al., 2005	X			Experimental
Chu et al., 2008		X		Experimental
Hao et al., 2010		X		Case study/Experiment
Herrlin, 2005		X		Experimental
Hu et al., 2012		X		Experimental
Khargharia et al., 2008	X			Experimental
Kyoung-Don, and Basaran 2009	X	X		Experimental
Liu et al., 2009			X	Experimental
Liu, and Terzis. 2012	X			Case study/Experiment
Moore et al., 2004	X	X		Experimental
Mukherjee et al., 2007			X	Experimental
Nathuji et al., 2007	X			Experimental
Padala et al., 2007	X	X		Experimental
Parolini et al., 2008	X	X		Experimental
Patnaik et al., 2009		X		Experimental
Qinghui et al., 2006		X		Experimental
Rodriguez et al., 2011	X	X		Case study/Experiment
Sharma et al., 2005	X	X		Experimental
Stack and Mowrer, 2009	X	X		Experimental
Tang et al., 2006	X			Experimental
Wang et al., 2011			X	Conceptual
Watson et al., 2009			X	Experimental

2.6.1. The Automation Role of SIS in Data Centres

SIS can be used to automate and substitute human efforts in performing CSSP and ICTP activities. In terms of the CSSP, BMS are used for monitoring a data centre facility's occupancy, as well as its temperature and airflow, and the water flow of cooling systems that use air compressors and chilled water (Tschudi et al., 2004; Qinghui et al., 2006). This allows the automation of cooling, lighting and security systems. The automation of these systems reduces energy consumption (Moore et al., 2004). However, benefits to data centres can be increased by extending the use of SIS into other areas of the CSSP and in supporting ICTP functions (Padala et al., 2007; Liu and Terzis, 2012).

SIS can automate CSSP operations and optimise air management by monitoring the airflow, thermal activity and heat transfer mechanism of the entire data centre facility (Sharma et al., 2004; Tang et al., 2006; Bash, 2006; Parolini et al., 2008). This allows the system to understand the airflow and thermal behaviour (by creating a thermal map) to accurately assess the performance of these aspects using real-time and historical sensor data (Kyoung-Don and Basaran, 2009). Cooling systems can then be automated more accurately by triggering cooling capacity and setting the correct temperature and humidity to match the requirements, based on the changing airflow and thermal performance (Liu et al., 2009). SIS can also redirect and focus cooling capacity to the most desirable areas, based on thermal conditions (Bash and Forman, 2007). In addition, SIS can potentially work as climate-control instruments for utilising free outside air by monitoring the inside temperature and humidity, and the outside temperature and humidity and switching between traditional cooling systems (for example, compressed air) and free outside air cooling systems (Stack and Mowrer, 2009). Further, SIS can support power management by monitoring the power transfer within the grid and the energy consumption per outlet (Khargharia et al., 2008; Kyoung-Don and Basaran, 2009).

Within the ICTP operation, SIS can be used to improve computing resource management by monitoring the data flow of the network and workload demand between servers and clients (Sharma et al., 2005; Mukherjee et al., 2007; Nathuji et al., 2007). Then, SIS can automatically put some servers into idle mode to conserve energy use and reduce unnecessary data traffic between many servers. In addition, SIS can monitor CPU performance in a virtual data centre, to measure how many cycles of a CPU are actually consumed by each virtual machine (Padala et al., 2007; Wang et al., 2011). This allows for the optimisation of resource utilisation in the context of IT virtualisation. Further, SIS can automatically gather detailed information about the thermal and power activity of each rack (Moore et al., 2004). This improves the operation of the CSSP, effectively delivering the desired power and cooling to the racks.

2.6.2. The Informatisation Role of SIS in Data Centres

SIS informatisation role refers to the augmentation of human efforts in performing the CSSP and ICTP activities. SIS informate up decision makers about performance measurements and informate down technical team about critical systems changes. The current use of the SIS is limited in monitoring CPU performance and informating down technical team about critical changes in the health of systems (Baird and Mohseni, 2008). Informating up involves informing the management team about important aspects of business operations. It is usually associated with enhanced organisational control and governance. Informating down is often associated with enhanced operational management as it informs the technical team about the system's operations and its performance, which allows early diagnoses of any local problem. This provided data centre operators with the required information to control overheated servers.

Within the CSSP, data centre operators can be informed about the climate conditions inside and outside data centres (Stack and Mowrer, 2009; Patnaik et al., 2009; Hu et al., 2012). This enhances decision making in choosing the most appropriate technique for air delivery. In addition, SIS can provide information about the electric power activities (Chu et al., 2008; Watson et al., 2009; Berl et al., 2010). SIS can then support operators' decisions to improve power management and power routing. Further, within ICTP, SIS can informate about workload and dataflow in between the servers and clients (Padala et al., 2007; Mukherjee et al., 2007). This allows data centre operators to make decisions where there is a need to shift workload between server clusters.

2.6.3. The Transformation Role of SIS in Data Centres

The transformation role of SIS refers to the restructuration of human effort through advanced automation and informatisation, which alter the way CSSP and ICTP activities are performed. By fully automating a facility, the cooling and power activities of the CSSP and informating the decision makers about their status and performance, SIS can transform the CSSP into an intelligent and agile platform that utilises different sources of data to exercise full control in the most efficient manner without human intervention (Liu et al., 2009; Watson et al., 2009). For example, automating air delivery, cooling and informing thermal activities can help in transforming these systems into intelligent systems that are able to adapt with changing conditions. By automating the computing resource activity of the ICTP and providing detailed information about performance to the decision makers and other IS, SIS can transform computing hardware and virtual platforms into smart resource management systems (Mukherjee et al., 2007; Watson et al., 2009; Wang et al., 2011).

The above review shows the potential value of using SIS for improving data centres' performance (for example, by improving energy efficiency, computing resource usage and the visibility of operations and by reducing operation cost). However, most of these studies were conducted in experimental settings. They do not inform the extent of actual use of SIS in data centres, nor do they show the impact of using SIS on data centre performance. This implies that there is a dearth of empirical research about the actual use and realisation of SIS' value in data centres.

Overall, from the analysis of the data centre, sensor and SIS literature, three important lessons can be learned. Firstly, most of the existing literature is experimental research conducted in a controlled environment. Thus, the actual status of SIS in data centres is yet to be explored. Secondly, the existing literature is skewed towards the computer science discipline in addressing technical issues. This means there is less research from an information systems perspective. Thirdly, there is a lack of theory-driven research that identifies the antecedent factors to the use and value of SIS in data centres. This implies that research that investigates the determinants of SIS use and value, which is required to understand the factors that could influence the use and value of SIS, needs to draw from the IS assimilation and value literature.

Against the backdrop of the existing literature on SIS application in data centres, the next section offers a review of the IS assimilation and value literature to identify relevant theories and factors for the development of the research model of this PhD study.

2.7. Technology Assimilation and Value

Technology assimilation helps organisations to leverage the advantages of using information technologies in their business activities and strategies (Damanpour, 1991; Armstrong and Sambamurthy, 1999). Within the organisational context, assimilation refers to the acquisition, fruition, full utilisation and institutionalisation of technology (Meyer and

Goes, 1988). Whereas the adoption of innovation implies the implementation and initial success of a system through using a new ICT (Damanpour, 1991; Agarwal et al., 1997), the assimilation of technologies implies the absorption of a technology into the traditions of an organisation or individual. Technology assimilation therefore helps organisations to understand how and to what extent a technology is being used, utilised and infused within their organisational frameworks.

Although assimilation of technology allows organisations to leverage the advantages of using IS (Armstrong and Sambamurthy, 1999), some researchers contend that the conditions by which organisations can observe and harvest business assimilation value are positively associated with the extent of assimilation in actual circumstances (for example, Bharadwaj, 2000; Santhanam and Hartono, 2003; Zhu and Kraemer, 2005). This implies that assimilation and assimilation value are mutually dependent.

2.7.1. Research on Technology Assimilation and Value

The IS literature on technology assimilation can be categorised into two main streams: (a) studies that have only investigated the assimilation of technology (assimilation); and (b) studies that have investigated the connection between assimilation and its impact on firm performance (value). These are further categorised into Focus and Locus. Focus refers to the specific technology under investigation. Locus refers to the area or domain whereby the specific technology is investigated. Table 2.6 provides a summary of assimilation as well as assimilation and value studies. These two categories are then discussed in more detail.

2.7.2. Assimilation Studies

Studies of technology assimilation have investigated several innovations, employed different theoretical lenses to model the assimilation, and have identified various factors that can influence the extent of use of innovation. Some have investigated the generic use of IT innovation (Karahanna et al., 1999; Armstrong and Sambamurthy, 1999), while others have focused on specific innovations.

Table 2.6: A summary of IS assimilation and value studies

Authors	Assimilation Research Categories		Focus	Locus	Method
	Assimilation	value			
Armstrong and Sambamurthy, 1999	X		Generic IT	Generic	Survey
Bala and Venkatesh, 2007	X		IBPS	IT	Case study
Banerjee and Ma,2011	X		e-market	Trading	Case study
Bharati, and Chaudhury,. 2012			Aggregate Tech	SMEs	Survey
Chatterjee et al., 2002	X		Web Tech	Generic	Survey
Cho and Kim , 2002	X		OOT	Generic	Survey
Fichman 2001	X		SPI	IT	Survey
Hsu et al., 2006	X		e-business	Four industries	Survey
Karahanna et al., 1999	X		Generic IT	Financial	Survey
Kouki et al., 2010	X		ERP	SMEs	Case study
Liang et al., 2007	X		ERP	Vendors	Survey
McGowan and Madey, 1998	X		EDI	Generic	Survey
Picoto et al., 2012		X	m-business	Generic	Case study and Survey
Purvis et al., 2001	X		CASE	Generic	Survey
Rai et al., 2009		X	EPI	Suppliers	Survey
Ranganathan 2005	X		CBD	IT	Survey
Ranganathan et al., 2004		X	Web Tech	Generic	Survey
Raymond et al., 2005		X	e-business	Manufacturing	Survey
Saraf et al., 2012	X		ERP	Generic	Survey
Setia et al., 2011		X	IT apps	Healthcare	Secondary data
Son et al., 2005	X		EDI	Retailers	Survey
Vykoukal et al., 2011	X		GRID	Financial	Survey
Wu and Chuang, 2009	X		e-SCM	Supply Chain	Survey
Zhu and Kraemer, 2005		X	e-business	Retailers	Survey
Zhu et al., 2006	X		e-business	Three industries	Survey

IS assimilation studies show that IS researchers have investigated various innovations, including the assimilation of electronic data interchange (EDI) (McGowan and Madey, 1998; Son et al., 2005), computer-aided software engineering (CASE) technology (Purvis et al., 2001), software process innovations (Fichman, 2001), object-oriented technology (Cho and Kim, 2002), web technology (Chatterjee et al., 2002; Ranganathan et al., 2004), e-business (Zhu and Kraemer, 2005; Hsu et al., 2006; Zhu et al., 2006; Raymond et al., 2005), component-based software development (CBD) (Ranganathan, 2005), e-SCM (Wu and Chuang, 2009), Electronic Procurement Innovations assimilation (Rai et al., 2009), ERP (Liang et al., 2007; Kouki et al., 2010; Saraf et al., 2012), third-party business-to-business (B2B) e-market (Banerjee and Ma, 2011), IT applications (Setia et al., 2011), GRID assimilation (Vykoukal et al., 2011), aggregate technologies (Bharati and Chaudhury, 2012), and mobile business (Picoto et al., 2012).

These studies have employed a variety of theoretical lenses to investigate the relevant determinants of assimilation using innovation theories such as DOI (Karahanna et al., 1999; Purvis et al., 2001; Ranganathan et al., 2004; Wu and Chuang, 2009; Picoto et al., 2012), TOE model (Cho and Kim, 2002; Zhu and Kraemer, 2005; Raymond et al., 2005; Hsu et al., 2006; Zhu et al., 2006; Kouki et al., 2010; Picoto et al., 2012), institutional theory (Chatterjee et al., 2002; Liang et al., 2007; Banerjee and Ma, 2011; Bharati and Chaudhury, 2012; Saraf et al., 2012), theory of reasoned action (Karahanna et al., 1999), social exchange theory (Son et al., 2005), economic theories of diffusion and Attewell's theory of technical knowledge and know-how (Ranganathan, 2005),transaction cost theory (Son et al., 2005; Banerjee and Ma, 2011), organisational inertia theory (Bala and Venkatesh, 2007), and structuration theory (Rai et al., 2009). This reveals that most of the assimilation literature has drawn from DOI, TOE and institutional theory to study the assimilation of innovation.

The literature also shows that the majority of researchers have drawn from Massetti and Zmud's (1996) four facets of assimilation to define assimilation constructs. For example, researchers have used volume, diversity (for example, McGowan and Madey, 1998; Son et al., 2005; Liang et al., 2007), depth (for example, McGowan and Madey, 1998; Zhu and Kraemer, 2005; Liang et al., 2007) and breadth (for example, Zhu and Kraemer, 2005) as the dependent variables of assimilation.

Though previous researchers (as seen in Table 2.6) have studied technology assimilation as a phenomenon, the factors that influence the assimilation levels were found to be different (for example, Chatterjee et al., 2002; Zhu and Kraemer, 2005; Kouki et al., 2010). Building on the above theories and using different research approaches such as survey (for example, Zhu and Kraemer, 2005; Rai et al., 2009; Saraf et al., 2012), case studies (for example, Bala and Venkatesh, 2007; Kouki et al., 2010; Banerjee and Ma, 2011) or mixed approaches (for example, Picoto et al., 2012), the above studies identified a number of antecedents to the assimilation of IS, which have helped to explain the variations in technology use. These antecedents include technological, organisational, institutional and environmental factors, as well as factors specific to the contexts under investigation.

More specifically, the technological factors identified include relative advantages (Wu and Chuang, 2009; Picoto et al., 2012), technology compatibility (Cho and Kim, 2002), complexity (Cho and Kim, 2002; Wu and Chuang, 2009), maturity of technology (Cho and Kim, 2002), Perceived Risk (Banerjee and Ma, 2011), networking intensity (Raymond et al., 2005), technology competence (Zhu and Kraemer, 2005; Picoto et al., 2012), technology attributes (Kouki et al., 2010) and technology integration (Zhu et al., 2006; Picoto et al., 2012). The organisational factors include top management (Chatterjee et al., 2002; Rai et al., 2009; Kouki et al., 2010; Bharati and Chaudhury, 2012), size (Purvis et al., 2001; Zhu and Kraemer, 2005; Bharati and Chaudhury, 2012), knowledge (Fichman, 2001; Purvis et al., 2001; Ranganathan, 2005) and technical expertise (Cho and Kim, 2002; Chatterjee et al., 2002). The institutional factors include coercive forces, mimetic forces and normative forces (Hsu et al., 2006; Liang et al., 2007; Wu and Chuang, 2009; Vykoukal et al., 2011; Saraf et al., 2012; Picoto et al., 2012); environmental (market) forces, including factors such as supplier interdependence, IT activity intensity and competitive intensity (Ranganathan et al., 2004); power and reciprocal investments (Son et al., 2005); competitive pressure and regulatory support (Zhu and Kraemer, 2005; Hsu et al., 2006; Zhu et al., 2006; Banerjee and Ma, 2011); environmental uncertainty and supplier interdependence (Wu and Chuang, 2009); and environmental sustainability (natural environment) (Vykoukal et al., 2011).

In addition, a few researchers have extended their studies and incorporated factors specifically relevant to their areas of interest. For example, Karahanna et al. (1999) included factors relevant to local computer specialists; Rai et al. (2009) incorporated factors relating to technology standards efficacy; and Raymond et al. (2005) discussed the manufacturing context and manufacturing technology. This shows that including factors specific to the research context is important for understand emerging factors in assimilation in particular areas.

2.7.3. Value Studies (Studies Linking Assimilation with Value)

Studies of assimilation value have investigated the connection between assimilation and its impact on firm performance. These studies have investigated the impact of several innovations, such as the impact of web technology assimilation on firm performance (Ranganathan et al., 2004), the impact of e-business use on the creation of business value (Zhu and Kraemer, 2005), the impact of e-business assimilation on a firm’s market performance (Raymond et al., 2005), the impact of electronic procurement innovations assimilation on productivity (Rai et al., 2009), the impact of IT applications assimilation on a firm’s financial performance (Setia et al., 2011), and the impact of mobile business usage on market and operational performance (Picoto et al., 2012). These studies also reveal the usability of RBV to investigate the value of technology assimilation (for example, Zhu and Kraemer, 2005; Raymond et al., 2005; Picoto et al., 2012).

Value studies suggest that the extension of assimilation models to account for the value of assimilation on firm performance is very important, as the conditions by which firms can observe and harvest business value from technology assimilation are positively associated with the extent of assimilation in actual circumstances (Ranganathan et al., 2004; Zhu and Kraemer, 2005; Rai et al., 2009). Thus, it can be concluded that IS researchers interested in technology assimilation studies need to connect the assimilation with its value to arrive at a successful model of technology assimilation.

By synthesising the previous studies in Table 2.6, six observations can be made. Firstly, most existing empirical IS research has employed innovation theories such as DOI, TOE and institutional theory. However, in some cases, researchers have used innovation theories, either partly (for example, to focus only on technology, organisational or environmental factors) or to draw insights from the contextual lens of the theory (for example, McGowan and Madey, 1998; Cho and Kim, 2002; Chatterjee et al., 2002).

Secondly, most studies reviewed for this literature review selected a few sets of factors from innovation theories relevant to the context being studied and excluded other variables. This implies that the innovation attributes under investigation and the setting within which technology is being implemented could influence the assimilation level.

Thirdly, although the variables used to measure the assimilation dependent construct were all appropriate to inform the use of technology innovation, they were very different. This implies that there is no consistent or generic approach to inform the assimilation of innovation.

Fourthly, although the IS studies reviewed here investigated various technologies in different settings, such as software, web technology and ERP (Purvis et al., 2001; Chatterjee et al., 2002; Liang et al., 2007), none of these studies specifically investigated SIS assimilation and value in the context of data centres. Therefore, IT assimilation models must be drawn from theories and from the findings of other research on IT assimilation in general as well as from other relevant areas, such as EDI or ERP (Bolloju and Turban, 2007). Since SIS have different features to other IT innovations, and data centres have specific characteristics, it is expected that the conditions of this research context are not the same as other research contexts. Thus, antecedent factors of assimilation models might not be adequate to explain the variation in the assimilation and value of SIS in data centres. Nevertheless, studies on innovation use in other contexts can contribute constructive insights that can be combined in this research into an integrated theoretical framework for studying SIS assimilation and value.

Fifthly, researchers, rather than relying on a single theory, tend to draw from different theoretical and contextual lenses and add relevant factors to their context to inform the technology under investigation. This implies that, although there is a wide range of IS theories and models of innovation assimilation, IS assimilation literature lacks a unifying framework (Aladwani, 2002); there is no one-size-fits-all model that explains the assimilation of all innovations. Fichman (2000) argues that future research in the area of IT innovation should endeavour to combine multiple theoretical streams into a more integrated view, rather than merely relying on a single model or theory. Thus, the present research proposes an integrated model built around different theoretical and contextual lenses derived from major theories on technology innovation use and value, as well as factors relevant to the context of the research, to identify the factors that influence the assimilation and value of SIS in data centres.

Sixthly, a significant link between the extent of use of IS and level of impact (value creation) has been demonstrated by several researchers (Devaraj and Kohli, 2003; Ranganathan et al., 2004, Zhu and Kraemer, 2005; Rai et al., 2009). This implies that linking assimilation and its impact is fundamental for a successful assimilation model.

Consistent with these observations, the current study proposes an integrated model that is not exhaustive, but that provides a good starting point for studying the assimilation and value of SIS in data centres. Since there is a lack of knowledge in this area of research, the present research will include an exploratory case study on the actual applications of SIS in data centres to understand any unique factors relevant to the research context. This step is consistent with existing trends in studying technologies within the data centre context.

2.8. Summary

This chapter began with an argument about the double side effect of IT on sustainability. The chapter then briefly reviewed the existing arguments within the fields of Green IT and Green IS to identify the relevant category of this research within the context of sustainability. The chapter showed that the current study suits the theme of Green IS and shows how Green IS can be used to achieve Green IT. The literature on data centres outlined data centre performance aspects and showed that various techniques, methods and technologies are proposed and used to improve the performance of data centres. The literature depicted IS as one of the effective technologies used for managing the business functions of data centres. The section concludes by highlighting the opportunities underlying the use of sensors and SIS to overcome data centre issues through enhancing the data centre management business functions.

An overview of sensor technology in general, and it use in SIS in particular was presented. The literature showed that sensors and SIS, with their unique capabilities, can enhance the capabilities of decision makers by assisting in the management of different functional areas. As such, it was argued that the advantages of SIS, recognised in different disciplines, can be applied to manage data centre operations. Literature on SIS adoption and use and SIS applications in data centres was then reviewed to understand the determinants of SIS adoption and use in general, how SIS can be used to overcome data centre issues, and to identify the gap in the literature. The chapter concluded by reviewing the literature of IS assimilation and value to identify the theories used by other researchers and any relevant factors that could be used to guide this study of the assimilation and value of SIS in data centres. A sample comparison showing the strengths and limitations of the most cited theories in IS literature that were used to investigate the use, adoption and value of technology are summarised in Table 2.7.

Table 2.7: A Summary of the most cited theories in IS literature

Theory	Strength	Limitation
DOI	• Identifies two groups of factors that encourage and/or inhibit the use of technology innovation: technological and organisational factors. • Widely used in IS research.	Limitation to explain complex technologies and external factors.
TOE	• It is basically an extension of DOI and identifies three key factors: technological , organisational, and environmental. • The framework has a generic nature to study different types of technologies. • Widely used in IS research.	Environmental context does not cover the emerging issues such as environmental sustainability. Rather, it refers to the external factors such as industry, market, and government regulation
Institutional	• Helps to identify the critical role played by institutional isomorphism on technology use and it has three basic types of institutional isomorphism: normative, coercive and mimetic pressure. • Widely used in IS research to study external forces.	It does not cover emerging issues such as natural environmental, sustainability and its related pressures.
RBV	• Help to explain why the performance might differ from one organisation to another within one industry. • Used by researcher in various research disciplines.	It focuses only on competitive advantages and performance through acquiring valuable, rare, and inimitable heterogeneous resources and capabilities.
NRBV	• It builds on RBV and help to explain how the environmental strategies of firms contribute to the creation of economic and environmental value. • Due to the emerging issue of environmental sustainability and shortage of theories that address these concerns, the theory has received growing interest by IS researchers.	It is only address the role of emerging environmental sustainability issues in the development of economic and environmental value.

The search for a particular model of SIS assimilation and value reveals that there is a lack of theoretically driven research in this area. The search for a particular model of SIS assimilation and value reveals that there is a lack of a unifying theory in this area. The finding from Table 2.7 suggests that developing an integrated theoretical model to investigate the SIS assimilation and value by borrowing from these theories would help to consolidate the strengths and overcome the limitations that can be found in a single theory.

CHAPTER 3

3. A PILOT STUDY TO EXPLORE THE ROLE AND UTILISATION OF SENSOR INFORMATION SYSTEMS IN DATA CENTRES

3.1. Introduction

The demand for and on data centres continues to pose several power, cooling, and performance constraints associated with the environmental and economic inefficiency. The inefficiency of ICTP and CSSP operations of data centres is becoming a non-negligible risk to business performance because of the rise of operation costs, the consumption and availability of energy, inefficiency of resource utilisation which could directly impact the business continuity and the environmental responsibility of IT departments (Velte et al., 2008; Lefurgy et al.., 2003; Kant, 2009). Improving the operational performance (e.g. operation cost, processing optimisation) and environmental performance (e.g. reducing energy consumption, improving water efficiency) is therefore at the forefront of organisations' actions for supporting business continuity (Schulz, 2009; Smith, 2011).

Data centre mangers are adopting various practices, methods and techniques that can help to convert data centre operations into a more sustainable practice. In this regard, the use of sensors and sensor information systems (SIS) hold great potential for making data centres both economically and environmentally sustainable (Moore et al., 2004; Watson et al., 2009). However, as indicated in chapter 2, although previous research has identified a number of potential benefits of sensors and SIS, the use of sensors for enhancing the operational and environmental performance of data centres and the factors that could affect the use and impact of SIS on data centres is an under-researched phenomenon. In order to get a deeper understanding of SIS use in data centres, an exploratory pilot study was conducted.

The pilot study was necessary to enhance the researcher's understanding about the current state of SIS application in data centres, what shape the use of SIS, and how the data centre context would influence both constructs of SIS assimilation and value.. For this purpose, the main research questions of the study included:

- To what extent are SIS assimilated in data centres? And for what purpose SIS are used for?
- What are the factors that explain the assimilation of SIS among data centres?

The output of the study was used in the design of the research framework, to redefine some concepts within the context of data centres as well as to operationalise the relevant factors to SIS assimilation and value.

3.2. Research Method

The pilot study was designed to explore the extent of SIS assimilation, and the determinants of SIS assimilation in the data centres. Thus, it was essential to decide on the appropriate research method that needed to be followed in order to understand the phenomenon under investigation (Myers, 2009). In the event where there is little known about a particular phenomenon, the qualitative approach (e.g. case studies) is advocated as the preferred method to gather evidence and to obtain adequate understanding about the phenomenon (Eisenhardt 1989; Yin, 2003; Myers, 2009). To this end, case studies of five Australian data centres were undertaken during the first half of 2010 to explore the extent of SIS assimilation and the factors that could facilitate or inhibit the assimilation of SIS in data centres. As stated by Eisenhardt (1989, p. 533), case studies help to understand the dynamics present either within a single or multiple settings. A case study method can be used to answer research questions such as 'why' and 'how', and to analyse an emerging phenomenon (Yin, 2003), and as such is relevant for the purpose of the pilot study. According to Myers (2009, p.73), 'the purpose of case study research in business and management is to use empirical evidence from real people in real organisations to make an original contribution to knowledge'.

Conducting case studies based entirely on a few interviews with key informants is a well-accepted method commonly used in the early stage of research on a particular phenomenon (Myers, 2009; Yin, 2003). Therefore five case studies were assumed to be adequate for the purpose of this research. The five data centres were identified using snowball sampling techniques based on contacts developed through attendance at data centre workshops and conferences. The data were collected after ethics clearance from RMIT University. The main data collection method was face-to-face interviews with data centre managers at their own locations. Except for one, all interviews were tape recorded and the sessions transcribed before the data were analysed. Four of the data centres kindly offered the researcher a tour of their facilities including a demonstration of the SIS used. To enhance the validity of the answers, the findings of each interview were verified by the participants at the end of each interview session. Furthermore, to ensure consistency and reliability, the structured interview guides were used (Myers, 2009). The data were then analysed using content analysis techniques. A summarised description of the five data centres is presented in Table 3.1

Table 3.1: Description of the data centres used in the sample

Case No.	**1**	**2**	**3**	**4**	**5**
Industry	Education	Education	IT	Telecommunication	IT
DC type	Corporate	Corporate	Co-located + Managed	Co-located + Managed*	Co-located
Targeted business	Internal clients	Internal clients	Large, medium and small firms.	Large, medium and small firms.	Public enterprises and agencies.
Age of the facility	Old**	Old**	New**	Old**	New**

*The managed services of case 4 represent only 3% of total operations.
**Old (three years old and under <=3 years), New (Four year old and over >=4 years).

3.3. Findings and Discussion

3.3.1. Current Trends in SIS Applications in Data Centres

Although all the five cases have installed sensors and adopted SIS, they differ slightly in the assimilation of SIS. Based on Massetti and Zmud's (1996) facets of assimilation, the volume, diversity and intensity of SIS were explored.

In terms of volume, there can be three indicators for evaluating the volume of SIS — the number of installed sensors, the types of sensors and the type of SIS. Therefore SIS volume can be defined as the number of sensors, number of sensors types and number of SIS used in the data centre. The number of installed sensors refers to a headcount of active sensors. The sensor type refers to the variety of sensors such as environmental sensors (e.g. temperature, air pressure, and humidity), magnetic sensors (e.g. motion) and occupancy sensors (e.g. detect the room vacancy). The SIS type refers to the unique features and functions of a SIS used in a data centre. The findings indicate that except for one (case five) all the other data centres have relatively comparable SIS volume. Table 3-2 provides a summary of the SIS volume indicators derived from the five data centres. Notably, in all cases, the common SIS is a BMS. In one case (case five), in addition to the BMS, other integrated SIS such as InfraStruXure Central, InfraStruXure Management and InfraStruXure Capacity developed by APCC are implemented. According to the manager of case five, the incorporation of these SIS is necessary because the advanced capability of these specialised systems provides a sophisticated monitoring and management tool set. The SIS in case five has an executive blackboard that enables managers to review and manage their entire infrastructure. For instance, it automates and transforms the cooling infrastructure into a "super intelligent platform" by synchronising the outside and inside temperature and shifting the load between gas and free-air cooling systems. The system helps the managers to adjust the cooling capacity based on the changing temperature, workload and equipment conditions.

Table 3.2: A Summary of the SIS volume indicators from the five data centres

Case No.	**1**	**2**	**3**	**4**	**5**
SIS volume					
Number of Sensors	5-10	NG*	30+	5-10	60+
Types of Sensors					
-*Temperature*	✓	✓	✓	✓	✓
-*Humidity*	✓	✓	✓	-	-
-*Airflow*	✓	-	-	-	✓
-*Waterflow*	✓	-	✓	-	✓
-*Powerflow*	-	✓	-	-	✓
-*Smoke*	✓	✓	✓	✓	✓
-*Infrared*	✓	✓	✓	✓	✓
-*Odour*	-	-	-	-	✓
SIS Type					
- BMS	✓	✓	✓	✓	✓
- InfraStruXure Central	-	-	-	-	✓
- InfraStruXure Management	-	-	-	-	✓
- InfraStruXure Capacity	-	-	-	-	✓
- Nimsoft Server Monitoring	✓	-	-	-	-

*NG= not given

In terms of diversity, four areas of SIS application have been identified — *facility, cooling, power and computing resources management*. Therefore SIS diversity can be defined as the number of data centre functional areas that are supported by SIS. Facility management refers to the security, safety, lighting and auxiliary systems of the data centre physical building. Cooling management refers to internal climate control in the data centres including Computer Room Air Conditioning (CRAC), HVAC and Water-Chiller plants. Power management refers the delivery and distribution of primary and secondary power systems in the data centres including Power Distribution Units (PDU), Switchboards, Power Generators and Uninterruptable Power Supply (UPS). Computing resources management refers to the IT equipment used for performing the computation functions in the data centres including servers, network, storage, peripherals, and back-up devices.

The findings indicate that while SIS are mostly applied in facility, cooling and power management, they are less used in computing resources management. For example, in reference to facility, cooling and power management, the manager of case one stated, "*I can't imagine a data centre that wouldn't make use of sensors*." However there are differences in terms of the granularity of the SIS use in cooling and power management. While case one applied SIS for monitoring energy consumption at the entire data centre level, cases two, three and four have more detailed applications that measure the energy at the CRACs levels. Case five, in addition to these applications, extends it to cover the energy measurement of the rack. SIS application in case five includes reading the measurement from PDUs, providing a wider view and an accurate measurement for the power activities of the entire data centre. SIS use for computing resources management appears to be very rare. Case one is the only data centre that has applied narrow SIS use for IT assets management limited only to the monitoring function and with no additional automated task beyond that. This finding contradicts the potential capabilities of SIS reported in theoretical and experimental research. An interviewee commented that '*It is conceivable, but in my view, it is a very long shot*'. Table 3.3 provides a summary of the findings from five data centres in respect to SIS diversity.

Table 3.3: A Summary of the SIS diversity indicators from the five data centres

Case No.	**1**	**2**	**3**	**4**	**5**
SIS diversity					
Facility Management	Yes	Yes	Yes	Yes	Yes
Cooling Management	Yes	Yes	Yes	Yes	Yes
Power Management	Yes	Yes	Yes	Yes	Yes
Computing Management	Yes	No	No	No	N/A

In terms of intensity, the interviews have identified two types of intensity: use intensity and integration intensity. For use intensity, four important functions of the data centre facility, cooling, power and computing resources management were identified**.** These are monitoring, analysing, and automating functionalities. These functionalities constitute the functional hierarchy of SIS as depicted in Figure 3.1. This hierarchy places monitoring as standard functionality, analysing as second level of use and automating as the most advanced functionality. Therefore SIS *use-intensity* can be defined as the extent to which SIS functionalities are used in performing the business processes of each functional area identified above. For integration intensity, three types of integration of SIS were identified including integration with existing ICTP platform, integration with existing CSSP platform, and integration with other IS used in the data centre. Therefore SIS *integration-intensity* can be defined as the extent to which existing SIS are integrated with ICTP platform, CSSP platform and other IS.

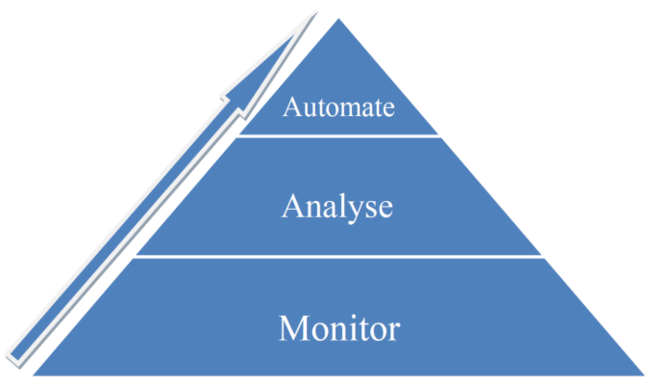


Figure 3.1: The SIS Functional hierarchy

The SIS functionalities that are used in performing the business processes include monitoring, analysing, and automating functionalities. 'Monitoring' refers to the process of observing the behaviour and status of the facility, cooling, power and ICT resources within the data centre without performing additional tasks. In this function the system operates in the background and the data centre operator can access the system any time and view the real-time or historical readings when desired. 'Analysing' refers to the process of automatically diagnosing the behaviour of monitored data centre objects, and performing certain checks and evaluations in order to understand the cause and effect of any changes in the behaviour. This function represents the data processing phase and uses the real-time and historical data of the monitored object together with some predefined parameters as inputs for processing. 'Automating' refers to the process of executing the decision-making process in respect to the data centre business functions with the substitution of human efforts. This function automatically performs actions such as triggering or activating equipment or processes.

Table 3.4: A Summary of the SIS intensity indicators from the five data centres

SIS Use Intensity	Case ID	Functional Area			
		Facility	**Cooling**	**Power**	**Computing**
Monitoring	1	High	High	Very Low	Very Low
	2	High	High	Medium	No use
	3	High	High	Low	No use
	4	Very High	High	Very Low	No use
	5	Very High	Very High	High	N/A
Analysing	1	Medium	Low	Very Low	Very Low
	2	Medium	Low	Low	No use
	3	High	Low	Very Low	No use
	4	Medium	Medium	Very Low	No use
	5	Very High	High	Medium	N/A
Automating	1	Medium	Medium	No use	No use
	2	Medium	Medium	Very Low	No use
	3	High	Medium	No use	No use
	4	High	High	No use	No use
	5	High	Very High	Medium	N/A

N/A= Not Applicable

In three out of the five cases (cases one, two and three), the application intensity of SIS was more or less the same. These data centres use SIS to monitor and analysis, and in less occasions to automate the different processes of the cooling infrastructure management. Case four extends this and uses its SIS to automate the process of shifting the load between chillers. Case five shows relatively higher utilisation of SIS as it had invested in customised BMS together with specialised SIS. This has allowed the transformation of most of the infrastructure into a smart platform. According to the manager of case five, '*We use [our SIS] to monitor the temperature and humidity of the room and racks (front to back), accesses to and security of the rack doors, airflow of the cooling system, water flow, power generators, the status of the batteries, the status and power activity of the UPS, power into/out of the main switchboard, the sub-distribution board, the power draw on each rail and all phases of power delivery to each rack and each UPS ... and from an automation perspective ... all of those tasks are fully automated ... to the point we can remotely start* *generators and things from home*.' Table 3.4 provides a summary of the findings from five data centres with respect to the SIS intensity.

3.3.1. Factors That Influence the SIS Use in Data Centres

After establishing the extent of SIS use in the five data centres, some of the factors that explain the current trends were also explored, as summarised in Table 3.5. These factors can generally be classified into technological (that is, SIS complexity affordability, reliability and compatibility), organisational (such as data centre green strategy, SIS know-how of manager, and data centre governance) and data centre particulars (infrastructure requirement, data centre type and age) and environmental (such as regulatory requirement) factors.

3.3.1.1. Technological factors

Based on the observations, perceived SIS complexity, perceived affordability, perceived reliability and SIS compatibility are identified as the technological factors that influence the volume, diversity, and intensity of SIS. The perceived complexity of broadening and deepening the use of SIS beyond the traditional application is found in some cases to have a negative effect on the diversity and intensity of SIS. The managers of cases one and three have reported complexity as a number one issue not to extend the use of SIS beyond the facility and cooling management. The manager of case one commented that every data centre has unique equipment and configurations and needs to be handled on a case by case basis which makes it complex to integrate SIS into existing platforms. Case three's manager noted that '*extending the intensity of our existing SIS for performing advanced power management would push the systems beyond their capability and could compromise the platform or create unintended outcomes*'.

He continued that all the IT assets hosted in the facility are owned by external clients which make it complex for integrating IT asset management together with the other management areas using one comprehensive SIS in the data centre. On the other hand, the managers of cases two and five have a broader understanding of sensor developments and advanced SIS applications with a lower perception of complexity. This suggests that the perception of complexity might relate to SIS know-how of the manager.

Table 3.5: A Summary of the identified factors of SIS assimilation in the five data centres

Case No.	**1**	**2**	**3**	**4**	**5**
<u>**Key Factors for Assimilation**</u>					
Technological					
Perceived SIS Complexity	✓		✓		
SIS Affordability		✓	✓	✓	
Perceived Reliability	✓	✓	✓	✓	✓
SIS Compatibility			✓		
Data Centre Particulars					
Infrastructure Requirement	✓	✓	✓	✓	✓
Data Centre Age	✓	✓	✓	✓	✓
Data Centre Type			✓	✓	✓
Organisational					
Green IT Policy		✓			✓
SIS Know-how of Manager			✓		
Data Centre Governance		✓			✓
Environmental					
Regulatory Requirement	✓	✓	✓	✓	✓

In four out of the five cases, the perceived SIS cost was one of the significant factors that affected wider SIS use. The manager of case two commented, '*We can have SIS that could do thermal dynamics and show what each rack is consuming, and turn your air conditioning up and down. We haven't gone down that path, it's just too expensive*.'

The case four manager added, '*In order to install these systems, we would need to replace all our PDUs, power boards, and then interface it into the system. I looked at the cost: that was going to be $300,000 to replace all the power systems, buy the software and incorporate it. It's just not going to happen.*'

All respondents agreed that the decision to buy new SIS always involves buying additional products/systems or changing the existing ones, due to compatibility issues. The case study suggests that the perceived SIS reliability influences the SIS intensity. In cases two, three and four, the managers perceived lower reliability of SIS for automating the performance of some of the tasks especially within the areas of power management and IT asset management. The case two manager stated, '*We have to do the tasks manually because we* *don't really want the system to do it automatically ... We want to find out whether the sensor is faulty ... If suddenly all your sensors go off, we've got a major problem in our room*.'

It seems that these three cases were uneasy about using SIS for managing and automating mission critical facilities. However, this was not the case for the managers of cases four and five. This variation is due to the actual realisation of SIS benefits, infrastructure compatibility, and the accumulated experience of use. In other words, a greater level of actual SIS utilisation led to a better perception of its reliability. Only case five has integrated different SIS within air/cooling and power platforms. Although case one has no integration, the manager stated, '*There will be no problems if we want to integrate it; it could be integrated because the output of these sensors is quite flexible*.' However, the manager of case five argues that, '*Although others might say they don't want to integrate, they actually can't ... because their infrastructure is not compatible*.'

This is because the majority rely on the BMS to do all of the jobs. In addition, most of the computing and SIS products are not standardised in terms of interoperability. '*We acquire our infrastructure from one vendor, so all our platforms are compatible*,' said the case five manager. This might explain why case five has achieved better SIS integration. However, the manager of case two argued that '*the problem with this strategy is that you're being hooked into one vendor*.' The case three manager stated, '*All our racks are sensors-based, but we do not utilise them practically ... however, if our client wanted to, then we would*.' This suggests that higher SIS compatibility with existing infrastructure is positively associated with the level of SIS assimilation.

3.3.1.2. Organisational factors

The study has identified some organisational factors that influence the assimilation of SIS. The most important ones are green IT policy, SIS know-how of manager, and data centre governance. Green IT strategic orientation refers to the existence of green IT policy in data centres, or within the overall organisation and influences the level of SIS use. Only case five had a green IT policy and it has achieved the best state of SIS utilisation. Case two, which had an active energy efficiency initiative including the installation of energy meters, purchase of mostly efficient systems, and retirement of inefficient systems, to improve the energy efficiency by 20% within the next three years, has recorded a high level of willingness to assimilate SIS in the very near future. The manager of case two says, '*There's a sensor-based system for power management called Energy Wise that's done by CISCO and we're looking at that at the moment*.'

The SIS know-how of managers was found to influence their willingness to extend the level of SIS use. Though case three can be ranked as the second best position in infrastructure readiness for assimilating SIS, the data centre manager of case three has a lower level of knowledge about SIS features and capabilities, which was also associated with lower level of SIS use. The managers of cases two and five had good understanding of sensor capability and development of SIS platforms in the market. The manager of case five commented, '*You would be talking to a lot of data centre operators and they don't even know what we are talking about here ... For them, it is just a big black hole that they keep pumping the power into.*'

This suggests that managers' know-how of SIS is positively associated with their ability to determine the best SIS volume that needs to be acquired, the diversity of functions that can be supported, and the level of SIS intensity. The data centre managers of cases two and five have reported a relationship between the type and intensity of SIS, and the responsibility and accountability of data centre managers for energy efficiency. *'The university is looking very seriously to the power consumption of our data centre and started to install power meters [sensor based] in all buildings ... so we [data centre] have got to look at ways for reducing the energy consumption ... our goal is to get that as low as possible*', says the manger of case two.

Further, the clients that case five hosts have demanded the data centre maintain energy transparency in its operations, which in turn drives case five to assimilate SIS. This suggests that data centres governance with respect to the accountability and responsibility of energy efficient and transparent operations is positively associated with the level of SIS assimilation.

3.3.1.3. Environmental factors

The regulatory environment within which data centres operate and the requirements for regulatory compliance can foster the assimilation of technologies. In such conditions, regulatory environment can influence the volume, diversity, and intensity of SIS. All respondents stated that compliance to regulatory requirements such as emission reporting will push the entire data centre industry to opt for the adoption of SIS in the near future. Whereas case five has already applied SIS for this purpose, case two is looking to utilise SIS for the same objective in the very near future. This supports the proposition that regulatory requirements might directly or indirectly lead to an accelerated and higher SIS assimilation in the data centres.

3.3.1.4. Data centre particulars

In addition to the TOE antecedents, the study has discovered that the characteristics of the data centre infrastructure, the age of data centre and the type of data centre are additional factors that influence the assimilation of SIS. The characteristics of a data centre's infrastructure influence the decision of choosing the appropriate system required to support that infrastructure. In particular, the type of equipment or system used, the method used in operating equipment or systems, and the special requirement to manage the operations of that equipment or systems influence the volume, diversity and intensity of SIS. The type of equipment or system refers to the unique characteristic of an equipment or system that operates in the facility, cooling, power and computing resources management areas. The method refers to the techniques used to configure the systems of the four main data centre areas. The special management requirement refers to the set of functions required to administer and manage the operations of equipment or system and method used.

In most cases, the method used in operating a system influences the volume, whereas the management requirement of a system influences both volume and intensity. For instance, cases one and four used only the water-based CRAC cooling system with room-based cooling and raised-floor method. Most CRAC units are set with one sensor that reads the temperature of the entire room and therefore only one sensor is used per room in the two data centres. The CRAC units were designed to operate automatically based on the reading from the one sensor, and thus the special management requirement was limited to monitoring, reporting and alerting about the behaviour of the system with only some minor control functions. Although both cases four and one have adopted the raised-floor method, case four did not use underfloor airflow sensors like case one. Case five uses water-chillers plant and free air cooling systems coupled with direct cooling to the 'pods'. Water-chillers systems require different sets of sensors types such as water-flow, water pressure, and water leakage sensors. Free air cooling requires another set of sensor types such as outside temperature, humidity, airflow, and odour. Direct cooling via pods requires the diffusion of a large amount of sensors at each rack to ensure the effective cooling delivery. These systems have special management requirements with high intensity of SIS functions use. Thus case five uses four SIS to effectively handle the operations of the infrastructure. This suggests that the more the data centre is to have an infrastructure that needs higher observation and control, the higher the level of SIS assimilation.

In respect to the age of data centre, case five, which has a newly built facility, has a well-integrated SIS platform whilst recording the highest level of SIS volume, diversity and intensity. The other cases have yet to integrate SIS. This is partly because their infrastructure is either an old platform (which has retrofit limitations) or is comprised of diverse equipment and applications from different manufacturers (which are not fully compatible). This suggests that the age of data centre can affect a data centre's capability to integrate SIS and, hence, its overall level of SIS utilisation.

In terms of business scope, data centres can be classified into three types: corporate data centres, co-location data centres, and fully-managed data centres. Corporate data centres are usually large data centres owned by an organisation for the purpose of supplying computation and information functions specifically to that organisation. In co-location data centres, organisations (clients) rent a space in a shared data centre facility owned by another organisation and bring their own IT equipment into the facility. In fully-managed data centres, organisations (clients) outsource their entire IT resources and host their IT requirements in servers and a facility that is fully owned by another organisation. The type of data centre influences the level of SIS use and the application scope of the SIS. For instance, in co-location data centres, the data centre is mainly responsible for managing the cooling chillers, HVAC systems, power generation, network links and physical security. Thus, the integration of the CSSP and the ICTP is neither necessary nor easily manageable.

Furthermore, in co-location data centres, the application scope becomes narrowed with the exclusion of computing infrastructure.

3.4. Summary and Implication

The main objective of the pilot study was not to identify all the factors that influence the assimilation of SIS, but rather to enhance the researcher's understanding about the current state of SIS application in data centres, what shape the use of SIS, and how data centre context would influence SIS assimilation. The pilot study was also intended to get information that can improve the definitions and measurements of the key concepts of the research.

The findings revealed that there is a significant variation in the assimilation of SIS in data centres. The study showed the utility of Massetti and Zmud's (1996) facets of assimilation and Ravichandran's (2000) and Gupta and Whitehouse's (2001) modifications for studying the application of IS in data centres. The findings also identified that three SIS functionalities, that is monitoring, analysing, and automating can be used within the two data centre platforms, that is ICTP (servers, network and storage) and CSSP (site, cooling and power management). The integration between these platforms and other IS influence a data centre's ability to extend SIS usage. In particular, the results suggested that volume, diversity, use-intensity and integration-intensity can be good indicators for understanding SIS assimilation in data centres.

The implications of these findings are three-fold: SIS assimilation, factors to SIS assimilation and items operationalisation. In terms of assimilation, the study helped the researcher to understand the current status of SIS in data centres. The findings led to the formalisation of SIS assimilation constructs which has not been explored before. Building on insights from existing approaches for technology assimilation, the study found that SIS assimilation can be measured using four dimensions including SIS volume, SIS diversity, SIS use-intensity and SIS-integration-intensity.

In terms of factors to SIS assimilation, the study allowed the researcher to outline some of the relevant factors in the research context. Guided by the TOE model, the study identified a pool of factors including technological, organisational, data centre particulars and environmental factors. These factors were scrutinised and discussed with the PhD supervisors, and the most relevant factors will be used as an input to the development of the conceptual framework and the development of research hypotheses. In terms of items operationalisation, the study helped the researcher to develop the research instrument. The findings therefore will be used to develop the question needed to capture the items of new factors and also to accommodate the findings to redefine some of the measurement of common factors to the technology assimilation (e.g. relative advantages, top management etc.).

Based on the findings of the pilot study and the literature review, in the next chapter the development of the conceptual framework and the hypotheses will be presented.

CHAPTER 4

4. THEORETICAL BACKGROUND AND HYPOTHESES DEVELOPMENT

4.1. Introduction

This research is intended to understand both the factors that explain the assimilation of SIS and the operational and environmental value of assimilating SIS. Therefore it is essential to draw from not only theories that explain technology assimilation but also those that help to understand the value of technology in both operational and environmental terms. In addition, because the research is also concerned with the effect of the natural environment on the extent of SIS use, it was important to derive insights from natural environment-based theory in order to extend the external context of classical innovation theories.

This chapter employs the theories of technology use, technology value, institutional and natural environment and findings from the exploratory study to develop an integrated model for SIS assimilation and value. The chapter is a composite of three main sections that are aligned and closely linked, namely, theoretical background (4.2), theoretical framework of SIS assimilation and value (4.3), and hypothesis development (4.4). Each section forms a foundation for the following section.

4.2. Theoretical Background

The IS literature reviewed in Chapter 2 (e.g. Karahanna et al., 1999; Cho and Kim, 2002; Raymond et al., 2005; Liang et al., 2007; Saraf et al., 2012) revealed that the most commonly used theories for studying organisational assimilation of technology are diffusion of innovation theory (DOI) (Roger, 1983), technology-organisation-environment framework (TOE) (Tornatzky and Fleischer, 1990) and institutional theory (DiMaggio et al., 1983). In addition, the literature (e.g. Zhu and Kraemer, 2005; Raymond et al., 2005; Nishant et al., 2011; Dao et al., 2011; Picoto et al., 2012) reveals that the most commonly used theory for studying IT assimilation value and Green IT/IS value as well as the factors that could affect the value of technology innovation is the resource-based view theory (RBV) (Barney, 1991; Peteraf, 1993; Penrose, 1995). On the other hand, the natural resource-based view (NRBV) model developed by Hart (1995) provides a good starting point to extend the environmental context of IS innovation theories by including the natural environment dimension. NRBV was used to understand how the choice of Green IT affects firms' ability to realise the value from investments in Green IT (Corbett, 2010). Although the NRBV focuses on a firm's value and competitive position (e.g. strategic natural environmental values), it also provides a strong theoretical foundation to capture the constraints and challenges posed by the natural environment.

Therefore, the foundation of the theoretical framework for the present research as indicated in Figure 4.1 and Table 4.1 is comprised of elements from the Diffusion of Innovation theory (DOI), Technology-Organisation-Environment (TOE) framework, Institutional theory, Resource-Based View theory (RBV) and Natural Resource-Based View (NRBV) theories. This section lays down the theoretical background of the research framework to be pursued in the study.

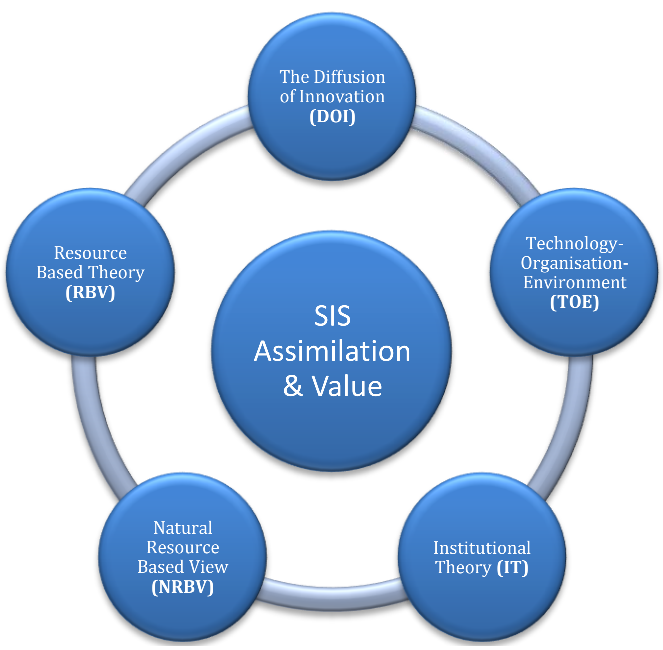


Figure 4.1: The theoretical foundation of the current research model

Table 4.1: The foundation of the research theoretical framework

	DOI	TOE	Institutional	RBV	NRBV
Seminal reference	Roger, 1983	Tornatzky and Fleischer 1990	DiMaggio et al., 1983	Barney, 1991; Peteraf, 1993; Penrose, 1995	Hart, 1995
Main Argument	Perceived attributes of technology and firms' characteristics influence the adoption and use of technology innovation	The use of technology can be influenced by three key factors: technological, organisational and environmental context	The use of technology can be influenced by institutional isomorphism	Organisations can create value, by acquiring heterogeneous resources and capabilities that are valuable, rare, inimitable and/or imperfectly mobile	Developing organisational capabilities is rooted in the capabilities that facilitate the environmentally sustainable economic activity
Explanatory Variables	relative advantage, compatibility, complexity, trialability, observability, size, slack resources, centralisation, formalisation, interconnectedness	available technology characteristic, size, slack, structure, communication	normative pressure, mimetic pressure, coercive pressure	unique heterogeneous resources and capabilities	pollution prevention, product stewardship, sustainable development
Implications for SIS Assimilation and Value	The theory helped to identify the following factors: relative advantage, compatibility, complexity, perceived risk size, top management support	The theory provided insights to identify the external forces such as energy pressure, environmental preservation	The theory helped to identify the following factors: normative pressure, coercive pressure	The theory provided insights to identify the value facilitating factors such as SIS unique functionalities, know-how of manager as well as operational value of SIS	The theory provided insights for the effect of natural environment including data centre green policy, energy pressure, environmental preservation pressure as well as environmental value of SIS

4.2.1. The Diffusion of Innovation Theory

The Diffusion of Innovation theory (DOI) (Roger, 1983) is a widely recognised theory used by many researchers within the IS discipline to address the use of innovation. DOI posits that both perceived attributes of technology and firms' characteristics influence the adoption and use of technology innovation (Roger, 1983). DOI therefore identifies two groups of factors — technological and organisational — that either encourage and/or inhibit the assimilation of technology innovation. *The technological context* refers to relative advantages, compatibility, complexity, trialability, and observability. *The organisational context* refers to firms' centralisation, complexity, size, slack, formalisation, and interconnectedness.

DOI has widely been used in the IS research to study the use of technology (Karahanna et al., 1999; Purvis et al., 2001; Ranganathan et al., 2004; Wu and Chuang, 2009; Picoto et al., 2012). Roger's model provides a concise overview of many considerations that influence the innovation diffusion process. However, it has received criticism due to its limitation to explain complex technologies. As a result researchers continue to investigate other contexts that could influence the technology innovation and combine them with Roger's theory to get richer models that have better explanatory power (Prescott and Conger 1995). Therefore, new models and theories have emerged as an extension of DOI to explain the innovation of technology for firms with emerging and high complexity natures. One of such models is the TOE framework by Tornatzky and Fleischer (1990).

4.2.2. The Technology Organisation and Environment (TOE) Framework

The Technology-Organisation- Environment (TOE) framework developed by Tornatzky and Fleischer (1990) provides a good theoretical underpinning to understand the key factors that could affect the assimilation of technologies at the organisation level. The foundation of the TOE model stems from the diffusion of innovation (DOI) theory developed by Roger (1983). The TOE identifies three key factors that influence the assimilation of technology innovation: *the technological context* (refers to existing and new technology), *the organisational context* (refers to firms' measurable characteristics such as size, scope and resource availability), and *the environmental context* (refers to the realm in which an organisation performs its business such as industry, market, and government regulation) (Tornatzky and Fleischer, 1990). Tornatzky and Fleischer's (1990) model extended the DOI by adding the environmental context as a third factor together with Roger's two factors of technology and organisation. This addition was very important for addressing innovation use in a complex environment in which the external environment could provide both constraints and opportunities (Tornatzky and Fleischer, 1990).

The environmental context refers to the external environment in which firms conduct their business such as industry, market participants, and government (Tornatzky and Fleischer, 1990). This extends to any factor or source that could directly or indirectly motivate and/or inhibit firms' operation or decision towards innovation (Tornatzky and Fleischer, 1990). The TOE framework has sufficient empirical support in IS research to study the implementation and use of technology such as object-oriented technology (Cho and Kim, 2002), web technology (Raymond et al., 2005), e-business usage (e.g. Zhu and Kraemer, 2005; Hsu et al., 2006), ERP assimilation (Kouki et al., 2010), e-market (Banerjee and Ma, 2011) and Green IT (e.g. Bose and Luo, 2011), and has utility for studying the use of most complex innovations (Zhu et al., 2004) such as SIS.

The majority of the TOE-based research has identified a number of factors that are specific to their research setting such as the expectation for market trend, maturity of technology, intensity of new technology education, satisfaction with existing technology (Cho and Kim, 2002), financial commitment (Zhu and Kraemer, 2005), manufacturing context, manufacturing technologies, networking intensity (Raymond et al., 2005), trading partner pressure (Hsu et al., 2006), reward system, consultant effectiveness and vendor support (Kouki et al., 2010). In other words, by building on the TOE structure, researchers can develop the relevant factors that are specific to their research context and focus only on the most relevant factors. In addition, some researchers (e.g. Cho and Kim, 2002; Wu and Chuang, 2009) argue that some of the technological, organisational and environmental factors that appear to be more important indicators for the adoption stage could be less important or irrelevant to the post-adoption stage. Therefore, researchers should carefully select the important factors to their research context. As such, the TOE has a generic nature that makes it suitable to study different types of technology innovation and accommodates context-based constructs. Thus it is useful to be applied as one of the conceptual foundations for investigating SIS assimilation.

Although the TOE appears to be robust, the researcher argues that it is not adequate to cover emerging issues such as environmental sustainability (e.g. Bose and Luo, 2011). Therefore, this research extends the TOE and redefines the TOE environmental context (e.g. market forces and regulatory pressures) to include the natural environment by drawing insights from the NRBV (Hart, 1995) as discussed in a later section. Furthermore, because the external environment in which firms conduct their business is always influenced by institutional isomorphism (DiMaggio et al., 1983), investigating the influence of institutional pressure becomes very important in the study of organisational assimilation of technology.

4.2.3. Institutional Theory

The institutional theory (Meyer and Rowan, 1977, Zucker, 1987; DiMaggio et al., 1983) provides a useful theoretical lens to study the use of technology (Chatterjee et al., 2002). It helps to understand the critical role played by institutional forces beyond the market in making organisations responsive to the interests of others (Scott, 2003). Institutional theory offers a rich and complex view of how organisations become homogeneous under social pressures; sometimes from within the organisation itself and at other times due to external sources (DiMaggio et al., 1983). These pressures can direct an organisation's attention to widely practiced elements, such as professional certification, and well-established activities across other firms in the industry. The institutional forces typically refer to three basic types of institutional isomorphism: normative, coercive and mimetic pressure (DiMaggio et al., 1983).

Normative pressure refers to the conditions, methods and standards set by a group of professional members of a particular occupation, which enable them to establish and control their practices (Larson, 1977; Collins, 1979). Coercive pressure results from interdependence conditions in which pressure is exerted on an organisation by a parent organisation or by dominant stakeholders within which the organisation executes its business (DiMaggio and Powel, 1983). Mimetic pressure results from mimicking actions of other organisations by a firm responding to uncertainty or poorly understanding technology (DiMaggio and Powel, 1983). Technology assimilation has been observed in previous technologies (e.g. ERP) as the objects and the carriers of external institutional forces (Liang et al., 2007). Thus, institutional forces may not only facilitate the assimilation of IS but may also have a powerful effect on how these systems are configured during actual use (Gosain, 2004).

Institutional forces have been widely used in studying the assimilation of technology (e.g. Chatterjee et al., 2002; Banerjee and Ma, 2011; Bharati and Chaudhury, 2012; Saraf et al., 2012), Green IT (e.g. Butler, 2011), Green IS (e.g. Chen et al, 2008) and data centres (e.g.

Karanasios et al., 2010). According to Damanpour (1991), communications with external forces may be as important in the later stages as it was during the early phases of an innovation's life cycle. Hence, institutional theory is highly relevant in studying the assimilation of SIS.

4.2.4. The Resource-Based View (RBV) Theory

Resource-based theory (RBV) can be a useful starting point for identifying factors that could affect the value of technology innovation (Kraaijenbrink et al., 2010). RBV proposes that organisations can create value, maintain competitive advantages and achieve long-term performance by acquiring and controlling heterogeneous resources and capabilities that are valuable, rare, inimitable and/or imperfectly mobile across organisations (Barney, 1991; Peteraf, 1993; Penrose, 1995). RBV's basic concepts are fundamentally based on resource and value. The foundation of RBV emerged as a complementary theory to the industrial organisation view developed by Bain (1968) and Porter (1979). The industrial organisation view posits that factors which could influence the organisation performance are located in the industry structure (external source) in which the organisation conducts its business. RBV aims to complement the industrial organisation view and examine the organisation's structure (internal source) and explain why the performance might differ from one firm to another within the same industry (Barney, 2002).

RBV has been used in IS research for studying the IT business value and analysing IT capabilities, IT assets and organisation skills that link information technology capability to firm performance (e.g. Bharadwaj, 2000; Ross et al., 1996; Santhanam and Hartono, 2003; Zhu and Kraemer, 2005).

The literature revealed important links between the extent of actual use of IS and improved firm's performance (Ranganathan et al., 2004), creation of e-business value (Zhu and Kraemer, 2005), firm's market performance (Raymond et al., 2005), productivity (Rai et al., 2009), market and operational performance (Picoto et al., 2012). It also revealed a link between Green IT and firm's market value (Nishant et al., 2011) and development of sustainability capabilities (Dao et al., 2011). IS assimilation studies (e.g. Ravichandran 2004; Zhu and Kraemer, 2005; Rai et al., 2009; Picoto et al., 2012) found that higher degrees of technology usage is associated with improved business performance. Their findings confirm the early research postulation (e.g. Devaraj and Kohli, 2003) that actual use could be a missing link to the payoff of IT. Since there is linkage between the technology assimilation and value creation, which was been pointed out by previous research, RBV forms one of the theoretical legs of this research.

4.2.5. The Natural Resource Based View (NRBV)

With the increasing global concern towards the natural environment, it is inevitable that current and future businesses will be challenged to create and maintain environmental sustainability strategies (Gladwin, 1992; Hart, 1995). Therefore, Hart (1995) incorporates the natural environment into the RBV given the increasing magnitude of natural environment on a firm's development capability. He noted that, "*one of the most important drivers of new resources and capability development for firms will be the constraints and challenges posed by the natural (biophysical) environment"* (Hart, 1995, p. 989).

The foundation of the Natural Resource Based View (NRBV) model stems from the RBV theory developed by Barney (1991), Peteraf (1993) and Penrose (1995). The NRBV developed by Hart (1995) postulates that "strategy and competitive advantage in the coming years will be rooted in capabilities that facilitate environmentally sustainable economic activity" Hart, 1995, p:991. Researchers increasingly turned to use NRBV as the dominant natural-resource theoretical paradigm, to understand how the environmental strategy of organisations creates economic value (Sharma and Aragón-Correa, 2005), and how the investment of Green IT creates business value (Corbett, 2010). Previous studies suggested that NRBV can be used for studying the natural environment dimension of Green IS and IT practices (Chen et al., 2011). The NRBV provides a good starting point for understanding both the impact of SIS assimilation on the environmental performance of data centres as well as to draw insights for identifying the factors related to SIS assimilation in data centres. Therefore, the use of NRBV in this study is twofold.

First, NRBV is used to understand the impact of SIS on the performance of data centres in environmental terms. Given that SIS is promoted as one of green IS solutions, the NRBV was assumed to be relevant for this study to identify SIS for improving environmental performance. NRBV posits that developing rare, valuable and sustainable capabilities is rooted in the heterogeneous resources that facilitate environmentally sustainable economic activity (Hart, 1995). It can therefore provide better understanding of the environmental value and competitive advantages that can be derived through incorporating the natural environment (biophysical) aspects into a research model (Chen et al., 2008; Corbett, 2010). Thus, the use of NRBV can help organisations to obtain strategic environmental values such as reducing environmental burden of an organisation's development, reducing emission effluent and improving products' lifecycle, (Hart, 1995), This implies that through more extensive use of SIS capabilities, data centres would be able to create environmental values, such as reducing environmental footprint and improving IT lifecycles.

Second, in addition to the NRBV's contribution to the research model for understanding the impact of SIS on the environmental performance, the study draws insights from two environmental strategies proposed under the NRBV. Although NRBV is a theory of environmental value, it also offers argument about the growing effect of environmental sustainability and that future businesses will be challenged by the natural environment considerations (Hart, 1995). To get more understanding about the role of the natural environment dimension in the research model, the concepts underlying product stewardship and pollution prevention strategies were found to be relevant to the data centres businesses. As such, borrowing insights from NRBV concepts can therefore help identify and develop the natural environment dimension that could drive the use of SIS at the organisation level. Thus, it was decided that NRBV would be useful to redefine the organisational context (e.g. internal policies that promote Green IT), and natural environment context (e.g. external policies that help to prevent the CO2 emission and use of non-renewable energy sources).

Although previous technology use models of IS research such as TOE (Tornatzky and Fleischer, 1990), use the term 'environment', the term was not used to refer to the natural environment, rather to the dynamics of market forces and regulatory pressures. This implies that although the TOE and DOI can help in studying the antecedent factors that explain the assimilation of SIS in data centres, they need to be extended to cover emerging environmental sustainability issues. Despite the increasing importance of environmental sustainability, this factor has only recently recognised in IS research (Chen et al., 2008). The challenges posed by the natural environment suggest that it can impact several domains such as strategic orientation (Cravens et al., 1987), marketing (Menon and Menon, 1997), and corporate strategies (Banerjee, 2002). The growing importance of natural environment issues requires the inclusion of this factor to understand both the drivers for innovation (Chen et al., 2008; Molla and Abrashie, 2012) as well as the value of the innovation in IS research (Dao et al., 2011; Schmidt et al., 2011).

The term ‘natural environment’ refers in general to biodiversity, natural resource and pollution (Mebratu, 1998). Biodiversity includes all forms of the planet’s ecological life such as humans and wildlife; natural resource refers to land, water, atmosphere, and any component upon or within them (Vaughn, 2007); and pollution refers to emissions, effluents and waste to the land or atmosphere (Hart, 1995). This study focuses on three environmental sustainability dimensions, namely, the orientation of an organisation towards Green IT, the external pressure resulted from the use of non-renewable energy, and the external pressure towards environmental preservation that could facilitate the use of SIS in the data centres.

The challenges posed by the natural environment can play significant role in shaping the organisational strategies. With the respect to the growing focus on data centres operations and their interrelated environmental sustainability issues, organisations with data centres facilities will be under pressure to create Green IT policies and increase their usage of Green IT. Therefore, NRBV product stewardship strategy can provide insights to understand this factor.

Furthermore, the increased consumption of non-renewable energy associated with carbon emission (EPA, 2007; Loper and Parr, 2007), and e-waste (Köhler and Erdmann, 2004; Garbin and Chang, 2009), are the most environmental challenges to data centres’ business (Daim et al., 2009) that is creating considerable environmental impact. As the pressure of global regulatory and institutions (such as the EPA, the European Union) on data centres is increasing, data centres become under more environmental preservation pressure. Therefore, concerns regarding current and future effects of these issues can impact the steadiness of data centre businesses and hence creates a stimulating driver for adoption (Loper and Parr, 2007; Zheng and Cai, 2011). As such, NRBV’s concept that future businesses will be challenged by natural environmental considerations provides insights for the identification of relevant driving forces in the data centre industry.

4.2.6. .Summary

The aim of this section was to build the foundation of the theoretical framework for the SIS assimilation and value. Having (a) the context of research in mind, (b) assimilation and value literature from chapter 2, (c) the evaluation of some relevant factors to data centres using exploratory study from Chapter 3, the section outlined the most relevant theories that can inform SIS assimilation and value. These include diffusion of innovation theory (DOI), technology-organisation-environment framework (TOE), institutional theory, resource-based view theory (RBV) and natural resource-based view (NRBV) theories. The next step is to extract the most relevant factors of these theories that can be used in the research model.

4.3. Technology-Organisation-Institution-Natural Environment (TOIN): A Theoretical Framework of SIS Assimilation and Value

The theories of technology innovation and value discussed in the previous section as well as the exploratory case studies (Chapter 3) led to four distinct groups of contextual factors that are relevant in understanding the assimilation and value of SIS, that is, technological, organisational, institutional, and natural environment contexts. According to Fichman (2000), future research in the area of IT innovation should endeavour to combine multiple theoretical streams into a more integrated view rather than merely relying on a single model or theory. In addition, despite the fact that researchers use different theoretical lenses to examine similar or relevant IS, researchers have extended and redefined the technological, organisational, institutional and environmental factors to account for other factors relevant to their specific research context (Fichman, 1992) (See Appendix 4a). Therefore, consistent with this trend, the present research proposes an integrated model that is built on different theoretical and contextual lenses that are derived from major theories on technology innovation use and value, as well as factors relevant to the context of research to identify the factors that influence the assimilation and value of SIS in the data centres.

Thus the theoretical framework of the study is an integrated framework that uses relevant constructs from *DOI* (Rogers, 1983), *TOE* (Tornatzky and Fleischer, 1990); *institutional theory* (Meyer and Rowan, 1977; DiMaggio et al., 1983), as well as innovation value models including *RBV* (Barney, 1991; Peteraf, 1993) and natural environment models including *NRBV* (Hart, 1995) and five exploratory case studies of Australian data centres. This leads to the introduction of Technology-Organisation-Institution-Natural Environment (TOIN) framework. The TOIN framework was a very important step in attempts to accommodate various dimensions that are relevant to the context of research, and because of the lack of framework in this regard.

In particular, DOI is used to conceptually ground the technological attributes of SIS. Thus, technological factors can influence the extent of SIS use. While DOI and TOE are used to conceptualise the organisational factors that include different characteristics, mechanisms, and structures that influence the propensity of technology innovation, the institutional theory helped to identify the external forces that might influence the assimilation of technology either directly or indirectly through influencing the organisational condition for assimilation. Furthermore, the NRBV is used to identify the environmental factors that might indirectly influence assimilation through organisational effort and strategies towards sustainability, whereas the RBV and NRBV are both used to identify factors that could affect the value of assimilation. The developed integrative research framework is depicted in Figure 4.2. According to the underlying concept of TOIN structure, the unique characteristic of the assimilated technology as well as the attribute of managerial knowledge offer valuable and heterogeneous resources and capabilities that facilitate the business performance of organisations in operational and environmental terms. TOIN posits that the attribute of technology, the characteristic, structure and strategy of organisation, and the institutional isomorphism create a chain of effects that could drive or inhibit the assimilation of technology innovation. In addition, it posits that the effect of institutional isomorphism as well as natural environmental forces on SIS assimilation that could drive the organisational efforts towards the successful assimilation of technology are fully mediated by the characteristic, structure and strategy of organisations.

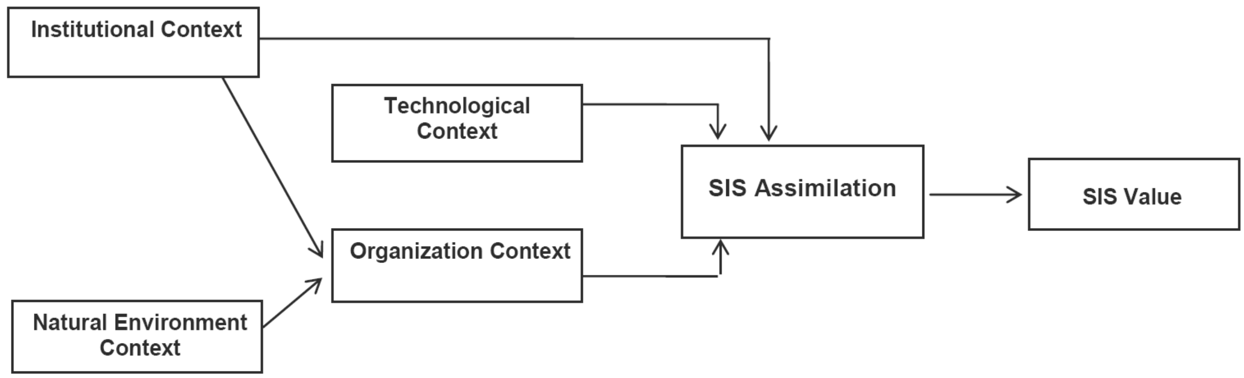


Figure 4.2: The general structure of the TOIN framework

4.3.1. Conceptualising SIS Value and Identifying Value Drivers

As discussed in chapter 2, SIS has unique and rare features that allow organisations to create and maintain valuable capabilities (e.g. Chong and Kumar, 2003; Diamond, and Ceruti, 2007; Fengzhong et al., 2010; Fraden, 2010; Hu et al., 2012). The SIS has several features and functionalities that can be used to generate positive impact on the performance of organisations. The SIS functionalities that were identified in Chapter 3 include monitoring, analysing, and automating. These functionalities are either not available through other systems or cannot be done effectively without the SIS (Middelhoek et al., 1995; Zhao and Guibas, 2004). One of the basic and unique SIS features is its monitoring capabilities that provide comprehensive and consistent overview about the state of any organisational platform (Meijer, 2008). Functions such as the comprehensive observation of the change of temperature, humidity, airflow, toxins, water flow, and occupancy within an organisation borders can only be done through SIS. The analysis and diagnostic capabilities embedded in most SIS, together with the real-time data, provide a unique architecture that is capable to report or recommend an action or control a particular operation based on the most effective conditions. Therefore, by assimilating SIS, data centres can add valuable capabilities that can support and improve the operations of the day-to-day business functions. IS impacts firm's performance in strategic, operational, managerial, economic and environmental terms (Bergeron and Raymond, 1992; Delone and McLean, 2004, Moore et al., 2005).

Building on insights from studies on data centre performance from sections 2.3.1 and 2.3.2 (e.g. Loper and Parr, 2007; Almoli et al., 2012), the advantages of SIS applications from section 2.5.1 (e.g., Chong and Kumar, 2003; Beloglazov et al., 2012) the studies of SIS application in data centres from section 2.6 (e.g. Watson et al., 2009; Liu and Terzis, 2012), IS value from section 2.7.3 (e.g. Raymond et al., 2005; Picoto et al., 2012) as well as the exploratory study, the impact of SIS use on data centres performance is categorised in this research into two dimensions: operational performance and environmental performance. The operational performance of data centre includes cooling and thermal performance, and power and energy performance of CSSP; and information processing performance of ICTP. The environmental performance refers to the efficiency of energy consumption and other associated environmental footprint. In addition to assimilation of SIS, SIS value creation and realisation within the context of data centres, however, need other requirements that need to be established (Zhu and Kraemer, 2005). The discussion in section 2.7.3, from chapter 2, section 3.3.2 from chapter 3 and next section 4.3.4 from this chapter, suggested that these could include supplementary factors including manager's knowledge on how, what and where to use SIS, and moderating factors of supplementary factors including time since implementation.

4.3.2. Conceptualising SIS Assimilation

The technology 'assimilation' construct has been defined in the IS literature in different ways. Previous studies on the use of innovation reviewed in Chapter 2 reveal that researchers have developed different dependant variables to measure the innovation use. For example, McGowan and Madey (1997) used volume, diversity and depth to measure the use of EDI. Chatterjee et al. (2002) used a scale from 0 to 9 to measure the Web assimilation. This shows that there is no consistent approach for measuring the technology assimilation dependant variable; rather, researchers employ a mixed methods approach by drawing insights from previous theories and IS research as well as adding measures specific or relevant to their research context.

However, a sample review of the IS literature (i.e. McGowan and Madey, 1998; Zhu and Kraemer, 2005; Son et al., 2005; Zhu et al., 2006; Liang et al., 2007) reveals most researchers draw from Massetti and Zmud's (1996) four facets of assimilation including *volume, diversity, breadth, and depth*, to develop the measurement of their dependant variable. Thus Massetti and Zmud's facet-based approach is applicable to inform the assimilation constructs in this study. Volume represents the percentage of an organisation's processes that are handled through a system. Diversity refers to the variety of business functions that are performed routinely through a system. Breadth represents the extent to which an organisation has used a technology to conduct routine functions. Depth refers to the degree of a system's functionalities that have been established in performing the business processes (Massetti and Zmud, 1996).

Although Massetti and Zmud's facet-based approach provided the basis for defining the dependant variable of SIS assimilation, the four facets in this approach could not be replicated precisely in the present research because of the context of the current study. Previous researches that have used Massetti and Zmud's approach argued that all the four facets are not applicable to their research context. Thus, some researchers limited the use to the most relevant facets to their studies. For example: McGowan and Madey (1998) used only volume, diversity, depth; Son et al. (2005) used volume and diversity; and Zhu and Kraemer (2005) used breadth and depth. Other researchers tended to render or redefine some of the facets to accommodate the nature of their research context if necessary, such as Ravichandran (2000) and Gupta and Whitehouse (2001) who use intensity instead of breadth and depth.

In accordance with previous research on technology assimilation that have used Massetti and Zmud's facet-based approach, the present research employed the most relevant facets to the research context using observation derived from exploratory study in section 3.3.1. As a result SIS assimilation is defined as the volume, diversity (Massetti and Zmud, 1996) and intensity (Ravichandran, 2000; Gupta and Whitehouse, 2001) of SIS use.

The *volume* refers to the total number of SIS used in the data centre (that is unique in functions and capabilities). *The diversity* refers to the number of data centre functional areas that are supported by SIS, including facility, cooling, power and ICT management. The *intensity* is comprised of two sub-constructs: *the use-intensity* and *integration-intensity.* The *use-intensity* of SIS refers to the extent to which SIS is used in monitoring, analysing, and automating the data centre facility, cooling, power and computing resources management functions. The *integration-intensity* of SIS refers to the extent of SIS integration with ICTP platform, CSSP platform and other IS.

4.3.3. Defining and Identifying Technological Factors

Technology attribute describes the characteristics of technology innovation (Roger, 1983). Roger indicates five attributes of technology innovation including relative advantages, compatibility, complexity, trialability, and observability (Roger, 1983).

A meta-analysis conducted by Tornatzky and Klein (1982) found that only the first three innovation characteristics — relative advantage, compatibility and complexity — have been related consistently to innovation adoption. Thus several researchers have only focused on examining the first three characteristics (Agarwal, and Prasad, 1998). Further, Table 4.2 provides a summary of relevant technology innovation research and the pattern of using DOI's five constructs.

Table 4.2: A list of relevant technology innovation research and the pattern of using DOI constructs

Authors	Journal Title	Dependent variables	DOI constructs				
			Relative Advantage	Compatibility	Complexity	Trialability	Observability
Premkumar, et al., 1994	Journal of Management Information Systems	EDI implementation	✓	✓	✓		
Karahanna et al., 1999	MIS Quarterly,	Adoption and continued use of Windows.		✓		✓	
Cho and Kim, 2002	Journal of Management Information Systems	Organisational assimilation of object-oriented technology	✓	✓	✓		
Bradford and Florin, 2003	International Journal of Accounting Information Systems	ERP implementation success		✓	✓		
Hsu et al., 2006	International Journal of Electronic Commerce	E-business use	✓				
Liao and Lu, 2008	Computers and Education	Adoption and continued use of e-learning websites	✓	✓		✓	
Wu and Chuang, 2009	Electronic Commerce Research and Applications	e-SCM diffusion (adoption. implementation, assimilation)	✓		✓		
Lai et al., 2010	Decision Support Systems	ERP assimilation	✓	✓	✓		
Frequency			7	6	5	2	0

Table 4.2 illustrates that, of the five DOI constructs, relative advantage, compatibility and complexity are the most widely used constructs in the IS innovation research. Whereas the first two characteristics always show a positive association, complexity is always negatively associated with technology assimilation. In addition, the literature on data centre shows that the adoption of innovation can be influenced by complexity and compatibility issues (Mukherjee et al., 2010; Kant, 2009). Further, the literature on the factors that influence the adoption of SIS from section 2.5.2 shows that perceived benefits (Huang, 2010), and compatibility (Lowry, 2002; Hafeez-Baig and Gururajan, 2009) effect the adoption of SIS. Consistent with the above literature, the present research focuses on relative advantage, complexity and compatibility of SIS. Though most of the above literature falls in the area of adoption and implementation, it can also provide a ground for studying the technology assimilation. The appropriateness of this selection is further checked through the exploratory case studies of the five data centres. The case findings suggest that SIS's relative advantage compared to the precursor technology and techniques used for monitoring (i.e. stand-alone sensors), the degree to which SIS implementation requirements are compatible with the existing data centre infrastructure, and the perception towards the complexity of integrating and/or extending the use of SIS in the data centres were all found to have an influence on the assimilation of SIS in data centres. This preliminary finding supports the inclusion of these constructs to study the assimilation of SIS in the data centres.

On the other hand, Fichman and Kemerer (1993) posit that potential users of an innovation look unfavourably on systems that are difficult to put on a trial period or whose advantages are difficult to observe. Thus, they argue that trialability and observability are both related to the risk of systems and hence can increase the uncertainty about the true value of an innovation. The assimilation of emerging technologies, such as SIS, can often be influenced by internal barriers such as the perceived uncertainty about the evolution and the future of technology innovation (Son et al., 2005) which has not been covered by DOI. Though DOI's trialability is deemed to reduce the uncertainty of an innovation, it has more to do with the uncertainty regarding the evaluation of the innovation's true value (Fichman and Kemerer, 1993), rather than the uncertainty about the innovation's future (Ravichandran, 2005) such as its development, success and its diffusion in the industry.

Research on economic perspectives of technology innovation has emphasised the use of economic theories of diffusion to understand the influence of those barriers (katz and Shapiro, 1986; Arthur, 1996). According to the economic perspective, the adoption of innovation depends on whether technologies are sponsored by external entities. It suggests that network externalities have two fundamental effects on the dynamics of industry evolution, including demand-side economies of scale and the future success of the competing products (Katz and Shapiro, 1986). The economic perspective has been used in studying the assimilation of both complex and emerging technology innovations. For instance, Son et al. (2005) and Ravichandran (2005) build on the economic perspective to add the technology uncertainty construct as another dimension of the technology context. Technology uncertainty refers to the subjective assessment made by an organisation about the current and future prospects of a technology (Ravichandran, 2005).

Likewise, in the context of this research, the emergence of SIS user networks can reduce the uncertainty of technology assimilation in several ways. First, SIS vendors and developers can be expected to continue to support the system and drive its evolution. Second, the standardisation of SIS, the deep knowledge about SIS and the availability of support mechanisms would likely increase in such circumstances. Lastly, the availability of technology would likely increase and the costs of adopting and assimilating SIS would likely decrease significantly with time. Under such circumstances, it is rational for data centres to postpone the assimilation if they do not have positive future expectations about the SIS. Thus, data centre manager (owners or IT executives) perceptions about the uncertainties associated with the future of SIS can be expected to influence its assimilation. Therefore, building on the DOI and economic perspectives of technology and for the purpose of this research, technology context includes *relative advantage, compatibility, complexity and perceived technology uncertainty.*

4.3.4. Defining and Identifying Organisational Factors

This research is concerned with studying the assimilation of SIS in the context of data centre sustainability. Chapter 3 shows that data centres have unique organisational characteristics and thus studying data centres requires some basic understanding about the nature of their organisational structure. Since most data centres are IS units that exist within organisations, the wider organisational context within which data centres operate is likely to create either facilitating or inhibiting conditions for the adoption of technologies within data centres. Nevertheless, a data centre sometimes represents an organisation by its own right. Thus it is essential to consider data centre specific factors as part of the organisational factors. Previous researchers as indicated in section 2.5.2 (e.g. Hafeez-Baig and Gururajan, 2009; Huang, 2010) and section 2.7.2 (e.g. Raymond et al., 2005; Rai et al., 2009) have incorporated factors that are specifically relevant to their areas of interest. Therefore, the organisation context of the present research incorporate factors from two dimensions: organisational factors and data centre factors. The organisational factors that could influence the assimilation of SIS were therefore borrowed from the organisational theories on innovation (i.e. DOI, TOE), natural environmental (i.e. NRVB) (see Table 4.3), that were identified from sections 2.2.2, 2.5.2, 2.3.4 and 2.7.2 as well as from the findings of the exploratory study (see chapter 3).

Table 4.3: A summary of theories used for developing the research's organisational context

Theory	Coverage	Constructs	seminal references
DOI	organisation's characteristics	• size • slack resources • centralisation • formalisation • interconnectedness	Roger, 1983
TOE	organisation's characteristics, mechanisms, and structures	• size • slack • structure • communication	Tornatzky and Fleischer, 1990
NRBV	organisation's environmental sustainability strategies	• pollution prevention • product stewardship • sustainable development	Hart, 1995

Generally speaking, organisational context identified in the classical innovation theories can be summarised into four categories: descriptive measures, structural characteristics, characteristics of leaders and the workforce and communication environment (Fichman, 2000) (see Table 4.4).

Table 4.4: A summary of organisational factors used in classical innovation theories

Category	Commonly used variables and reference
Descriptive measures	size, IS unit size, scale, slack resources
Structural characteristics and strategies	centralisation, formalisation, specialisation, vertical differentiation
Characteristics of leaders and workforce	professionalism, technical expertise, managerial support, education, specialists
Communication environment	information sources, communication channels

Nonetheless, many other researchers have extended and redefined the definition of organisational context to account for other factors relevant to their specific research context (Fichman, 1992). Table 4.5 provides some examples for redefining the organisational factors extracted from IS research in section 2.7.2.

Table 4.5: A summary of organisational factors derived from IT assimilation research

Author	Journal Title	Dependant variable	Organisational context
Hsu et al., 2006	International Journal of Electronic Commerce	E-Business Use	• Firm size • Technological resources • Globalisation Level
Kouki et al., 2010	Decision Support Systems	ERP assimilation	• Top management support • Strategic alignment • Manager’s involvement • Users’ involvement • Absorptive capacity • Reward system • Organisational culture
Ranganathan et al., 2004	International Journal of Electronic Commerce	Web Technologies assimilation	• Managerial IT knowledge • Formalisation • Centralisation
Raymond et al., 2005	Electronic Markets	The Assimilation of E-business	• Strategic orientation, • Managerial context • Manufacturing context
Zhu and Kraemer, 2005	Information Systems Research	e-business use and value	• Firm size • International scope • Financial commitment

Although the theoretical foundation of previous research in Table 4.5 borrows from seminal theories of technology innovation (e.g. DOI, TOE), there is an obvious variation in number, title, and nature of the organisational factors selected by these researches. In addition, the final results of these researches in respect to the influence of organisational factors were most likely obtained when *'researchers extended diffusion theory to account for new factors specific to the IT context under study'* (Fichman, 1992, p. 195). This implies that researchers are not bound to use the factors of DOI or TOE as exactly developed by the seminal authors of these theories; rather, they can use the general contextual lens of the theory and borrow insights to develop their own context-based construct if necessary.

Therefore, in defining organisational context, the present research focuses on (a) descriptive measure, (b) characteristics of leaders and the workforce, and (c) structural characteristics and sustainability strategies. These three categories contain the commonly used factors in most IS research (Fichman, 2000). However, incorporating sustainability dimension was important due to the emerging environmental concerns (Hart, 1995), especially, within the context of data centres (Schulz, 2009; Dedrick, 2010). In discussing each of the three categories in this chapter, the literature of IS are reviewed in order to extract the most relevant factors to the context of this research. The argument is extended, where necessary, to account for factors specific to data centres. Data centres factors refer to the IS unit factors that are specific to the data centres identified from the exploratory case study (Chapter 3). Incorporating the context under investigation is very important for understanding the special characteristics of that context which could influence the IT assimilation. Some researchers incorporated the context under investigation into their models such as manufacturing context (Raymond et al., 2005) and object-oriented technology context (Cho and Kim, 2002).

(a) In respect to the descriptive measure and related variables– referred here as the characteristic of host organisation or data centre, the most cited organisational characteristic in the IS literature is the size of organisation and the size of IS unit (Fichman, 2001; Purvis et al., 2001; Zhu and Kraemer, 2005; Bharati and Chaudhury, 2012; Barbosa et al., 2010). The size of organisation usually refers to the number of employees, level of sales, and annual gross income (Meyer and Goes, 1988; Eder and Igbaria, 2001). The size of organisation has been found to influence the adoption of SIS in manufacturing firms.

In the context of this research, where data centres are more likely IS units rather than organisations, the size of organisation would be inappropriate for examining the use of SIS in the data centres. Though one might argue that the larger the size of organisation, the larger the size of their data centres and hence the more likely the firm to assimilate SIS, the present research is not intended to study the association between the size of organisations and the size of their data centres; rather, it examines the assimilation and value of SIS in the data centres. The size of IS unit, which includes the number of IT employees and the size of IT functions (Fichman, 2001; Cho and Kim, 2002), is more appropriate. In our case this variable will be represented by the size of the data centre. By considering the special characteristics of data centres, a further two descriptive measure were identified from chapter 3. These are the age and type of the data centre. The discussion about the importance of these two factors to the model of SIS assimilation and value can be found in chapter 3.

(b) In respect to the characteristics of leaders and the workforce– referred as the characteristics of organisations' members that influence the use of innovation inside the organisational context, many researchers have concluded that organisational support factors such as top management support (Rai et al., 2009; Kouki et al., 2010; Bharati and Chaudhury, 2012), nature of user involvement (Schultz, 1984), training (Sanders and Courtney, 1985), managerial knowledge (Fichman, 2001; Purvis et al., 2001; Ranganathan et al., 2004; Ranganathan, 2005) and technical expertise (Cho and Kim, 2002; Chatterjee et al., 2002) consistently show a positive relationship with the innovation assimilation.

Top management support and managerial knowledge are often cited as key elements in facilitating the assimilation of technology (Meyer and Goes, 1988; Attewell, 1992; Fichman, 2001; Chatterjee et al., 2002; Purvis et al., 2001; Ranganathan et al., 2004), which support their usefulness for studying SIS assimilation in data centres. Top management support, especially to support the long term strategies and the use of technology in IS units, provides a positive environment for the success of most IS innovation (McGinnis and Ackelsberg, 1983). Thus, top management support would likely be relevant to study the assimilation of SIS in data centres. On the other hand, a manager’s knowledge stock which refers to the deeper managerial knowledge on how, what and where to use the technology is perceived as a facilitating factor for the value creation of technology assimilation (Ranganathan et al., 2004) and for enhancing the performance of data centres (Tschudi et al., 2004). Thus, this factor is discussed in the SIS value section because the aggregated knowledge and expertise on how to effectively utilise SIS to support various business function offer valuable resource that allows an organisation to develop rare and valuable capabilities.

c) In respect to the structural characteristics and sustainability strategies–, the study borrows some insights from the natural environmental perspective (Hart, 1995). The importance of environmental factor incorporation to the organisation context is due to the fact that natural environment considerations can play significant roles in shaping the strategies of organisations. Within the context of natural environment sustainability, current and future businesses will be pushed to create and maintain environmental sustainability strategies (Gladwin, 1992; Hart, 1995). The literature from section 2.2 revealed that the growing importance of natural environment factors implies that the use or misuse of technology might be influenced by environmental considerations (Hart, 1997; Lamb, 2009). It is predicted that organisations with activities that could cause direct environmental impact (i.e. natural resource degradation) are more likely to consider the use of clean and environmentally friendly technologies (Sharma, 2000; Aragón-Correa, 2000). With the growing importance of environmental sustainability, such organisations with negative environmental impact will become under the focus of global society and regulatory and are more likely to be under pressure to pursue positive actions. With these conditions, organisations is expected to embrace more environmental sustainability policies. As the proportion of sustainability policies increases, the more likely the organisation is to have better orientation towards Green IT (Molla et al., 2009; Schmidt et al., 2010).

Environmental commitments can for example lead organisations to embrace green IT strategy. Due to the impact of data centre operation on environmental sustainability (EPA, 2007; Koomey, 2011) improving the environmental performance of data centres is at the forefront of organisations green actions (Loper and Parr, 2007; Zheng and Cai, 2011). One step to accomplish this objective is to develop stewardship strategies to retrofit or replace inefficient systems and techniques into more efficient ones. Stewardship strategies incorporate the voice of the environment into product design and development processes (Hart, 1995).

In the context of data centres, SIS can directly and indirectly facilitate data centre stewardship (redefined here as green IT orientation, as explained in the next section). For instance, when SIS is used to reduce the energy consumption of data centres through monitoring and automating the business functions of data centres as discussed in chapter 3, it directly contributes to an organisation's green IT/IS strategy. As such, it can be considered as one of the Green IS solutions that can be used as part of organisation's green IT strategy. When SIS is used to monitor and measure the energy consumption of different equipment or processes in order to help the decision-maker in evaluating the environmental or operational performance of data centre, it indirectly contributes to an organisation's green IT/IS strategy. As such, it can be used to facilitate the effort of managerial members to peruse the environmental and operational performance of data centres. Thus, organisations with activities that could cause direct environmental impact (e.g. data centres) are more likely to adopt green IT/IS orientation (Schmdit et al, 2010) (e.g. through establishing green IT/IS policies and strategies) in their data centres, and hence more likely to assimilate SIS as part of data centre green IT orientation. Moreover, by considering the structural characteristics and strategies specific to data centres, a further important factor, that is, data centre energy governance was identified from chapter 3. The discussion about the importance of data centre energy governance to the research model (based on the evaluation of the actual use, existing technologies and current practices in the five cases) was reported in chapter 3.

By consolidating the findings of organisational factors as well as the factors specific to data centres, the organisational context of this research includes top management support, green IT/IS orientation, data centre energy governance, size of data centre, type of data centre and age of data centre. The last three factors (descriptive measures) are used as control variables. The classification of identified organisational factors is shown in Table 4.6.

Table 4.6: A summary of the research organisational context

Category	Variables selected for this study	
	Organisational	Data centre specific
Descriptive measures	--	Size of data centre Type of data centre Age of data centre
Structural Characteristics and sustainability strategies	Green IT/IS orientation	Data Centre energy governance
Characteristics of leaders and workforce	Top management support Manager's knowledge stock	--
Source and references	Hart, 1995; Fichman 2000; Ranganathan et al., 2004	Exploratory case study, Chapter 3

4.3.5. Defining and Identifying Institutional Factors

Institutional theory is a widely recognised theory used by many researchers within the IS discipline to address the use of innovation (Orlikowski et al., 2001; Teo et al., 2003; Liang et al., 2007). The institutional forces typically refer to normative, coercive and mimetic pressure (DiMaggio et al., 1983). Despite the importance of institutional forces in the study of technology assimilation, the effect of the common institutional isomorphism, that is mimetic, coercive and normative, on technology assimilation might not be equally significant (Liang et al., 2007). Thus, some researchers may focus on the most important factors in their research context (Kouki et al., 2010).

Although empirical results show that the effects of each institutional pressure are not clearly identifiable and that each pressure derives from a different process, the finding also depicts a simultaneous relationship between one or two (DiMaggio et al., 1983; Mizruchi et al., 1999). The present research focuses on the normative and coercive pressures with the exclusion of mimetic pressure. First, although normative and mimetic pressures are theoretically different from each other, the distinction between the two is not empirically clear (Burns et al., 1993). This suggests that studying one pressure might stand in for the other one. In addition, empirical IS research on technology assimilation has revealed a significance influence of both normative and coercive pressure, but not mimetic pressure, on the assimilation such as ERP (Kouki et al., 2010). Furthermore, some argue that the accumulation of certain normative factors can consequently result in coercive pressures

(Chen et al., 2009). This implies that normative and coercive pressure might be theoretically intertwined. For the purpose of this research, the institutional context focuses on the effect of normative and coercive pressure.

4.3.6. Defining and Identifying Natural Environment Factors

Businesses are increasingly challenged to create and maintain environmental sustainability strategies (Gladwin, 1992; Hart, 1995). This is because human and organisation activities might degrade and jeopardise the natural environment (Brundtland, 1987). For instance, some reports depict that human activities such as land degradation, deforestation, and hazardous pollutions have affected the eco-system to a significant level (Wall, 1994). Natural resource usage and waste generation would certainly stress earth's natural systems beyond recovery (Meadows et al., 1992; Hart, 1995), hence requiring more regulations and scrutiny upon organisations' activities that could degrade the environment. Several researchers have focussed on the relationship between natural environment and IT and have showed the significant relationship between natural environment and IT using literature review and empirical data as depicted in section 2.2 (e.g. Chen et al., 2008; Jenkin et al., 2011; Elliot, 2011; Molla and Abrashie, 2012).

In this research, natural environment factors focus on factors relating to environmental preservation (e.g. non-renewable energy, CO_2 emissions) (Schulz, 2009; Molla, and Abareshi, 2011) and energy (Loper and Parr, 2007; Zheng and Cai, 2011). Particularly these factors relate to regulatory and market influences to preserve the environment and promote energy efficiency that could create a pressure on data centres towards the use of technology innovation. The research borrows from Hart's pollution prevention and product stewardship concepts (Hart, 1995), which focus on emission and waste related issues, to guide the development of the two constructs of the natural environment context.

Environmental preservation pressure refers to the pressure to reduce the effect of an organisation's activities (e.g. level of none-renewable energy use, CO_2 emissions) on the natural environment. Such pressures can influence the decision to use SIS in the data centre. Energy pressure refers to the effect of energy related issues (e.g. availability of energy, cost of energy, and electricity price) on the decision to use SIS in the data centre. The research focuses on these two factors because the environmental impact of data centres include excessive energy consumption (i.e. in the form of consuming non-renewable energy) (EPA, 2007), and natural resource degradation (i.e. global CO_2 emissions, electronic wastes) (EPA 2007, Schulz, 2009). These two issues are the most relevant to data centres and are intertwined in terms of the natural environment context.

For example, the excessive use of energy entails the need for more electricity and hence the need to burn more fossil fuel (95% of energy comes from consuming non-renewable natural resources (Schultz, 2009)), thus degrading the world's reserve of non-renewable natural resources. Similarly, the increase of CO_2 emissions degrades the atmosphere which is also a natural resources component. In the data centres industry, the increased volume of energy consumption and the associated CO_2 emissions is creating energy pressure as well as natural resource issues. These pressures stimulate the effort made by data centres managers to develop, use and maintain more energy efficient and environmentally friendly technologies. Therefore, energy and natural resource issues are all important factors in shaping the organisations' decisions in respect to the selection of technology innovation (such as SIS) that can be used to improve the environmental performance of data centres.

Furthermore, the availability of energy, a fundamental source for the data centres which is controlled by energy markets (Loper and Parr, 2007) and also influenced by natural resource availability, is an important environmental dimension that could influence the use of SIS in the data centres. For instance, the increase of electricity prices guided by the increase of oil and natural gas in the energy market would push data centres to use more energy-wise systems which are typically SIS-based systems. As such, SIS can help data centre managers to reduce the energy consumption through the use of SIS automation function and also to observe and measure the efficiency of other equipment through the use of SIS monitoring and analysing functions. Thus, the effect of energy availability issue is another dimension of energy concerns and would likely have an influence on the level of SIS assimilation in the data centres. Therefore, for the purpose of this research, natural environment context include environmental preservation and energy pressure.

4.3.7. Summary

The objective of this section was to conceptualise the key variables of this research. Building on the theories identified in the first section of this chapter, *DOI* (Rogers, 1983), *TOE* (Tornatzky and Fleischer, 1990), *institutional theory* (DiMaggio et al., 1983), *RBV* (Barney, 1991; Peteraf, 1993) and *NRBV* (Hart, 1995), and by findings from exploratory study in Chapter 3, the section concludes by identifying and justifying the selection the of the most relevant factors of SIS assimilation and value. These identified variables constitute the key input to the conceptual framework and hypothesis development discussed in the following section.

4.4. HYPOTHESIS DEVELOPMENT

The conceptual model for this study uses constructs from seminal innovation assimilation and value theories. The developed integrative research framework is depicted in Figure 4.3. The left-hand side of the model shows the antecedents of SIS assimilation. As discussed earlier in chapter 4, the assimilation of technology innovation would be influenced by technological, organisational, institutional, and natural environment factors. The right-hand side shows how the assimilation of SIS would impact data centres' performance and their ability to create business value.

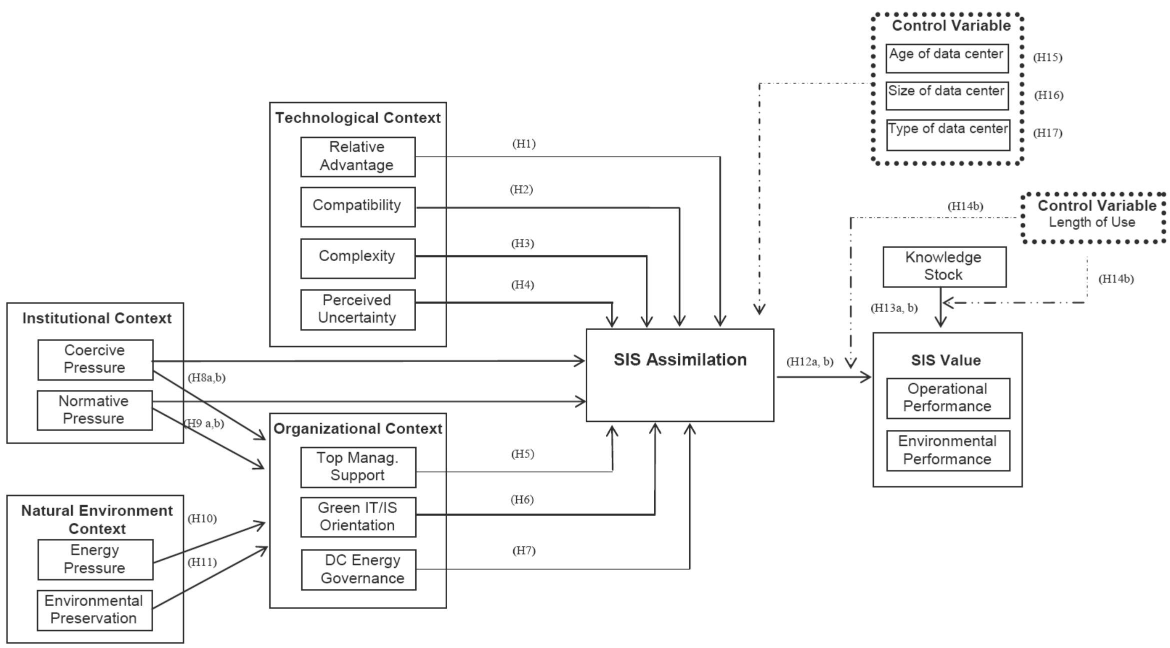


Figure 4.3: Conceptual model

4.4.1. Technological Factors and SIS Assimilation

Technology attributes typically describe the characteristics of technology innovation (Roger, 1983). In this research, technology attributes refer to the *relative advantage, compatibility, complexity* (Roger, 1983) *and perceived uncertainty* (Son et al., 2005; Ravichandran, 2005) of SIS.

Relative advantage refers to innovation's superior or unique advantages such as its capability, cost and functionality (Roger, 1983). Previous IS literature shows that relative advantage constructs can influence the use of technology innovation (e.g. Hsu et al., 2006, Liao and Lu, 2008; Wu and Chuang, 2009; Picoto et al., 2012). SIS provides real-time and comprehensive monitoring about the activities of an organisation (Garg and Bansal, 2000; Shabha, 2006). In addition, SIS can perform advanced information analysis about the objects under observation which allows for better decision support and automated task processing (Chong and Kumar, 2003; Terry et al., 2005; Wamba, 2012).

Within the context of data centres, monitoring and automation of business processes are perceived as one of the top priorities of data centre managers according to a survey conducted by Emerson Network Power covering 170 data centres facility managers, and IT managers in North America (DCUG, 2010). Sensors and SIS are promoted as one of the best practices in monitoring the status of data centre infrastructure (facility, power, cooling and ICT platforms) such the change in temperature, humidity, load, pressure, air and so on (Gartner, 2008; Kant, 2009, European commission, 2010). Thus, data centre managers' perception of SIS's relative advantages, such as what business process can be handled by SIS and what can be delivered to data centres through the use of SIS, is key for determining the assimilation of SIS. The SIS relative advantage construct is being hypothesised as follows:

Hypothesis 1: The higher the level of the perceived SIS relative advantage, the greater the extent of SIS assimilation in data centres.

Compatibility is the degree to which the technology innovation is consistent with the existing values, norms, experiences, and requirements of the assimilating organisation (Rogers, 1983). It refers to the perceived alignment between the technology innovation and the culture, values, and favourable work practices of an organisation (Jones and Beatty, 1998). Following the initial implementation stage, new incompatibilities might be discovered during the actual use of the technology that could hinder its assimilation (Liang et al., 2007). The literature shows that the adoption of innovations in data centre is likely to be influenced by compatibility of new system with existing infrastructure (Mukherjee et al., 2010; Kant, 2009). Empirical IS research on innovation assimilation found that compatibility can significantly influence the level of innovation assimilation (i.e. Purvis et al., 2001; Liao and Lu, 2008; Cho and Kim, 2002) and the adoption of SIS (Hafeez-Baig and Gururajan, 2009; Lowry, 2002). Compatibility of SIS requirements with existing technologies refers to the degree of compatibility of SIS technical requirements to apply SIS with the variation of existing equipment, protocols and practice that are used in the data centres.

Within data centre context, the hardware and software making up data centre infrastructure comprises of various hardware (e.g. servers, network switches, storage drives, and power distribution units) and software (e.g. several specialised IS to manage the infrastructure) that is purchased from different vendors (Magoulès and Yu, 2009). Typically, each hardware and software is manufactured based on specific technical standards of a particular vendor that in some cases do not support the technical standards of others manufactured by different vendors (Kant, 2009). Thus, we expect that when the data centre infrastructure and SIS technical requirement are mutually compatible, the level of SIS volume, SIS diversity and SIS intensity can be positively reinforced, thereby promoting SIS assimilation. This leads to the following hypothesis.

Hypothesis 2: The higher the level of perceived SIS compatibility, the greater the extent of SIS assimilation in data centres.

Complexity refers to the difficulty to understand, learn and use a technology innovation (Rogers, 1995). A technology becomes a slow mover in a particular industry or organisation due to its inherent complexity (Fichman and Kemerer, 1993). Investigating the impact of complexity on emerging innovation is very important for the inhibition or adoption of the innovation. Therefore, several IS researchers have studied the diverse influence of complexity across various stages of innovation diffusion (Karahanna et al., 1999; Cho and Kim, 2002; Wu and Chuang, 2009). SIS complexity refers to the complexity of understanding, using, and integrating SIS in the context of data centres. The complexity of integration includes the difficulties to communicate, coordinate, synchronise and exchange data of SIS with diverse hardware and software used in the data centres.

The complexity of data centre cooling, power management and ICT platforms might inhibit the extended use of SIS beyond the traditional use (e.g. use for facility and cooling management only) (Raghavendra et al., 2008; Mukherjee, et al., 2010). Every data centre has unique equipment and configurations and needs to be handled on a case by case basis which makes it complex to integrate sensors and SIS (Kant, 2009; Watson et al., 2009). Especially when the IT assets hosted in a data centre facility are owned by external clients (such as in the case of co-located data centres), integrating SIS that is used for IT asset management together with other SIS used for management of power or cooling systems under one comprehensive SIS is currently a complex undertaking. Therefore, it's expected that complexity could inhibit the extension of the SIS volume, SIS diversity and SIS intensity. Complexity is hypothesised as follows:

Hypothesis 3: The higher the level of perceived SIS complexity, the less the extent of SIS assimilation in data centres.

Technology uncertainty refers to the subjective assessment made by an organisation about the current and future prospects of a technology (Ravichandran, 2005). Fichman, and Kemerer (1993) posit that potential users of an innovation look unfavourably on systems that are difficult to put on a trial period and whose advantages are unobservable. They argue that trialability and observability of innovation are both related to the risk of systems and hence can increase the uncertainty about the true value of an innovation.

The assimilation of emerging technologies, such as SIS, can often be influenced by internal barriers such as the perceived uncertainty about the evolution and the future of technology innovation (Son et al., 2005). Ravichandran (2005) conceptualises uncertainty as *demand side uncertainties* and *supply side uncertainties.* Demand side uncertainties refer to innovation's uptake by IS units. Supply side uncertainties refer to the availability of innovations and continued vendor support for them. In the case of SIS, uncertainty about the SIS future, technical support, and SIS ability to carry out control of critical equipment can constitute a risk factor to assimilation. For instance, the uncertainty perception about the maturity of SIS markets by data centres managers might restrain their volume, diversity and intensity level of SIS because they would be afraid of inviting in immature technologies. Thus, the study hypothesises the following regarding the perceived SIS uncertainty:

Hypothesis 4: The higher the level of perceived SIS uncertainty, the less the extent of SIS assimilation in data centres.

4.4.2. Organisational Factors and SIS Assimilation

Organisational context is defined in this study as top management support, green IT/IS orientation and data centre energy governance.

Top management support (TMS) refers to the extent to which innovation efforts are promoted by the top management of an organisation (Rai, and Bajwa, 1997). Actions undertaken by senior management can introduce complementary structures to facilitate technology assimilation, and modify and reinforce the norms that value the use of an innovation (Kwon and Zmud, 1987). There is a greater likelihood of IS assimilation success when positive top management mind-set regarding a particular technology have been communicated effectively to the users (Damanpour, 1991). Conversely, the lack of sufficient involvement of top management (such as CEOs, CIOs, CFOs) in strategy and decision making could hinder the development and the choice of technology (Jarvenpaa and Ives, 1991). The importance of top management support (TMS) for IS assimilation is widely accepted in the literature (Chatterjee et al., 2002; Rai et al., 2009; Kouki et al., 2010; Bharati and Chaudhury, 2012). Chatterjee et al. (2002) assert that effective participation by top management in shaping the vision and strategies for the use of the technology innovation can serve as powerful signals to stimulate the rest of the managerial community.

The definition of top management within the context of data centres could refer to different types depending on the structure of the data centre discussed in chapter 3, that is whether it is a single (corporate) or multi-tenant (managed or co-located) data centre. For example, in the case of single-tenant data centres, the data centre manager is at the middle management level whereas the top management level is represented by CIO, VP of IT and/or CEO. Conversely, in multi-tenant data centres, the facility manager represents the top management level. The participation by senior management in the data centre strategy and planning and their support for improving data centre operations can create the necessary condition for the success of technology use (Brill, 2007).

In addition, the collaboration and support by top management for a particular system can help increase the awareness levels among data centre owners and professionals and disseminate the knowledge about the importance of that system (Loper and Parr, 2007). And thus it can motivate them for successful technology adoption. As the discussion in section 2.6 shows that SIS can offer several advantages to data centres in strategic, managerial, operational and environmental terms (e.g. Moore et al., 2004; Watson et al., 2009; Khargharia et al., 2008; Wang et al., 2011), the support by top management is expected to lead to the successful use of SIS either directly or indirectly by supporting strategies that could encourage the use of SIS (e.g. operation sustainability, efficiency). Thus, top management support (e.g. CIOs, CEOs) is expected to play an important role in facilitating the use of SIS in the data centres. The TMS construct is being hypothesised as follows:

Hypothesis 5: The higher the level of top management support for improving data centre operation, the greater the extent of SIS assimilation in data centres.

Green IT/IS orientation refers to the incorporation of natural environment policies to use, upgrade or purchase a technology, systems or IS that can improve the overall environmental performance of an organisation. The term green IT/IS orientation is guided by the concept of product stewardship (Smart, 1992; Hart, 1995). Environmental stewardship strategies refer to incorporating the voice of the natural environment into product design and development processes (Hart, 1995). It is predicted that organisations with activities that could cause direct environmental impact (i.e. natural resource degradation) (Sharma, 2000; Aragón-Correa, 2000) would likely embrace green policies and environmentally friendly technologies. As the proportion of these technologies and policies increases, the more likely the firm is to have greater green technology orientation (Molla et al., 2009; Schmidt et al., 2010).

Most organisations that consider Green IT/IS start their actions by focusing on reducing the environmental impacts of IT by making their data centres more energy efficient (Dedrick, 2010; Molla and Abrashie, 2011). With the energy efficiency and environmental performance of data centres being at the forefront of organisations' actions in 'greening' their information technology (Schulz, 2009; Dedrick, 2010), developing green IT/IS strategic orientation in the form of policies to retrofit or replace inefficient systems and techniques into more efficient ones as well as policies that limit the purchase of new systems to the most efficient and environmentally friendly ones (Chen et al., 2011; Molla and Abrashie 2012) has become a key consideration of data centre management practice (Karanasios et al., 2010). Therefore, green IT/IS orientation is likely to facilitate current and future levels of SIS assimilation in data centres. Thus, the following hypothesis is suggested:

Hypothesis 6: SIS are likely to be assimilated to a greater extent in organisations that have developed green IT/IS orientation.

Data centres energy governance refers to the existing strategies or procedures with respect to the accountability and responsibility of energy efficiency and transparency of data centres operations. Responsibility and accountability are important concepts when making decisions in the use of technologies (Huber and McDaniel, 1986). Roles and responsibilities for organisational tasks need to be separated and individually assessed (Simons, 2005). This includes specifying 'who is accountable for fulfilling which responsibilities and to allocate, to those accountable, authority sufficient to enable them to carry out these responsibilities', Huber and McDaniel, 1986, p. 573).

In the context of data centres, responsibilities of managers, which are routinised in the majority of data centres, includes the facility site management, cooling and thermal management, power management and IT asset management (Bianchini and Rajamony, 2004, Tschudi et al., 2004) in order to ensure availability/uptime, security, agility and scalability (DCUG, 2010). For several years, these functions were exercised without having transparency or accountability towards the impact on firm economic performance (Loper and Parr, 2007). However, the effects of operational and environmental performance of data centres on organisations and data centres business continuity as discussed in sections 2.3.1 and 2.3.2 have increased the importance of governance over the data centres performance. Therefore, governance on data centres activities such as energy efficiency and cost efficiency came into focus, requiring more scrutiny on the performance of data centres from an economic and environmental perspective (Loper and Parr, 2007; Lamb, 2009).

In this vein, separating the metrics of data centre operations to identify their detailed performance parameters and their impact upon the entire organisation's performance is fundamental for effective energy governance (Loper and Parr, 2007). Data centres' energy governance has came into focus following the realisation that these digital power houses consume a lot of energy and have been inefficient in terms of their energy utilisation (Schulz, 2009; Zheng and Cai, 2011). Therefore, the existence of energy governance standards for data centre activities and data centre managers' energy performance would provide an economic driver that pushes data centres' managers to be more energy conservative (Loper and Parr, 2007) and opt for IS to assist this effort. Thus, the study hypothesises the following regarding the data centres' energy governance:

Hypothesis 7: SIS are likely to be assimilated to a greater extent in organisations that have developed data centre energy governance policies

4.4.3. Institutional Factors and SIS Assimilation

In this study, the institutional forces are hypothesised to effect the SIS assimilation directly and indirectly through top management support, green IT/IS orientation and data centre energy governance constructs.

By direct effect, we mean the effect of coercive pressure or normative pressure (independent) on SIS assimilation (dependent). This means that changes in one variable (e.g. normative pressure) will cause direct changes in SIS assimilation. In the indirect effect interaction, coercive pressure or normative pressure affects one of the organisational constructs- that is top management support, green IT/IS orientation or data centre energy governance (mediation), which in turn affects the SIS assimilation. This means, for example, that changes in normative pressure in respect to industry practice changes the top management participation in the sustainability strategy of the data centre, which in turn increases the use of SIS in the data centres as a best practice.

The decision to hypothesise both direct and indirect effect of institutional forces was made for the following reasons. First, previous IS studies that have investigated the effect of institutional pressure found that institutional pressure has direct and direct effects on the assimilation of technology (Linag et al., 2007). In addition, other IS studies reported a mix of direct (Kouki et al., 2010) and indirect (Molla et al., 2010) effect of institutional forces. This implies that institutional forces can play direct and indirect role in a research model. Second, looking only at the direct effect of latent variables on another variable may not be optimal. In most cases, direct effects depict how two variables interact with each other while all other variables are held constant. Therefore, the indirect effect helps to capture the effect of interaction between more variables that could significantly affect each other. Third, because the study is the first to test the influence of institutional pressure on the SIS assimilation in data centres, it was assumed that investigating both direct and indirect effects would offer better understanding about the role that can be played by institutional forces in the process of SIS assimilation.

Institutional context refers to the institutional forces including coercive pressure and normative pressure. *Coercive pressure* results from interdependence conditions in which pressure is exerted on an organisation by a parent organisation or by dominant stakeholders where an organisation executes its business (DiMaggio and Powel, 1983). This includes dominant stakeholders such as suppliers, customers, industry associations and regulatory agencies. Coercive pressures have been found to directly influence the assimilation of innovations such as ERP assimilation (Linag et al., 2007; Kouki et al., 2010). In addition, coercive pressures was found to effect the ERP assimilation indirectly through top management (Linag et al., 2007), and effect the use of e-business through organisational readiness (Molla et al., 2010). Furthermore, coercive pressure was found to have significant effect on pollution prevention, product stewardship (e.g. Green IT/IS orientation) and sustainable development (Chen et al., 2011). These suggest that coercive pressures could directly and indirectly create a chain of effects that can increase the use of technology. The pressure exerted by regulatory agencies and industry associations, such as to reduce the environmental impact or to use energy monitoring software, is relevant to the context of data centres.

First, coercive pressure is expected to have direct influence on SIS assimilation. Data centres have attracted the concern of global regulatory agencies and institutions (such as the EPA, the European Union) due to the impact of data centre operations on the natural environment (Lamb, 2009). In many countries where government agencies exert significant influences on business policies and practices (Park and Luo, 2001), coercive pressures are more likely to arise from regulatory and collective industry associations (Linag et al., 2007). The regulatory bodies around the world have started to impose compliance and reporting requirements about the environmental impact of organisations, and others are planning to do the same in the near future. For instance, the *National Greenhouse and Energy Reporting Act 2007* (NGER) in Australia imposes reporting requirements in respect to energy use, production and CO_2 emissions (OLDP, 2007). Under NGER, all Australian businesses generating in excess of 25,000 tonnes of carbon dioxide equivalent or consuming (or producing) in excess of 25,000 megawatts of electricity per annum are subject to the reporting scheme. Thus, the data centre owners or operators would encounter some pressure to improve the impact of their operations by cutting down the energy consumption levels of their data centres.

Under these conditions, the use of SIS (e.g. power consumption and emission monitoring softwares) can help data centres owners and operators to accomplish energy efficiency and improve the environmental performance. SIS can facilitate this either directly by automating some tasks (i.e. lighting, cooling) (Tang et al., 2006; Parolini et al., 2008) or indirectly by observing the consumption of energy of different devices in order to suggest more efficient ways for executing formal operations (Padala et al., 2007; Wang et al., 2011). Thus, within the contemporary condition where it becomes mandatory for data centres owners to opt for technologies that reduce the environmental impact of data centres operations and help meet the environmental compliance requirements, their extent of SIS volume, diversity and intensity is likely to be facilitated. Thus, the following hypothesis is proposed:

Hypothesis 8a: Coercive pressures will have a positive influence on the assimilation of SIS in the data centre.

Second, coercive pressure is also expected to have indirect influence on SIS assimilation through top management support, green IT/IS orientation and data centre energy governance constructs. This hypothesis is guided by the finding of previous studies discussed earlier in section 2.2.2 (e.g. Molla et al., 2010; Mithas et al., 2010; Chen et al., 2011) and section 2.7.2 (e.g. Linag et al., 2007). SIS is one of the Green IS solutions

(Watson et al., 2010) that can help organisations to improve the sustainability of their data centre operations. The pressure resulted from regulatory and collective industry associations of data centre discussed above (in the direct effect section) could also cause significant pressure on top management, organisation's green IT/IS policies and/or governance policies regarding data centre energy. In such case, coercive pressure can lead top management to participate more effectively in the sustainability strategy of data centre; drive the organisation to establish more green IT/IS initiatives and policies, and/or entail the need for the governance of energy usage. Thus, the following hypotheses are proposed:

Hypothesis 8b: Organisational context (that is top management support, green IT/IS orientation and data centre energy governance) mediates the influence of coercive pressure on SIS assimilation.

The normative pressure can be another institutional factor that could influence the IS assimilation. The source of normative pressure stems from professionalisation (DiMaggio and Powel, 1983). Professionalisation refers to collectively defined conditions, methods and standards set out by a group of professional members of a particular occupation, which enable them to control their practices and establish legitimation for their occupational independence (Larson, 1977; Collins, 1979). DiMaggio and Powel (1983) assert that normative forces could, directly or indirectly, influence the organisation's decision-makers and force them to choose a particular system or strategy. The literature from section 2.3.4 revealed that the adoption of innovative technologies and best practices by peer data centres can accelerate the adoption and acceptance by data centre operators and owners as it reveals successful stories about the value of best practice and innovation (Loper and Parr, 2007). The direct impact of normative pressure on the assimilation of technology has been supported by IS research such as IS use and ERP assimilation (Linag et al., 2007; Kouki et al., 2010). Further, normative pressure could also have indirect effect on technology assimilation thorough organisational or managerial factors (Linag et al., 2007). These imply that normative pressure could directly and indirectly drive the decision to use IS.

In terms of the direct effect of normative pressure, the data centres community may include professional associations that provide recognition and certification in the data centres industry. Data centres might encounter normative pressure that is exerted by the data centres community to implement a defined set of best practices, of which SIS use is promoted as solution to resolve some of data centre issues (Gartner, 2008; European Commission, 2010). Consequently, this pressure can create a direct driver to use SIS. In addition, internal clients (e.g. other departments of an organisation), or external clients (e.g. tenants of a multi-tenants facility), could directly constitute normative pressure on the data centres to use SIS as a best practice. For example, building management departments may push for more usage of SIS within the data centre infrastructure in order to achieve effective facility management. Thus

Hypothesis 9a: Normative pressures will have a positive influence on the assimilation of SIS in the data centre.

Furthermore, the institutional effects on SIS assimilation can also be observed in the form of indirect pressure through shaping the organisational settings or management minds. For example, the adoption of SIS (e.g. to monitor the energy and environmental impact) in data centres might be a prerequisite for green certification that is issued by a professional association. Thus, normative pressure could indirectly lead to higher SIS usage through stimulating the top management participation in the improvement of data centres sustainability (Loper and Parr, 2007) and/or shaping an organisation's green IT/IS policy. Given that data centre 'best practices' are not yet standardised, institutional norms about SIS can guide data centres managers in making decisions about when and how to improve existing business processes through SIS. In such circumstances, the pressure of data centres to follow the best practice, or fulfil client requirements, can shape the institutional norms regarding implementation and consequent assimilation of SIS. Thus, normative pressure is being hypothesised, as follows:

Hypothesis 9b: Organisational context (that is top management support, green IT/IS orientation and data centre energy governance) mediates the influence of normative pressure on SIS assimilation.

4.4.4. Natural Environment Factors and SIS Assimilation

Natural environment context refers to energy pressure- and environmental preservation pressure. *Energy pressure* refers to the effect of energy related issues in driving the decision to use SIS in the data centres. Energy is a fundamental resource for data centres (Loper and Parr, 2007; Schulz, 2009; Zheng and Cai, 2011) and external pressure regarding the energy is expected to have indirect influence on SIS assimilation by affecting the organisational context (top management support, green IT/IS orientation and data centre energy governance). Market fluctuation and uncertainty with respect to the supply and cost of electricity could motivate organisations to use innovative technologies (Fink, 1998; Molla and Abrashie, 2011). The energy prices and their effect on the long-term growth of business play a central role in businesses success. Early work on the price-induced technical change predicted a linkage between relative profit incentives (coupled with high prices) and the demand for certain types of technology (Binswanger, 1974; Acemoglu, 2002).

Results from previous research on the effect of energy price fluctuation such as Doms and Dunne (1995), Pizer et al. (2002) and Linn (2008) found that global energy prices have an effect on the adoption of efficient and energy-saving technologies. With the growing demand for energy and the increasing energy consumption by data centres, the risk of global economic change, such as an increase in the electricity prices, can impact the data centre industry (Loper and Parr, 2007; Zheng and Cai, 2011), internal policies and strategies, and managerial minds and push them to opt for more energy-efficient technology (Brill and Ratio, 2007). Because SIS are internally focused systems within a data centre of an organisation, it is unlikely that external energy forces cause direct effect on its use. This implies that external energy pressure is more likely to have indirect effect on SIS assimilation through shaping the organisational effort and its preferences towards the system that can be used accordingly. Thus, the study proposes the following hypotheses regarding the energy pressure:

Hypothesis 10: Organisational context (that is top management support, green IT/IS orientation and data centre energy governance) mediates the influence of energy pressure on SIS assimilation.

Environmental preservation pressure refers to the effect of natural environment resources and its related issues in driving the decision to use SIS in the data centres. The environmental impact of data centre operation (Dedrick, 2010; Molla and Abrashie, 2011) (e.g. use of non-renewable natural resource, degradation of earth’s atmosphere), is creating growing pressure on the senior management and sustainability strategies of organisations

(Schulz, 2009). Thus, it is expected that natural resource issues to cause indirect influence on SIS assimilation by affecting the organisational context.

The growing importance of natural environment factors implies that the use or misuse of technology might be influenced by environmental considerations (Hart, 1997). The degradation of natural resource could include negative activities that can jeopardise the natural resource (earth's reserves) (Vaughn, 2007). As the concerns and awareness about the health of natural environment have escalated in recent decades, the degradation of natural resource and it related matters is likely to create tremendous forces that push organisations to reduce the impact of their activities that could degrade or jeopardise the environment (Hart, 1995).

The environmental impact of data centres includes large amount of use of natural resources (e.g. non-renewable-based energy, and water) and cause of pollution (e.g. global CO_2 emissions), and increase of e-waste (EPA 2007; Schulz, 2009), and thus degrading the world's reserve of non-renewable natural resources. In this vein, the senior management and data centres managers face increasing pressure to improve the environmental impact of their operations through effective participation in planning and strategies designed to improve the performance of data centre operations; promotion of more green IT/IS policies; and/or increase of energy governance procedures which could influence their usage of different technologies including SIS. Similar to the energy pressure, environmental preservation pressure is more likely to affect the assimilation of SIS indirectly through shaping the organisational effort and its preferences towards the system. Thus, environmental preservation construct is being hypothesised as follows:

Hypothesis 11: Organisational context (that is top management support, green IT/IS orientation and energy governance) mediates the influence of environmental preservation pressure on SIS assimilation.

4.4.5. SIS assimilation and SIS value

The importance of the actual usage of information systems and its impact on the value creation has been pointed out by several researchers (Ranganathan et al., 2004; Zhu and Kraemer, 2005; Raymond et al., 2005; Rai et al., 2009; Picoto et al., 2012). Consistent with these ideas, the present research examines the link between the two. The study draws on the RBV and NRBV to explain how the assimilation and value can be connected. According to RBV, the greater the extent of heterogeneous resources, the most likely the firm is to develop capabilities that are rare, valuable and sustainable (Barney, 1991; Penrose, 1995). According to NRBV, developing capabilities is rooted in the heterogeneous resources that facilitate the environmentally sustainable economic activity (Hart, 1995). Through deeper usage of these capabilities, organisation would be able to create unique IT assets that enable them to create competitive advantages. If the firm does not recognise the value from extending the use of SIS, then it would likely degrade the assimilation level.

Previous research demonstrated significant links between the extent of use of IS and firm’s performance (Ranganathan et al., 2004), the creation of business value (Zhu and Kraemer, 2005), firm’s market performance (Raymond et al., 2005), productivity (Rai et al., 2009), firm’s financial performance (Setia et al., 2011), and market and operational performance (Picoto et al., 2012). As indicated in earlier section 4.3.1, SIS assimilation was conceptualised to impact two areas of data centres business, that is, operational performance and environmental performance. By increasing the extent of SIS applications and utilisations of their various capabilities to mange diverse tasks and processes of ICTP and CSSP operation, data centres can realise several operational benefits from the use of SIS. This could include, but not limited to, reducing the cost of running data centre, enhancing operations visibility and supporting the management control capability. Furthermore, the features of SIS make them one of the effective solutions that can bring environmental benefits to the data centres as they can contribute, for example, to the reduction of energy consumption, accurate measurement of the environmental footprint, as well as enhancement of environmental compliance of data centre operations. Thus, the following are hypothesised.

Hypothesis 12a: Greater extent of SIS assimilation is more likely to improve the operational performance of data centres.

Hypothesis 12b: Greater extent of SIS assimilation is more likely to improve the environmental performance of data centres.

4.4.6. SIS knowledge Stock and SIS value

SIS knowledge stock of data centre managers is hypothesised to predict the SIS value. A previous study by Ranganathan et al., (2004) found that deeper managerial knowledge about a particular system of an organisation has significant impact on the extent of use and value. The knowledge stock can be defined as the extent to which an organisation acquires the specific knowledge of a technology innovation that is necessary for assimilation (Ravichandran, 2005). It covers managerial receptivity of know-what, know-how, and know-why which are required to successfully assimilate any complex technology (Attewell, 1992). ‘Know-what’ refers to the knowledge about the technology innovation and its advance features and capabilities, ‘know-how’ refers to the knowledge about how to effectively apply and utilise the innovation in the unique settings of an organisation, and ‘know-why’ refers to the factual knowledge required to meaningfully evaluate the issues associated with assimilating an innovation such as cost and benefits.

Deeper knowledge of managers’ is being observed as a facilitating condition for the absorption of capabilities that is required to innovate successfully (Cohen and Levinthal 1990). As such, high level of knowledge can influence the managers’ capabilities and enhance their understanding about the business functions that need to be handled by a particular IS (Raymond et al., 2005; Ranganathan et al., 2004). In addition, previous studies have assessed the economic benefits of knowledge stoke during assimilation and found that the lack of this construct may constitute a barrier to the utilisation of technology assimilation (Ravichandran, 2005).

Building on the RBV concept, the current study argues that accumulated knowledge and expertise on how to effectively utilise SIS to support various business function of data centre operations allow organisations to acquire unique resources that can help them to develop valuable capabilities. Through these capabilities, organisations can improve their operational and environmental performance.

Data centre managers’ expertise and experience of how to and where to implement sensors and SIS, and their knowledge about sensors and SIS capabilities and requirements, can therefore facilitate the value recognition of SIS. As such, SIS knowledge stock can influence firms' ability to realise the operational and environmental advantages of SIS. Thus, knowledge stock is hypothesised as follows:

Hypothesis 13a: Greater extent of managers' SIS knowledge stock is more likely to improve the operational performance of data centres

Hypothesis 13b: Greater extent of managers' SIS knowledge stock is more likely to improve the environmental performance of data centres

4.4.7. The Boundary Conditions of TOIN

There are some factors that can moderate the TOIN framework of SIS assimilation and SIS value creation and realisation within the context of data centres. These can be classified into moderating variables of SIS value and moderating variables of SIS assimilation.

4.4.7.1. Moderating variables of SIS value

The length of use is expected to mediate the linkage between value drivers and SIS value. The assimilation value of technology innovation is often influenced by the accumulated organisational learning and experience (Fichman 2001). Organisations that have maintained a particular technology for a protracted period of time are more likely to have more experience and better insight about how to effectively create the value through the use and utilisation of an innovation within its own platform (Chatterjee et al., 2002; Liang et al., 2007).

In the context of this research, the length of use is predicted to influence the linkage between SIS assimilation and SIS value creation as well as managers' knowledge stock and SIS value creation. For example, greater time since SIS use may strengthen the SIS accumulated knowledge. However, because of the nature of SIS market and its application in the context of data centres, the length of use might behave differently. For example, a two years old data centre that uses specialised SIS (for power, cooling or ICT management) may achieve higher extent of value realisation than a 15 years old data centre that uses conventional BMS. Therefore, it is predicted that the length of SIS use can moderate the value of SIS and its determinants. Thus, the study hypothesises length of SIS use as follows:

Hypothesis 14a: Length of SIS use moderates the influence of SIS assimilation on SIS value.

Hypothesis 14b: Length of SIS use moderates the influence of SIS knowledge stock on SIS value.

4.4.7.2. Moderating variables of SIS assimilation

Three variables are important in controlling the SIS assimilation: the age of data centre, the size of data centre, and the type of data centre.

The age of a data centre's infrastructure can influence its ability to embrace and support new technology innovation, such as SIS. Previous IS research showed a linkage between the age of organisation (e.g. time since establishment of business which influence structures of signification, legitimization, and domination) and technology assimilation (Chatterjee et al., 2002). Chatterjee et al. (2002) state that, 'Metastructuring actions to promote cognitions, norms, and rules that promote web assimilation might be less effective because of the structural inertia associated with organisational age.' Infrastructure characteristics are among the key elements in forming the IS capabilities (Bharadwaj, 2000). Therefore, the age of a data centre's infrastructure would influence a data centre's ability and manager's willingness to embrace and support SIS. In the context of data centres, both IT and facility infrastructure traditionally represent long-term investment and are designed to be used for long periods (e.g. more than 10 years). For example, an old data centres might favourably invest in SIS as a tool that can improve their existing infrastructure. On the other hand, some might argue that new data centres are assumed to have more readiness for SIS usage. Therefore, the study aims to explore how the differences in the age of data centres influence the volume, diversity and intensity of SIS as well as the latent variables on SIS assimilation. Thus, the study hypothesises data centres' infrastructure age, as follows:

Hypothesis 15: The influence of technological, organisational, environmental, and natural environment factors on SIS assimilation varies due to differences in data centre age.

The size of IS unit which includes the number of IT employees and the size of IT functions have been reported as an important factor for IS use (Fichman, 2001; Cho and Kim, 2002). The size of data centre is an indicator of the volume of business and operations of a data centre, which can shape the technology used to manage that business and/or operations. Due to the nature of data centre business, the literature of data centres (e.g. Lévesque et al., 2010) and exploratory study suggest number of IS employees, number of servers, the size of floor space and the size of IT budget can be used as indicators for the size of data centres. Data centres with large IT infrastructure might focus on the use of systems that can provide comprehensive and consistent surveillance of the entire infrastructure. On the other hand, one can argue that small data centre businesses or large IS units may find it less complex to integrate or use SIS due to small diversity or volume of equipment. Therefore, the study seeks to understand whether the differences in size of data centre influences SIS assimilation as well as its relationships with latent variables.

Hypothesis 16: The influence of technological, organisational, environmental, and natural environment factors on SIS assimilation varies due to differences in data centre size.

Data centres can be classified in terms of business objective and nature of business into three main categories: corporate data centres, co-located data centres, and managed data centres (see Chapter 3 for more details). Investigating different types of data centres are very important because each one has its own objectives and strategies. Exploring the moderation effect of data centre type could help in understanding the process of SIS assimilation among different types of data centres. For instance, in a co-located one, the owner owns the CSSP and network connections only, whereas ICTP are fully owned by the clients. As such, from the perspective of the manager of co-located ones, investing in SIS that can manage the ICTP infrastructure may have no direct return to the host data centre facility and could be beyond the manager's responsibility. Therefore, the study aims to understand the role of the type of data centre in moderating the SIS assimilation and its relationships with its latent variable. To this end, the following hypothesis is formulated:

Hypothesis 17: The influence of technological, organisational, environmental, and natural environment factors on SIS assimilation varies due to differences in data centre type.

4.5. Summary

The theoretical framework of SIS assimilation and value section conceptualised the key dependant variables of SIS assimilation and value and defined and identified independent variables that could drive or inhibit the SIS use and value. Building on the theories identified in the first section of this chapter, *DOI* (Rogers, 1983), *TOE* (Tornatzky and Fleischer, 1990), *institutional theory* (DiMaggio et al., 1983), *RBV* (Barney, 1991; Peteraf, 1993) and *NRBV* (Hart, 1995), and by findings from exploratory study in Chapter 3, the theoretical framework section concluded by identifying and justifying the selection of the most relevant factors to SIS assimilation and value. The identified variables constitute the key input to the conceptual framework and hypothesis development discussed in the following section.

After the theoretical background was established and theoretical framework conceptualised, the study developed a conceptual model and research hypothesis in accordance to the first two sections. The next step is to select, explain and justify an appropriate and rigorous research methodology that is required to validate and test the conceptual model and hypotheses.

CHAPTER 5

5. RESEARCH METHODOLOGY

5.1. Introduction

One of the important pillars in any empirical research is rigorous and well-designed methodology (Orlikowski and Baroudi, 1991). Therefore, before developing and initiating the operationalisation of research instruments, researchers need to think carefully about the nature of data and research structure required to answer the research questions adequately and in a valid and reliable manner (Collin and Hussey, 2003; DeVellis, 2003). In this vein, there are several factors that determine the appropriate research design, with topic under investigation and nature of research question being the primary drivers (Remenyi et al., 1998 cited in Amaratunga et al., 2002). Research design is therefore, a structure that offers an effective mechanism for ensuring the ability of the collected and analysed data of a research to answer the research question literally (DeVellis, 2003).

This chapter begins with a discussion of the research philosophical assumptions and the research paradigms in conjunction with the selected philosophy (5.2). This is followed by the research methodology section (5.3). The research method is then outlined including instrument design, sample design and research ethics (5.4). It further reports more details regarding the sample selection strategy adopted in this study followed by sample design discussion. The chapter concludes with data collection follow-up method.

5.2. Research Paradigms

In a broader sense, a paradigm is *'the progress of scientific practice based on people's philosophies and assumptions about the world and the nature of knowledge; in this context, about how research should be conducted'* Collis and Hussey (2003, p.17). Blaike, (1993) further describes it as *'The nature of reality being made up in components which are reflected in various concepts, laws and theories. Techniques are chosen which are considered appropriate for investigating this reality (epistemology) and accepted examples of past achievements are held up as exemplars to provide the foundation for further practice and for those to follow who wish to become accepted members of the community'* (Kuhn cited in Blaike, 1993, p. 106).

In general, there are two questions which underlie the philosophical assumptions of research paradigms, that is, *what is the nature of the reality from which knowledge is derived?* And *how can we access this reality?.* The first question is referred as *Ontology*, whereases the other one is called *Epistemology.* Therefore, it is essential to understand the philosophical assumptions that underlie the research paradigms.

5.2.1. Ontology

The word Ontology is derived from the Greek word *ont* which means *"the science or the study of …*", and *ology* which means *study.* It encompasses "claims about what exists, what it looks like, what units make it up and how these units interact with each other" (Blaikie, 1993). The philosophy underlying the ontological understanding is the method in which the nature of reality is recognised from which knowledge is derived (Collin and Hussey, 2003). These include questions about the way the world functions and the commitment held to particular perspectives (Mingers, 2003). In short, ontology philosophy describes the researchers view (be it assumptions or claims) about the nature of reality. Particularly, it focuses on whether this reality do exists (objective reality), or merely created in the researchers' minds (subjective reality).

5.2.2. Epistemology

Epistemological assumptions are concerned with the practical matter of accessing reality so that a researcher can "know" it (Hirschheim, 1992). The word Epistemology is also derived from the Greek word, *ology* of *episteme* which means *'.. grounds of knowledge'.* It encompasses a set of assumptions about the methods in which the knowledge of reality can be obtained (Blaikie, 1993), how the reality may be known, what is possible to be known (Chia, 2002), knowing how someone can know, how is knowledge generated (Hatch and Cunliffe, 2006) and what criteria need to be satisfied in order to meet what stands for "knowledge" (Blaikie, 1993).

In business research, the Ontology and Epistemology philosophies have developed into different research paradigms including positivist, interpretivist and critical realist paradigms (Orlikowski and Baroudi, 1991; Cavana et al., 2001). A summary of the differences between the characterisation of these research paradigms (Orlikowski and Baroudi, 1991; Cavana et al., 2001) is illustrated in Table 5.1:

Table 5.1: Description of the difference between major methodological frameworks

Characteristic	Positivist	Interpretivist	Critical Realist
Ontology	Social reality is what can be sensed and observed in the physical world. Researcher is independent from reality	Social reality is what it is that make it (pre-interpreted). Researcher is fully inseparable from reality	Social reality is material world of contradiction and/or exploitation. Researcher is inseparable from reality but urges to change the reality
Epistemology	Knowledge of the world (objective reality) exists beyond the human mind (Objectivism)	Knowledge of the world is constructed through research observation and experience (Constructionism)	Knowledge of the world can be objectively known by removing tacit ideological biases
Methodology	Quantitative data	Qualitative data	Qualitative and Quantitative
Strategy	Deductive (move from theory to data, general to specific)	Inductive (move from data to theory, specific to general)	Deductive and Inductive
Purpose	Exploratory/Explanatory Theory/Hypothesis testing	Descriptive/Interpretive Theory generation	Uncover myths and hidden meaning Critical Theorising
Method	Experiment, Survey, Case study, Simulation, Forecasting, Simulation	Ethnography, Action Research, Grounded Theory	Field research, Historical analysis, Dialectical analysis
Analysis	Descriptive and inferential statistics	Qualitative contents and major theme identification	Descriptive statistics and qualitative contents
Data Collection	Observation Questionnaire Large samples	Interview Participant Observation Small samples	Historical Enquiry Oral History Interviewing
Primary remarks	Highly specific and precise, Rigour, High reliability, Low validity	Rich and subjective, Trustworthiness and authenticity, Low reliability High validity	Historical situatedness, Action stimulus
References	Orlikowski and Baroudi, 1991; Mingers, 2003; Galliers, 1992; Collin and Hussey, 2003; Weber, 2004	Mingers, 2003; Galliers, 1992; Collin and Hussey, 2003; Weber, 2004	Cavana et al., 2001

5.2.3. Research Paradigms under the Ontological and Epistemological Philosophies

A positivistic paradigm is fundamentally based on natural science. Its main focus is to measure the phenomenon as it occurs in reality (Mingers, 2003; Collin and Hussey, 2003). An interpretive paradigm is fundamentally based on social science. Its main focus is to understand the phenomenon under investigation from the perspective of human participants (Mingers, 2003; Collin and Hussey, 2003). A critical paradigm combines conflict theory and critical sociology within one theoretical backbone (Orlikowski and Baroudi, 1991; Cavana et al., 2001).

Understanding the characteristics of these philosophies and paradigms is essential for successful research methodology. For instance, a researcher that follows a deductive approach (that moves form general to specific) at the beginning of his/her research cannot jump to the inductive approach in which the structure is totally opposite (Saunders et al., 2003). However, research paradigms are evolving and researchers are innovating their own ways in conducting a research. This chapter is not intended to discuss the argument behind those paradigms in detail; rather, it provides an understanding of major philosophical assumptions underlying IS research and how it can guide the research.

The foundation of positivist and interpretive paradigms is developed from two different streams. The positivistic philosophy is fundamentally based on natural science. Its main focus is to measure the phenomenon as it occurs in reality. The interpretivist philosophy is fundamentally based on social science. Its main focus is to understand the phenomenon under investigation from the perspective of human participants. The critical realist paradigm, has taken its role in the business research field (Orlikowski and Baroudi, 1991; Cavan et al., 2001; Sekaran, 2000). Although many researchers adopted the critical research, Sarantakos (1998) believed this approach can be regarded as methodology rather than a paradigm. Therefore, most researchers use only the positivist and interpretivist classification when referring to philosophical assumptions to avoid the confusion of adding critical as a third class (Collin and Hussey, 2003). Thus, the present research follows this classification and focuses only on these two paradigms in the remaining discussion of this section.

In positivism, the ontological assumption is that reality and objects under investigation do exist in the world before researchers initially become interested in studying them. In addition, studies will cause no changes to the reality and objects under investigation (Blaike, 1993, Collin and Hussey, 2003). In interpretivism, the ontological assumption is that reality "*is regarded as the product of processes by which social actors together negotiate the meanings for actions and situations; it is a complex of socially constructed meanings"* (Blaike, 1993, p. 96). The epistemological assumption is that reality is derived from everybody's concepts and meanings. In addition, it attempts to diminish the distance between the researcher and what is being researched (Collin and Hussey, 2003).

In general, positivism infers the collecting and production of quantitative data. This involves more objectivity of data. The measurement of variables is normally presented in the form of numerical data. The data collection strategy can be of several forms such as survey, case study, simulation by using methods such as questionnaire and large samples. The data then can be analysed via the application of statistical tests (Mingers, 2003; Galliers, 1992; Weber, 2004).

On the other hand, interpretivism infers the collecting and production of qualitative data. This involves more subjectivity of data. The description, perception and the world's activity are normally presented in the form of word text. The data collection strategy can be of several forms such as ethnography and action research by using methods such as interview and small samples. The data then can be analysed via interpretive meaning and contextualisation (Walsham, 1995; Mingers, 2003; Galliers, 1992). However, most research is inclined to use a combination of quantitative and qualitative (mixed method) (Mingers, 2003). The issue here is where the researcher would position his/her research mostly.

The selection of research strategy at the research initiation is very important. It helps to determine the logical flow for the production of evidence. The most well-known strategies used by researchers are the deductive strategy used by positivists (where a researcher starts with a theory/hypothesis and then collects data to test it) and the inductive strategy used by interpretivists (where a researcher starts with collecting data and then building theory). There are also two other strategies which are abductive (a researcher immerses him/herself in reality in order to understand the phenomenon) and retorductive (involves imagination and analogy to work backward from data to explanation) (Blaikie, 2000).

In summary, and based on the above discussion in respect to the philosophical assumptions and research paradigms, it is believed that the positivist paradigm is most appropriate as on epistemological base for this research for the following reasons:

First, the current study is concerned with understanding the SIS phenomenon in the context of data centres which requires a defined construction and evaluation criteria. The epistemological assumption is applicable as it concerns with the established criteria by which valid knowledge in relation to a particular phenomenon can be constructed and evaluated (Orlikowski and Baroudi, 1991).

Second, the research model that is being tested in this study was developed by building on theories. These theories have been used and tested by several IS researchers. There is clear and sufficient evidence that they are not falsified theories. In this regard, the positivist perspective asserts that a theory is regarded as a true theory if it is repeatedly demonstrated by empirical events as being trustworthy (Chua 1986, p. 604).

Third, the study endeavours to empirically test a number of SIS assimilation and value hypotheses based on relevant IS theories. In this regards, the epistemological belief of positivist view is relevant as it concerns with the empirical testability of these theories (Chua, 1986).

Fourth, this study is concerned with the ongoing relationships between SIS technology and the performance of data centres. In particular, it is interested in the process of SIS use and value. The literature reveals that IS researchers who are interested in the investigation of technology implementation/use/adoption; the relations among IT and organisations; and in how IT can be successfully introduced into the structure of organisations usually adopt the positivist paradigm (Kling and Scacchi, 1982; Orlikowski and Baroudi, 1991).

Fifth, the positivist view appears to be the most dominant epistemology in IS research and can be viewed as a research tradition,(Orlikowski and Baroudi, 1991), accounting for about 81% of published empirical research (Chen and Hirschheim, 2004).

5.3. Research Methodology

Research methodology is *'the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcomes. This is our strategy our design that shapes our choice or particular* *methods and links them to desired outcomes. It is the rationale for the methods employed'* Crotty (1998, p.8). In this study, the research strategy that is formally adopted in conjunction with the positivist approach, is the deductive strategy (Collin and Hussey, 2003). This strategy requires the development of research hypotheses based on general observations derived from published literature and preceding theoretical frameworks together with direct feedback (qualitative) from data centre executives (exploratory study), and then designing a method to test them. This has facilitated building a tailored a theoretical framework that can explain the phenomenon under investigation. Moreover, this would allow us to effectively assign the most relevant constructs needed to enhance the conceptual model.

The current research adopted a mixed method (quantitative and qualitative) approach (Creswell, 1994; Mingers, 2003). The method provided comprehensive information about the use and value of SIS and gave the research a combination of rigour, reliability and validity. The purpose of research is both exploratory and explanatory. The research endeavoured to discover and confirm a set of factors and causal laws (Neuman, 1997) that can influence, determine and leverage the use and value of SIS within the context of a data centre environment. This required surveying a larger number of data centres. By using a survey, the researcher was able to explain the general patterns of SIS in a data centre setting, and the factors that could influence the extent of use and value of SIS. Therefore, the characteristics of a quantitative approach were most appropriate (Neuman, 1997). However, the use of a qualitative approach in this research was relatively important. In order to arrive at a better understanding and interpretation of SIS use and value and due to the lack of theory-driven research in these areas, the researcher needed to get into the depth of this phenomenon. This required conducting interviews to receive detailed feedback in a natural setting (Neuman, 1997) (see chapter 3, exploratory study). The qualitative part of the research was reported in chapter 3 and this chapter will focus on the conduct of the main and quantitative study.

5.4. Research Methods

Research methods are *'the actual techniques or procedures used to gather and analyse data related to some research question or hypothesis'* Blaikie (1993, p.7). These include instrument design, sample design, research ethics, and data collection.

5.4.1. Instrument Design

Adopting proper and well-designed empirical research methods is of a paramount importance to executing rigorous and relevant research output. A number of books and articles are devoted addressing the need for reliable and valid psychometric measures of constructs used in research (Churchili, 1979; Straub 1989; DeVellis, 2003). Achieving rigorous research results is dependent on the availability of adequate, reliable and valid empirical research strategies which are required for any empirical study to be successfully executed (Chau, 1999). In this vein, the development of valid and rigorous research measurement instruments become vital to the conduct of empirical research (Straub, 1989). The process of instrument measurement or constructs operationalisation involves “rules for assigning numbers to objects to represent quantities of attributes" (Nunnally, 1967, p. 2). These instruments constitute the reality check tools that allow investigators to evaluate to what degree the conceptual research problem or solution are consistent with actual practitioner experience (Straub, 1989).

One way to ensure the ability of instrument measurement to capture the constructs adequately is by applying rigorous rules in the process of instrument development (Churchili, 1979; DeVellis, 2003). The greater the rigour of instrument development, the less the error of the measurement. One of the most cited methodological guides for measurement of instrument development that has received support in the IS literature is the tool articulated by DeVellis (2003). Thus, the present research will follow the DeVellis research plan as a guide for the development of the research instrument. DeVellis (2003) introduced research procedures for developing better measures comprising eight steps. The procedures are as follows:

(1) Definition of constructs (5.4.1.1).
(2) Generation of pool of item (5.4.1.2).
(3) Choice of respondent format (5.4.1.3).
(4) Review of the items (5.4.1.4).
(5) Pilot testing of the instrument (5.4.1.5).
(6) Administration of the scale to a development sample (data collection) (5.4.1.6).
(7) Refinement of the scale using item analysis (data analysis and cleaning) (chapter 6).
(8) Evaluation of the scale (measurement model evaluation) (chapter 7).

The first six steps are explained in this chapter, step seven will be discussed in chapter 6 (data analysis), whereas step eight is applied in chapter 7.

5.4.1.1. Step 1: Definition of constructs

The first step in developing rigorous and valid instruments is to determine the domain of constructs adequate to inform the research problem or solution (DeVellis, 2003). Specifying the domain of constructs entails the development of clear and accurate definitions for each construct. This includes clarifying what is included and what is excluded in the definition of a construct (Churchili, 1979). As stated earlier, the constructs used in this research are token from IS literature, data centre literature and exploratory study. The TOIN framework was constituted of 21 constructs.

An extensive review of the IS assimilation and value literature, data centre literature and results from exploratory study led to the definitions of the 21 research constructs. Table 5.2 defines the research constructs and indicates the references from which they were derived.

Table 5.2: A summary of research constructs used in the research model

Variable	**Definition**	**Reference**
SIS Volume	The total number of SIS used in the data centre (that is unique in functions and capabilities).	Massetti and Zmud 1996; Case study
SIS Diversity	The number of data centre functional areas that are supported by SIS, including facility, cooling, power and ICT management	Massetti and Zmud 1996; Case study
SIS Use-Intensity	The extent to which SIS is used in monitoring, analysing, reporting, recommending and controlling the data centre facility, cooling, power and computing resources management functions.	Gupta and Whitehouse, 2001; Ravichandran, 2005; and Case Study
SIS Integration Intensity	The extent of SIS integration with ICTP platform, CSSP platform and other IS	Gupta and Whitehouse, 2001;Ravichandran, 2005; Case Study
SIS Value	The ability of an organisation or a data centre to improve the operational and environmental performance of data centre operations through extending the use of SIS	Barney, 1991; Penrose, 1995; Hart 1995; Zhu and Kraemer, 2005; Case Study
Relative Advantage	The SIS's superior or unique advantages such as its capability, features, effectiveness and functionality	Roger ,1983

Table 5.2 (Continued)

Variable	**Definition**	**Reference**
SIS Compatibility	The degree to which the SIS is consistent with the existing values, technologies, norms, experiences, and requirements of the assimilating data centre	Roger ,1983
SIS Complexity	The difficulty to understand, learn, integrate and use SIS.	Roger ,1983
Perceived. Uncertainty	The subjective assessment made by data centre members about the current and future prospects of SIS	Ravichandran ,2005
Top Management Support	The effective participation by top management in shaping the vision and strategies for the use of the SIS that can introduce complementary structures to facilitate SIS assimilation, and modify and reinforce the norms that value the use of SIS	Kwon and Zmud, 1987; Chatterjee et al., 2002
Green IT/IS Orientation	The incorporation of natural environment policies in an organisation to use, upgrade or purchase a technology, systems or IS that can improve the overall environmental performance of that organisation	Hart, 1995; Case Study
Data Centre Energy Governance	The existing procedures with respect to the accountability and responsibility of the energy efficiency and transparency of data centre operations.	Case Study
Coercive Pressure	The external pressure exerted on an organisation by regulatory, dominant stakeholders or a parent organisation where an organisation executes its business.	DiMaggio and Powel, 1983
Normative Pressure	The external pressure exerted on an organisation by collectively defined conditions, methods and standards set out by professional members of data centre industry, which enable them to control data centre practices of an organisation and establish legitimation for their occupational independence.	DiMaggio and Powel, 1983
Energy pressure	The effect of energy related issues in driving the decision to use SIS in the data centres.	Loper and Parr, 2007; Case Study
Environmental preservation pressure	The effect of natural environment resources and its related issues in respect to the volume of non-renewable energy sources, CO_2 emissions and hardware lifecycle in driving the decision to use SIS in the data centres.	Hart, 1995; Case Study
SIS Knowledge Stock of Manager	The extent to which an organisation or data centre acquires the specific knowledge of a SIS that is necessary for successful assimilation.	Ravichandran, 2005
Length of SIS Use	Time elapsed since first time use of SIS in the data centre	Fichman, 2001
Age of data centre	Time since establishment of data centre business in the current data facility	Chatterjee et al., 2002
Size of data centre	The number of IT employees and the size of IT functions including servers and data centre budget.	Fichman, 2001; Lévesque et al., 2010
Type of data centre	The nature of data centre business including organisation structure, objectives and infrastructure configurations.	Case Study

The concepts depicted in Table 5.2 are the foundation of the research model and were clearly defined in Chapter 4. The definitions of most of the above constructs were derived from the IS literature. The rest of the constructs relating to the data centres context were partially defined using both data centre literature and results from exploratory case study.

5.4.1.2. Step 2: Generation of pool of items

The second step following the dentition of the domain of constructs is the exploration of these constructs by identifying instruments from antecedent empirical research in order to develop a pool of items (DeVellis, 2003). Drawing from existing empirical research and previously validated instruments helps to eliminate error in measurement. Further, it helps to improve the measurement validity by ensuring that the pool of items is a good representative sample of items that can inform the concepts adequately. An extensive literature review of empirical IS research was conducted and relevant variables used to measure the concepts were extracted. The criteria for selection included how relevant the items were for the context of research, and how well they had performed in previous survey-based studies as discussed in chapter 4.

In view of the fact that the present research explores an under-researched phenomenon, the literature review was therefore insufficient to inform all the concepts used in the research instruments, especially those relating to data centres and SIS, which both lack empirical research. These new concepts were identified and defined using literature on data centres and SIS, and then further explored and validated using exploratory study discussed in chapter 3. A total of five data centre managers contributed to exploratory study and provided the researcher with constructive feedback about the concepts that motivate and/or inhibit the use and value of SIS in the data centres. Some of these concepts were firstly identified from data centres and SIS literature and then validated using the exploratory study; others such as data centre energy governance, size of data centre, age of data centre and type of data centre were newly discovered during the study.

The literature review and exploratory study led to an initial pool of 114 items for the defined research constructs. The initial pool of items was further improved and modified through a series of discussions with research supervisors to ensure the relevance of the items in relation to the constructs they measure, the adequacy of items to inform the constructs, the consistency of the items, and to identify proper phrasing for the items. Finally, a research instrument of 91 items was agreed upon. Table 5.3 illustrates some details about the steps used in selecting the number of research items.

Table 5.3: a summary of instrument's items development steps

Steps	**added**	**revised**	**deleted**	**Net**	**date**
First draft	114	-	-	114	22/10/2010
After first consultation	30	18	47	97	17/12/2010
After second consultation.	9	11	17	89	23/12/2010
After third consultation.	2	6	7	84	26/01/2011
After panel of expert	6	5	0	91	28/03/2011
After pilot testing	0	2	0	91	12/04/2011

The first three variables, SIS relative advantage, SIS compatibility and SIS complexity, were largely derived from previous research on technology innovation (Cho and Kim, 2002; Liao and Lu, 2008). The sample of items from these constructs has been utilised and validated in a number of previous studies (Grover and Teng, 1994; Agarwal, and Prasad, 1998; Cho and Kim, 2002; Bradford and Florin, 2003; Liao and Lu, 2008; Wu and Chuang, 2009). Top management support construct was derived from the IS research on the characteristics of leaders and workforce (Chatterjee et al., 2002). This construct has been operationalised and validated by previous researchers (Meyer and Goes, 1988; Attewell, 1992; Chatterjee et al., 2002). The concepts of normative pressure and coercive pressure were conceptualised and validated by previous IS research (Teo et al., 2003; Zhu and Kraemer, 2005; Liang et al., 2007; Chen et al., 2009), and hence the items were derived from their validated instruments. The variables of data centre size (IS units) (Fichman, 2001), the age of infrastructure (Chatterjee et al., 2002), and length of use (Cho and Kim, 2002), were derived from previous IS research. Because there was no previous conceptual framework for SIS assimilation and value, all of the research variables identified from literature have been slightly revised to suit the research context (e.g. system title, area of investigation).

The rest of the research constructs including SIS assimilation, SIS value,, perceived SIS uncertainty, data centre energy governance, green IT/IS orientation, energy pressure, natural resources, and knowledge stock, have received a dearth of empirical support and instrument validity in the IS literature. The concepts of perceived SIS uncertainty and knowledge stock were partially derived from previous research (Cho and Kim, 2002; Ravichandran, 2005; Zhu and Kraemer, 2005) and then adapted to the context of the study using further insights from exploratory study in order to generate the relevant items. Although literature from section 2.2 and 2.3 (e.g. Loper and Parr, 2007; Molla and Abrashie, 2011; Zheng and Cai, 2011; Chen et al., 2011) provided insights to conceptualise the concepts of data centre energy governance, green IT/IS orientation, energy pressure, and environmental preservation, these constructs were all new to the research and hence their items were generated using insights from both the literature and the exploratory study in chapter 3. Appendix 5a shows from which source the pool of items was drawn from and how the latent variables in research instrument were operationalised.

To ensure the rigour and validly of the above seven constructs, there was a necessity that the revised and generated constructs and their measures be scrutinised by knowledgeable academic and practitioner experts.

All the items that have not been validated and tested empirically by previous research — particularly those relating to SIS assimilation, perceived SIS uncertainty, data centre governance, green IT/IS orientation, energy pressure, environment preservation pressure, and knowledge stock, were then scrutinised through a panel of experts survey.

5.4.1.3. Step 3: Choice of respondent format.

In conjunction with the generation of items pool, the researcher must consider the format of the scale that is required to best answer the questions (DeVellis, 2003). Each item measuring one construct should have equally weighted scale. The most common format scales used in social science and business are the Thurstone scale, Guttman scale and Likert scale. These types of scales consist of statement questions and a series of responses such as Yes/No, Agree/Disagree. The number of scale responses or steps of answer can be varying from a question to another allowing for wide range of responses (DeVellis, 2003). For Likert scale, the wording of items must be strong enough to elicit a wide range of respondent responses. Gable and Wolf (1993) state that response format is “an open question from an empirical point of view”, and thus no approach is superior in scale format and researchers should evaluate the scale carefully, compare with other studies and consult with experts (Gable and Wolf 1993; DeVellis, 2003).

The current study used the Likert-scale consisting of a mix of Yes/No, Agree/Disagree, High/Low and open ended text. The scales used were in line with the other IS researchers who measured their research instruments (e.g. Cho and Kim, 2002; Chatterjee et al., 2002; Ravichandran, 2005; Liang et al., 2007; Liao and Lu, 2008). The developed scale was evaluated and extensively discussed with supervisors and final format was agreed upon. Further, the scale of new items was evaluated by a panel of experts for suitability and a summary of the scale is depicted in Appendix 5a.

5.4.1.4. Step 4: Review of the items (Panel of expert questionnaire)

The primary objective in this stage was to further improve the validity of the research instrument through consultation with knowledgeable and expert people in the fields of information technology and data centre to record their opinions and insights regarding the relevance of the items (DeVellis, 2003). A review process requires an evaluation of the instrument versions by experts who are familiar with the content of the research until a form of agreement is reached (Cronbach, 1971). A panel of experts consisting of 45 IT/IS academics and data centre practitioners and consultants were contacted. Table 5.4 illustrates the profile of the panel of experts.

Table 5.4: Profile of the panel of experts

Sent	Profile	Apology	Response	Country
13	Professors of IS with a profile of assimilation research	5	0	mixed
2	Professors of IS with a profile of green IT research	0	2	Australia
16	Professors of IS	6	3	Australia
6	Academics with a profile of green IT research	0	6	3 UK, 3 Australia
4	Practitioners with an interest in green IT/data centre research	2	0	
2	Data centre magazine editors/chief editors	0	2	Singapore
2	Data centre systems consultants	0	1	Australia
45		13	14	31.10%

All the nominated academic experts were known for their research in technology innovation, IS research and green IT, whereas the nominated practitioner experts were known for their expertise in data centre research, green IT and data centre information systems developments. The experts came from a variety of universities, research centres, and consultancy institutions and had a range of experience in IS and technology use. This kind of variety improves the quality of experts' feedback on the instrument. The panellists were all identified from publications, conferences, and professional profiles published in their organisations or other professional institutions. An online questionnaire was set up and the panel of experts was asked to judge the relevance of each of the items in the instrument by answering Yes/No questions and relevant/ not relevant questions. In addition, they were asked to rate the adequacy of existing items of each of the constructs to inform the scale by answering Yes/No questions, and adequate/ not adequate questions. Further, the panellists were encouraged to provide their feedback on the instrument scales and their measures and suggest additional items they believed are not covered in the instrument.

An email invitation containing a plain language statement, together with secure website link to the online questionnaire, was sent to the panel of experts. The invitation email and the panel of experts questionnaire are displayed in Appendix 5b. Follow-up procedures were applied to increase the rate of responses. One week later, a reminder was sent to the non-respondents. Out of the 45 approached, 14 responses were received in total — 6 responses after the first invitation and 8 responses after the second invitation. For this kind of study, a response rate of 31% was considered reasonable.

To determine the agreement and validity of the panel of expert results, an inter-judge reliability test was established. This test allows the measurement of agreement among the observers (panellists) through calculating the correlation-coefficient (Litwin, 1995). The test shows that F=2.47 and P=.020. Although the agreement was significant, the test was not completed correctly as six raters were excluded by SPSS due to zero difference in the agreement. Thus in addition to the inter-judge reliability test, the researcher decided to use an additional measure by calculating the percentage of agreement between respondents on each item as well as the agreement on the adequacy of the items of each construct to capture what they suppose to measure (see Appendix 5c). After discussion with supervisors, a rule of thumb was established to scrutinise any item that has an agreement less than 85% as well as when the agreement of the adequacy of items in each construct to capture the construct was less than 85%.

The majority of the 14 panellists have offered valuable feedback and insight regarding existing items. These feedbacks have allowed the researcher to improve the instrument by enhancing the clarity, refining wording, and adding new items. Table 5.5 provides an overview of the significant changes made after scrutinising the items and construct and taking into consideration the suggestions of the panel of experts.

Table 5.5: Instrument improvement after panel of experts survey

Construct	%	Recommendation/ Action required	Items
SIS Diversity	57.14%	Rephrase SD1 and SD4, adding new items for more explicitness	SD1 and SD4 items were rephrased. SD5 and SD6 items were added for more clarity. SD5: Management of data centre power usage. SD6: Management of IT resources load.
SIS Value	85.71%	Add one item SV6	SV6: Predictive analysis and preventative measures have improved.
SIS Integration-Intensity	71.43%	Separate SBI1 and SBI3 by adding three more items	SBI2: Integrated with cooling systems. SBI3: Integrated with power systems. SBI5: Integrated with each other.
Energy Consumption	64.29%	Rephrasing items EC4 and adding an item about design	EC5: Data centre design constraints that cause inefficiency of energy usage (including building, floor and structure design).
Environmental Preservation	64.29%	NC3 was rephrased to include IT hardware impact	NC3: The need to increase the lifecycle of IT hardware in data centres.
Knowledge Stock	85.71%	Rephrase KS2	KS3: The technical skills required to operate SIS.

In addition to the major amendment in Table 5.5, some other items were slightly modified to enhance the wording without changing the meaning of the question. After strengthening the validity of the new items, the research instrument is assumed to be adequate to measure the research constructs and has sufficient content validity. The next step was to test the revised research instrument with sample population to check how the instrument is interpreted by the targeted audience (DeVellis, 2003).

5.4.1.5. Step 5: Pilot testing of the scale instrument

The next step was to administer the revised research instrument to a sample of data centre managers. This step is recommended by a number of textbooks (Dawis 1987; Gable and Wolf, 1993; DeVellis, 2003). This step allows the researcher to check for potential problem with the instrument such as overall design, clarity of wording and instruction, time needed to complete the survey and the way potential respondents interpret the questions.

As part of a comprehensive pre-test (set of activities), the questionnaire was pilot tested with three data centre managers. The three managers were conveniently selected from a conference on data centres. This process ensures the content validity of the measures. The pilot test was conducted face-to-face and allowed for more understanding on how data centres interpret the wording and content of the questionnaire and respondents were handed out a hard copy version of the survey.

The survey was readable to all three respondents and their interpretation was in line with the objective of the scale; thus the clarity of wording and interpretation was assumed. However, the biggest issue that was raised was the time taken to complete the survey.

Based on the feedback, the preliminary instrument was scrutinised and amended. Through the use of some design work such as adjusting the page width, shrinking the distance between questions, removing unnecessary examples previously used to improve item clarity, and consolidating questions with similar instructions under one instruction, it was possible to reduce the number of pages needed. These improvements have made significant change in the survey layout and improved the appearance of the online version. After completing this step, the final version of the research instrument was ready for administration to the large population.

5.4.2. Sample Design

The design of the research sample is a very important pillar in order to obtain valid and reliable data in the conduct of empirical research (DeVellis, 2003). There are guidelines that a researcher can follow to design their research sample in a sound manner (Fowler, 1993; De Vaus, 2002; DeVellis, 2003). In general, the design of a good representative sample involves three key and interrelated decisions: the sampling frame, the sample size, and the sample selection criteria (Fowler, 1993).

5.4.2.1. Sampling frame

One of the objectives of sample design is to establish a method of information collection that can capture all the facets of diversity in one group. As such a goal is difficult in large populations, the use of sampling is more practical (DeVellis, 2003). Therefore, in large populations, as in most cases, researchers should draw a sample out of a particular population, which can be regarded as a good representative of the entire population (De Vaus, 2002). Thus, researchers should carefully select the sample that can best reflect the population. To ensure that the study is comparable to previous assimilation studies, a literature review was conducted covering IS assimilation research to identify the sampling frame of similar studies. Table 5.6 provides a comparison of sampling frames from previous studies.

The comparison of sampling frames from IS research in Table 5.6. indicates some interesting features that can be drawn from previous studies in order to understand the norm. *First*, most studies focused on specific industry segments (one or two industries) in their sample frames (Chatterjee et al., 2002; Raymond et al., 2005; Zhu et al., 2006; Liang et al., 2007;). Few others included a wider variety of industries (Ranganathan et al., 2004; Rai et al., 2009). These studies imply that focusing on particular industry segments is likely to allow better understanding about the influence of technology usage on particular populations and also helps to avoid the biases or differences in the perception of respondents from other sectors.

Secondly, the most common organisation size in inclusion criteria was large firms (Chatterjee et al., 2002; Ranganathan et al., 2004; Liang et al., 2007). Two had mixed large firms together with small and medium size firms (Zhu et al., 2006; Rai et al., 2009), whereas one research focused on small and medium firms only (Raymond et al., 2005). These studies imply that the phenomenon or nature of technology under investigation can be one of the reasons behind the focus on organisations with particular characteristics.

Table 5.6: Comparison of sampling frames from previous studies

Authors	Method	Industry	Firm Size	Country
Chatterjee et al., 2002	field and Online Survey	manufacturing and services	large (sales over $500m).	USA
Fichman, 2001	Survey	IT	corporate information systems, organisations	USA
Karahanna et al., 1999	mail Survey	not specified	all	USA
Liang et al., 2007	survey	ERP vendor	large (subsidiaries of a large firm)	China
Rai et al., 2009	mail Survey	industrial machinery and equipment, electronic equipment, wholesale trade, durable goods, and business services	All	USA
Ranganathan et al., 2004	field Survey	all	large (+500 employees and =+20 IT personnel_	USA
Raymond et al., 2005	mail Survey	manufacturing	SMEs	Canada
Zhu and Kraemer, 2005	Survey (through computer-aided telephone interviews)	retail/ wholesale industry	all	10 countries (Brazil, China, Denmark, France, Germany, Japan, Mexico, Singapore, Taiwan, United States)

In this research, one of the considerations in relation to the definition of the population was whether the data collection should be limited to particular sector, size or geographical arena. In particular, these considerations stem from four aspects. First, the study seeks to examine the factors that explain variation in the assimilation of SIS and the value of SIS and their influence on data centres. These factors are not confined to particular sectors and are recognised as being significant to nearly all industries. In addition, the inclusion of organisations from different industries that represent a wide variety of interests can help to access the different facets of the phenomenon under investigation. Moreover, the research was not intended to study the influence of industry characteristics on the assimilation and value of SIS and hence all types of industries were included in the sample selection.

Second, the research is not intended to study organisations, but rather the data centres of these organisations. Data centres have their own unique characteristics and they could be large IS units within organisations or sometimes represent organisations in their own right such as in the case of co-located data centres. Thus, limiting the focus on large organisations, as most other researchers do, would not be applicable to the case of data centres. For instance, large organisations with more than 500 employees may not have a dedicated data centre (i.e. because they outsource the entire IT operation), whereas organisation with less than 30 employee can run an entire co-located data centre (ACR, 2010). Under these circumstance, the size of organisation as a selection criterion would be inapplicable for identifying the data centres.

Third, due to the lack of this kind of research and the dearth of information about the research phenomenon, it was important to expand the targeted population to a wider geographical coverage. Lastly, because of the newness of SIS investigation in the data centre context, the ambiguity of what constitutes SIS assimilation and value in the data centres, and because SIS itself is an under-researched phenomenon, it was very important to know as much as possible about this phenomenon through the diversification of population selection, without delimitation to particular sector, size, or geographical arena.

Based on the above four considerations, it was decided to draw a sample inclusive of all types of organisations and explore potential relationships among the research constructs. In doing so, this study is intended to obtain data from organisations that have data centres irrespective of their sectors, sizes or location.

5.4.2.2. Sample size

The determination of the minimum required returned sample size (MRSS) that can inform a given phenomenon to a satisfying degree and the initial sample size (ISS) of organisations contacted is a very important process in the conduct of survey-based research (De Vaus, 1995; Bartlett et al., 2001; DeVellis, 2003). Understanding the difference between the two is important because the margin of error has an inverse relationship with sample size. That is, when increasing the sample size, the margin of error decreases. Nevertheless, it is fair to contend that in the conduct of quantitative research large sample size is not always a good indicator because it can carry adverse effects on the economics of the research (De Vaus

2001). Thus, there is a necessity to reach the 'optimum point' where sample size becomes adequate and the economics of the research can offset the desired research outcome.

The MRSS and ISS are dependent on a number of factors such as the desired accuracy and precision and types of data analyses. In respect to accuracy and precision, Bartlett et al.(2001) and De Vaus (1995) argue that the MRSS should be decided upon the desired degree of accuracy and anticipated confidence level (Bartlett et al., 2001; De Vaus, 1995). However, others (Fowler, 1993) argue that it is not feasible for a researcher to make precise numerical estimates or specify the desired level of the actual population, and thus using accuracy and precision to determine the MRSS is an inappropriate method. The determination of the MRSS can be influenced by the use of particular data analysis techniques that pose some requirements on the MRSS (Bartlett et al., 2001). Deciding the MRSS in accordance to data analysis have received acceptance in the conduct of quantitative research (Bartlett et al., 2001; Collis et al., 2003), and hence the present study adopted this method.

To this end, the researcher needed to determine the expected MRSS first and then arrived at the adequate ISS (Collis et al., 2003). Firstly, in order to determine the MRSS, a researcher must select the desired method or technique of statistical analysis. In this vein, several authors (Bartlett et al., 2001; Hair et al., 2006) inclined to set limits that need to be considered in selecting some types of statistical analysis. In the current study, the Exploratory Factors Analysis (EFA) and Partial Least Squares (PLS) statistical methods were used for data analysis. For EFA as a desired statistical analysis method, the number of observations should not fall below 100 (Bartlett et al., 2001). Comery (1973) describes 100 as poor, 200 as fair, while 300 as good MRSS. In the case of using multiple regression analysis the ratio of independent variables would need to be maintained at five or above (Bartlett et al., 2001). Nevertheless, others argue that a ratio as low as 1.3 subject per item is sufficient to obtain a stable factor structure (Arrindell and Van Der Ende, 1985).

PLS is one of the best techniques suitable for use with small sample sizes and complex exploratory models (Bontis et al., 2002). Although the PLS can accommodate small samples (e.g. 80), in general, some textbooks suggest that an MRSS of 200 is however required in most multiple regression analysis techniques (including PLS) to ensure the data has validity and reliability (Hair et al., 2010).

Despite argument around the ideal MRSS for a given type of statistical analysis, the decision on the sample size, in the final instance, is a matter of the researcher's judgment that takes into account the different factors and circumstances of particular research rather than of merely calculation (De Vaus, 1995; Fowler, 1993). Based on the above discussion regarding the determination of the MRSS in accordance to the desired statistical analysis method, that is EFA and PLS and considering the suggestions made by popular textbooks, an MRSS of 200 was assumed to be sufficient for this study.

Secondly, when determining the appropriate ISS, a researcher should look at the tradition in the relevant research areas regarding the sample size (Bartlett et al. 2001). This is one of the common methods to anticipate response rate in a situation where over sampling is required. A review of the literature was conducted to review the tradition used in the area of IT assimilation research in respect to the MRSS. Table 5.7 provides a list of the results.

Table 5.7: Comparison of sample sizes from previous assimilation studies

Authors	Method	Sample Size	Responses	%	Usable	%
Chatterjee et al., 2002	Field and Online Survey	525	75	14.3%	62	11.8%
Fichman, 2001	Survey	1500	608	40.5%	608	40.5%
Karahanna et al., 1999	Mail Survey	977	268	25%	268	25%
Rai et al., 2009	Mail Survey	1200	166	13.8%	166	13.8%
Ranganathan et al., 2004	Field Survey	1200	249	20.7%	176	14.7%
Raymond et al., 2005	Mail Survey	800	108	13.5%	108	13.5%
Zhu and Kraemer, 2005	Survey (computer-aided telephone interviews)	5400	701	13%	624	11.5%
Average		**1657**	**310**	**20%**	**287**	**20%**
Range		**800 - 5400**	**75 – 701**	**13.5- 40 %**	**62 - 624**	**11.5-40.5%**

There was also a need to consider the norms in respect to the expected response rate before making the final decision regarding MRSS. The comparison in Table 5.7 indicates that the MRSS ranged from 75 to 608 (average 245) observations. ISS ranged from 525 to 1500 (average 1033).

Further, the overall response rate for the majority ranged around 13–40%, and the average of invalid responses out of the sample sizes was 3.3%. Except for one study (40%), the prevailing response rates averaged at 16.7% and usable data rate at 15%. Because the previous studies in Table 5-8 were conducted in different time intervals, it can be observed that most of the previous research conducted from 2002 onward has gained response rates ranging from 13–20% (15% on average). Although previous studies suggested that the average response rate from relevant research areas was 15%, obtaining a response rate lower than expected rate is always a common phenomenon in IS research (Pinsonneault and Kraemer, 1993), which is also becoming more obvious in some recent studies which indicate that the response rate, especially in the case of web surveys, is getting less and less (Fink and Neumann, 2007; Peszynski and Molla, 2008). As a result, a researcher wanting to achieve the desired MRSS while conducting a web-based survey should decide to increase the ISS in order to avoid the likelihood of getting a low response rate.

Based on the above discussions which suggest 200 for MRSS, and 15% of response rate as the tradition, the calculation suggests that the ISS of this study should be 1333. However, for more precaution and to avoid the likelihood of getting lower response rate, the researcher decided to slightly increase the number to 1500 participants as the ISS.

5.4.2.3. Respondent selection criteria

After the sampling frame was defined and sample size was determined, the next decision was to identify the respondents that can best inform the study. Senior IT executives of organisations are regarded as appropriate respondents for IT-based research (Huber and Daniel, 1985). To ensure that the present research adheres to the tradition of previous IT assimilation research, a literature review was conducted to provide a sort of comparative basis for the selected criteria. The results are presented in Table 5.8.

Table 5.8: Respondent selection criteria in previous assimilation research.

Authors	Respondent	Database	Country
Chatterjee et al., 2002	Titles including Director and Vice President, CIO, Webmaster and others	On-Line Directory of Corporate Web Sites (www.hoovers. com).	USA
Gallivan, 2001	IS managers and non-management employees.	4 firms were chosen opportunistically --, the researcher sought firms that were beginning to implement client/server development	USA
Kouki et al., 2010	Operation/production/finance/accounting/, IT, and plant managers.	Six organisations were chosen opportunistically	Canada and Tunisia
Liang et al., 2007	Managing directors	the clients of UFIDA (known as UFSoft before 2005)	China
Rai et al., 2009	presidents, vice presidents, and operations and purchasing managers.	the membership database of the Institute for Supply Management™ (ISM) (www.ism.ws).	USA
Ranganathan et al., 2004	IT executive, often the CIO	ACR directory of top computer executives in North	USA
Raymond et al., 2005	SMEs' chief executive and functional executives	PDGH database	Canada
Zhu et al., 2006	IS managers and non-IS managers	CRITO Inc./International Data Corporation (IDC) and Market Probe	10 countries (developed and developing countries)

The results from Table 5.8 indicate that respondent selection was focused on IT executives and the most knowledgeable persons about the phenomenon under investigation. In addition, the majority have used single databases from online sources to assemble the contacting list, whereas few others involved in multi-geographical studies have used multiple databases. As in the case of this research where targeted population is data centres, the targeted respondents in each organisation were assumed to be the IT senior executives most familiar with the data centre management issues, and thus data centre managers were considered to satisfy this objective.

Applied Computer Research Inc. (ACR) — a professional institution specialised in providing databases of top IT executives in North America — has established criteria that help to identify the organisations that have data centre(s) (ACR, 2010). According to ACR criteria, the existence of job titles such as data centre manager, IT operations manager and IT infrastructure manager in organisations are highly associated with the existence of either a dedicated data centre or physical IT infrastructure similar to a data centre environment. Therefore, one way to capture the targeted population is through focusing on the three titles.

Out of the three titles, the present research focuses only on data centre managers as the most appropriate IT executives, for three reasons. First, depending on the organisational structure of data centres, an organisation might have more than one IT executive working in the same data centre, such as data centre manager and IT operations manager. Thus, collecting data in such circumstances might lead to obtain two or more responses from one data centre. This criterion also increases the accuracy of the selected sample and ensures selecting organisations that have dedicated data centres. Second, since the study was aimed to investigate the use of SIS in the data centres, rather than the perception of IT executives, it was decided that soliciting one IT executive from each data centre is the most appropriate method. Lastly, among the three common data centre executive titles, data centre managers are considered to be the most appropriate respondents because their key role is to understand data centre issues and manage data centre business functions. It was therefore assumed that data centre managers are the best people who can inform the phenomenon under investigation. Nevertheless, in cases where the main desired senior IT executives (data centre managers) were not contactable, the IT executives (IT operations manager and infrastructure manager) can be an alternative appropriate substitute for respondents, as suggested by Huber and Daniel (1985).

One of the difficulties the author had in defining the sampling frame was to find usable lists that identify the targeted organisations. Despite business organisations (such as Incnet or DNB) claiming to have lists of potential respondents that can accommodate the needs of the research, it was not possible to find a usable list (an often difficult task in the case of most IS research (Kraemer, 1991)) that contains all the organisations that have either a dedicated data centre(s) or physical IT infrastructure similar to a data centre environment. Thus, it was important for the author to find a reliable and valid database that suits the objective of the sampling criteria.

Due to the lack of existing commercial databases that classify data centres and data centre managers (such as Incnet or DNB), it was necessary to find an alternative usable source, such as professional institutions or networking databases. For the purpose of this research and based on the above considerations, a reputable professional directory, *LinkedIn*, that satisfies the above selection criteria, was identified as a frame from which the sample will be drawn.

An initial search through LinkedIn Corporation database, a professional networking website with over 85 million members in over 200 countries, returned with more than 40,000 active data centre senior professionals as of 10/12/2010 including IT managers, data centre managers, infrastructure managers, facilities managers, and anyone involved in the critical decisions and infrastructure planning of data centres worldwide.

Three considerations were put in place before making the decision regarding the selection of the appropriate contact database, including the validity of database, the geographical coverage and the availability of email contact. It was decided that the LinkedIn online database (http://www.linkedin.com) appears to be the most appropriate source that can fulfil the above considerations. LinkedIn is one of the most active and live social networking websites comprising professional members from a wide range of industries from all over the world, including data centres. Thus, it was practical to use the LinkedIn online database to get updated lists of data centre professionals. In addition, LinkedIn services allow the reach of global respondents, and support online survey through allowing direct online communications. Previous studies indicate that social network sites, including LinkedIn, are regarded acceptable for recruitment of participants, for obtaining further information about potential participants, and for helping the researcher in making the decision on who should be invited to participate (Butow and Taylor, 2009; Caers and Castelyns, 2010).

To examine the applicability of the respondent selection criterion and to validate whether the potential outputs of search results using this criterion can return the desired outcome, the investigator carried out a preliminary search through LinkedIn database for members who hold the job title of ”data centre manager”.

The preliminary search output showed that in most cases the result did not return members matching the job title “data centre manager” only. Some of these members have slightly different titles, but fill the role of data centre manager. It was observed (through inspecting the job description and tasks performed by each member as well as through consultation with two data centre managers from two LinkedIn groups), that organisations use a verity of titles such as “manager of data centre, director of data centre, data centre director, director of data centre service, director of data centre operation, director of mission critical facility, data centre infrastructure manager, mission critical facility manager, or president of data centre facility“ to refer to the person performing the role of data centre manager. Therefore, they were all considered as targeted respondents that fall within the category of “data centre manager”.

A LinkedIn (http://www.linkedin.com) search for members that currently hold the relevant job titles as identified above yielded 4312 records (see Table 5.9).

Table 5.9. A Summary of available relevant titles acting as data centre managers

British Style search	Count	**American Style search**	Count
Job Title		***Job Title***	
Data centre manager	475	Data center manager	1556
Manager of data centre	237	Manager of data center	1047
Director of data centre	57	Director of data center	567
Data centre director	5	Data center director	59
Director of data centre services	12	Director of data center services	70
Director of data centre operations	12	Director of data center operations	172
Data centre infrastructure manager	10	Data center infrastructure manager	22
President of data centre facilities	1	President of data center facilities	2
Mission critical facility manager	1	Mission critical facility manager	duplicate
Director of mission critical facilities	7	Director of mission critical facilities	duplicate
Sub-total	817		3495
Total			4312

5.4.2.4. Sample selection strategy

There are number of scientific methods a researcher can use to draw the ISS out of the sampling frame. This includes sampling techniques such as simple random sample (SRS), stratified sampling, cluster sampling, and purposive sampling (Patton, 1990; Särndal et al., 2003; Lohr, 2009). SRS is a basic sampling technique where potential participants are chosen by chance and each individual has an equal chance of being selected. Whereas stratified sampling involves the inclusion of independent samples from a number of strata, subpopulations within population, cluster sampling involves clustering the population into groups (cluster-level frame) and then selecting a random number of groups to represent the population (Särndal et al., 2003; Lohr, 200). Purposive sampling is a sampling technique in which the subject is selected because of certain characteristics to achieve a certain goal (Patton, 1990). It is a non-probability sampling method in which any particular sample may not be calculated.

In the current research, it was important to select the appropriate method that best suits the source of research data. The investigator consulted the LinkedIn support team about this and a sampling decision was made based on the following considerations.

Firstly, LinkedIn does not offer any kind of service for purchasing contact lists. In addition, the members' list of LinkedIn cannot be exported for the purpose of performing probability calculation. Therefore, the SRS sampling method could not be applied effectively.

Secondly, although most of the 4312 data centre managers are part of groups or subgroups, it was not possible to apply stratified or cluster sampling. For example, one person can join a number of groups, and exist in more than one group simultaneously. In addition, people self-enrol themselves into LinkedIn groups. As such, this is contrary to stratified and cluster sampling rules. Therefore, it was decided that purposive sampling best suited the data source used in this study.

One of the important considerations in making a decision on the use of purposive sampling is the question of how to sample the population efficiently (Bernard, 2002). As such, purposive sampling is most applicable to sample the population efficiently in this study due to the nature of LinkedIn databases. Purposive sampling is a popular technique used in qualitative research (Patton, 1990). It is also used in quantitative research (Campbell, 1955) including IS management field (Kraemer et al., 1991) such as using survey or questionnaires (Tongco, 2007). For example, Shi and Bennett's (1998) study on IS management knowledge, Pijpers et al.'s (2001) study on the use of IT, and Esteves's (2009) study on ERP usage have used the survey for data collection and adopted the purposive sampling design because they regarded it as the best technique for representing the population of interest and to serve their research purposes.

In purposive sampling, the investigator decides what needs to be known and apply particular criteria to find key informants, who are reflective members of the community of interest, who know a great deal about the phenomenon and who are willing to provide or share the required information by virtue of experiences or deep knowledge (Bernard, 2002; Tongco, 2007). The criteria for selecting the informants define what would make a good informant and typically composed a list of qualifications that the informant must have (Allen, 1971). However, the investigator needs to pay careful attention to the criteria that should be applied in order to reduce the chance of bias.

5.4.2.5. Criteria for applying sample selection strategy

In the first attempt to apply a carefully designed criterion, the investigator consulted the LinkedIn support team to identify the best criteria for sampling and contacting 1500 data centre managers out of the 4312 identified in the research. Since LinkedIn does not supply any form of a members contact list, the investigator was advised that the best and most effective method to communicate with targeted members was through joining existing LinkedIn groups. The support team also indicated that there are a number of active data centres professional groups that can be used for this purpose. Following this, a four step procedures (Figure 5.1) was developed to identify the sample respondents.

Step 1: *Identifying groups*. The first step was to search through all LinkedIn groups to identify data centres groups by using key word ‘data centre’—spelt both ‘centre’ and ‘center’—in Boolean format. The search returned 864 data centres groups that exist in the LinkedIn database. Since it was not possible to join all of these groups in order to gain access to their members, it was important to select a small number of groups (representative) using criteria designed to serve the objective of this study.

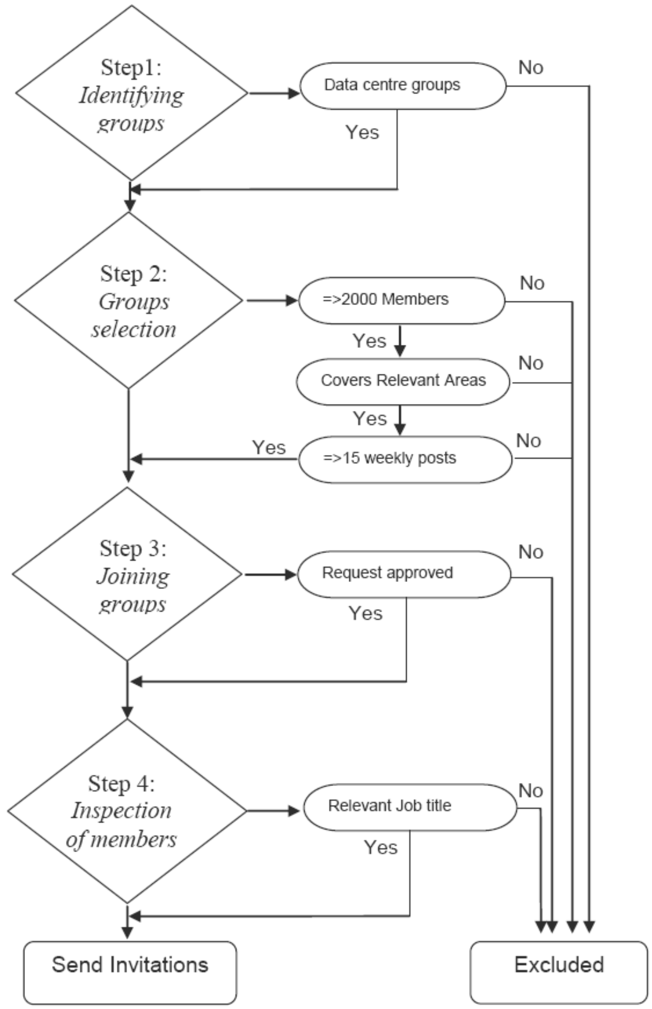


Figure 5.1: Structure of sample selection strategy

Step 2: *Group selection.* To increase the chance of contacting a larger number of key informants that satisfy the objective of this study, three criteria were established in conjunction with LinkedIn recommendations to select representative groups out of the 864 groups. This included filtering the groups based on the total number of group's members, the objective of group and its relevance to the current study, and the rate of members' activities with each group.

Firstly, the total number of members of each group was taken into account. It was assumed that groups with larger number of members would likely allow the investigator to gain access to a wide range of contacts. Thus, the first criterion was established to limit the selection to groups that have more than 2000 members (The ISS was 1500 and thus the number of members was set above it).

Secondly, the relevance of the objectives of each group to the current study was considered. As one of the considerations was to focus on who knew a great deal about the research phenomenon, it was important to focus on groups that are specifically concerned with issues relevant to the research context. In this regard, groups that focus on data centre management, monitoring software, infrastructure automation, best practices, and green data centre issues were considered relevant. Thus, the second criterion was to select groups that at least focus on one of the above five areas by inspecting the group's description/objective.

Thirdly, the rate of each group's activity was taken into account. Groups that have high number of active members would likely provide more indication about the value of the group to society and show to what extent their members are keen to share their experience and knowledge with others. Thus, the third criterion was to limit the selection to the data centre groups that have a posts rate of at least 15 per week (This rate was set in accordance with the consultation with LinkedIn which indicates the minimum active rate of groups). This has reduced the groups that meet the three criteria (combined) to 14 groups..

Step 3: *Joining groups.* A request to join the 14 groups were then sent to the administrators of these groups and only nine of them accepted the request. A follow-up was applied with the non-responding administrators, but no positive response was received during the time of data collection. At the completion of this step, the investigator became a part of nine data centre professional groups with 199874 members (some members exist in more than one group). Nevertheless, due to the restrictions imposed by LinkedIn, the investigator was only able to access 500 records of members from each group: 4500 in total.

Step 4: *Inspection of group members.* A thorough inspection was carried out covering all the 4500 members. This was done by visually checking the 'current' title of each member individually. The aim of this step was to find the key informant that holds the title of data centre manager, manager of data centre, director of data centre, data centre director, director of data centre service, director of data centre operation, director of mission critical facility, data centre infrastructure manager, mission critical facility manager, or president of data centre facility (using both the American and British spelling variations). This inspection was carried out (starting from largest groups) until the ISS were archived (1500). Table 5.10 provides a summary of key results from the four steps.

Table 5.10: A summary of selection steps

		Group selections			Sample Population	Respondent selection
Group No.	**Group Name** (at the time of study)	**Size of members**	**Average weekly post**	**Relevant area of inertest**	**Maximum viewed members (restriction)**	**Member meeting the title criteria**
1	Cloud Computing, VMware, Virtualization and Enterprise 2.0 Group	108,293	858	data centre management/ infrastructure automation	500	323
2	Australian IT Industry	39,928	259	data centre management/ best practices,/ green data centre	500	203
3	Data Center Professionals	19,697	176	data centre management,/ infrastructure automation	500	234
4	The Green Data Center Alliance	10,996	131	best practices /green data centre	500	317
5	Data Center and Cloud Marketplace	5,990	46	infrastructure automation / best practices	500	109
6	Datacenter2link	5,415	72	data centre management,/ monitoring software,/ infrastructure automation,	500	102
7	Data Center Pulse: INDUSTRY	3,997	44	data centre management	500	86
8	Afcom	3,258	36	data centre management/, infrastructure automation / best practices	500	124
9	Data Center Operations Management	2,300	23	data centre management,/ monitoring software,/ infrastructure automation	500	2
Total					4500	1500

Overall, the investigator cannot claim that the list of the nominated 1500 contacts is an accurate representation of the entire population or that it is free from bias because it was carried out in accordance to the purposive sampling, which is a non-probability sampling technique. However, despite this limitation in the sampling and considering the nature of data source (LinkedIn), the steps applied above represent a fair attempt to survey the population of interest. Overall, the surveyed 1500 potential respondents represented 35% of all relevant titles (4312) that are available in the entire LinkedIn database (see Table 5.9), which shows that the study captured almost a third of the population.

5.4.3. Research Ethics

Most if not all research involves one or more ethical issue (Miles and Huberman, 1994). The ethical issues may pose some risks (low/moderate/high) to the investigators, participants or institutions in the conduct of research. In business research the most important ethical considerations include; objective dealing with subject organisations, confidentiality and anonymity, informed consent, dignity and publications of data (Collis and Hussey 1997; Hussey and Hussey 1997). All research conducted through RMIT University involving the collection of data from people must obtain approval from the RMIT Human Research Ethics Committee (HREC). The HREC objective is to promote ethically good human research and ensures that rights of investigators, participants or institutions are protected and their responsibilities are clearly defined. For this purpose, the HREC follows the National Statement on Ethical Conduct in Human Research published by the Australian Research Council.

To conduct the preliminary pilot study, an ethics application was lodged to the RMIT-HREC and approval obtained with ref. 1000098 on November 2009. A second ethics application to conduct the main study (survey) was also approved by the committee with ref. 1000249 on 15 February 2011. Both applications were assessed by BCHEAN (Business College Human Ethics Advisory Network) – a subcommittee of HREC, and were classified as category 1 research (negligible or no risk).

5.4.4. Data Collection and Follow-Up

The current research uses LinkedIn as the main source for identifying the potential respondents. LinkedIn provides two methods of communication with the existing members. The first method can be done by creating a group and inviting people to join the group or by joining an existing group and then sending emails directly to all existing group members (through the LinkedIn internal email service). The second is the paid service where the investigator can send emails to anyone in the LinkedIn network (LinkedIn state that they guarantee the response to the email for US$10 per email). However, the communication methods must be done through LinkedIn's internal email service in which respondents can keep their actual email addresses invisible. Therefore, the most effective way was to use an online survey.

The first LinkedIn communication method was used as the main recruitment method to recruit potential participants. The investigator followed the practice and directions provided by LinkedIn as explained in section 5.4.2.4 on sample selection strategy.

A total of 1500 private invitation e-mail were sent to the internal LinkedIn email account of 1500 members asking them to participate in the study. The invitation included a brief introduction about the investigation, a link to the plain language statements explaining the nature of the research to recruit them to participation, and a website hyperlink that instantly directs the potential respondents to the online questionnaire (see Appendix 5d).

During the attempt to contact the 1500 members, the investigator experienced an issue (due to LinkedIn's policies), that is worth of reporting in this section. Since the contact list of group's members cannot be exported for use in mass email systems (e.g. email campaign programs), nor can the 1500 members be contacted with one click, the researcher had to find an alternative practical method for contacting respondents. It was believed that the only available method to the researcher was to contact each member through the internal LinkedIn email on an individual basis (member by member).

Overall, the steps applied for identifying groups, selecting groups and members, inspecting members as explained in the sample selection strategy section (see section 5.4.2.4), and process of sending the invitation letters was a time consuming process and required a great deal of effort. In particular, it required on-screen work of approximately 58 hours (over eight working days).

To collect the data, a web-based survey provider (http://www.questionpro.com) was used to collect the empirical data between April 2011 and July 2011. Further, in order to enhance the survey return rate, follow-up procedures were carried out in the form of two reminders to the non-respondents after nine days and three weeks. The reminder process required less effort, compared to the first attempt, as all the potential participants were already available in the outbox of the investigator's LinkedIn account (thus there was no need for a new search or validation process). Nevertheless, similar to the first attempt, every potential participant had to be contacted individually. This process required on-screen work of approximately 12 hours on two occasions.

To avoid sending reminders to participants who have already completed the survey, after completing the questionnaire, respondents were asked to voluntarily reply to the invitation letter through the LinkedIn system stating that the survey is completed. This procedure has not involved collecting email addresses or affected the anonymity of the survey.

The first invitation to all 1500 contacts was carried out in the middle of April 2011, via LinkedIn internal email (over a period of eight days). Due to the low response rate, a first reminder was sent to all non-respondents nine days after the last invitation (early May 2011) using the same method of communication (over a period of two days). Table 5.11 document details of all the stages of invitations and reminders.

Table 5.11: A brief summary of the number of attempts to contact potential respondents

	First wave	**Second wave**	**Third wave**	**Fourth wave**
Means of communication	LinkedIn internal email	LinkedIn internal email	LinkedIn internal email	LinkedIn internal email, and few web based emails
Survey Format	Web Survey	Web Survey	Web Survey + SSL link	Web Survey + SSL link+ soft copy+ hardcopy
Date	22 April	1 May	23 May	17 Jun
Duration	8	2	3	2
Sent Invitations	1500	1421	1372	1303
Received Response	48	75	51	69

After the first reminder, three data centre mangers contacted the investigator asking for a secure web link (SSL). They explained that they were very concerned about the security and potential threats to their critical infrastructure (e.g. computer viruses). They advised the researcher that failure to do so, could also restrain other data centre managers from participation in the study. In response, the investigator purchased an SSL web link from the survey provider and offered this link to all participants (in the second reminder)..The second reminder (third wave) was initiated three weeks later (late May 2011).

After the second reminder, and for security reasons, others requested an offline version of the survey since they were not keen to visit a web link offered by external parties or a link leading to a non-authenticated organisation (e.g. not hosted by a university website). In response, and as it was difficult to upload the survey on the RMIT University web servers, participants were offered a soft copy version of the survey in Microsoft Word format as well as the option to receive a hard copy version via express post. After the first attempt that was followed by two reminders, the fourth and final wave of invitation was re-sent to the non-respondents in the middle of June 2011, and the survey was closed two weeks later (on July, 4^{th}), after the responses (243) exceeded the MRSS (see also section 6.6).

5.5. SUMMARY

This chapter discussed the methodology of the research that is used to measure the research framework discussed in Chapter 4. In the first section, philosophical assumptions followed by research paradigms were discussed. The discussion led to the selection of the positivistic paradigm and epistemological philosophy as the base for this study as it was believed that it best suits the nature of the study. The research methodology was then reported. This was followed by the instrument design discussion. A number of rigorous procedures comprising eight steps were applied to develop sound and reliable measures. Another section has outlined the applicable sample design of the existing research. It was decided that an initial sample size of 1500 contacts would be sufficient to arrive at the desired minimum required returned sample size of 200 responses. The chapter also reported some details regarding how the data were collected as well as information about the research ethical issues. The chapter concluded with the main source of data collection that is used for the measures of the research framework. In summary, the chapter outlined a rigorous and valid research methodology that is capable of answering the research question.

CHAPTER 6

6. DATA PREPARATION AND SCREENING

6.1. Introduction

Before the data was exported to the statistical analysis software, the raw data needed to be examined, prepared and explored. The examination and screening of the collected data set are necessary steps in any research analysis (Lewis-Beck et al., 2004). Data preparation and screening process can help to reduce the measurement error and maintain sound data. It also helps to ensure that the data satisfy the requirement for multivariate analysis techniques (statistical techniques that analyse multiple factors simultaneously), which is discussed in the following chapter. The objective of examination and screening steps is to reveal the hidden effect of not apparent aspects in the actual data (Hair et al., 2010). The steps can be executed using several techniques as discussed in the following sections of this chapter.

In this chapter, series of steps are performed for the purpose of data preparation and screening. These steps include data cleaning and transformation (6.2), evaluation of missing data (6.3), identification of outliers (6.4), tests of normality (Appendix 6a) and response and non-response bias (6.5). The chapter also briefly reports details about the collected data including the profile of participating data centres, the respondents' profiles as well as the level of SIS usage among the surveyed data centres (6.6).

6.2. Data Cleaning and Transformation

Data cleaning involves the process of scrutinising the data set of the study to check its suitability for transformation into statistical software packages (e.g. SPSS). This process was performed through several steps. First, the data were imported from a third-party platform (online survey provider) into a Microsoft Excel file. The data of the Excel file were sorted according to the date and time of response. Second, a unique identifier (sequence number) was allocated to each response to allow unique identification of the cases. Third, the data set format and variable labels were adjusted so that they could be exported to the SPSS for statistical analysis. A total of 243 responses were ready to be used for further analysis.

6.3. Missing Data Analysis

Missing data is a common problem in the area of multivariate analysis, which is rarely avoidable in any quantitative research (Lewis-Beck et al., 2004). A data set is diagnosed to have a missing data problem when a valid value on one (or more) variable does not exist in the respondent record (Hair et al., 2010). According to Hair et al. (2010), a researcher should worry about missing data for two reasons. First, missing data has a practical impact on data analysis as it can cause the reduction of sample size because the software will normally exclude the observations with missing data on any of the variables. Second, missing data can raise substantive concerns as it can easily lead to erroneous results and could cause data bias. Thus, the researcher should carefully deal with missing data by applying available diagnosing and remedies methods. For these purposes, the current study adopted the four steps approach recommended by Hair et al. (2010) for identifying missing data and applying remedies, which include (1) determining the type of missing data, (2) determining the extent of missing data, (3) diagnosing the randomness of the missing data process, and (4) selecting the imputation method.

6.3.1. Step1: Determining the type of missing data

This step allows the researcher to determine the type, cause and source of the missing data, if applicable, that can be either ‘ignorable’ or ‘not ignorable’ (Allison, 2002). Whereas ‘ignorable’ missing data refers to the missing values that do not require any further remedies, ‘not ignorable’ missing data refers to missing values that may require further remedies. Non-ignorable data can be classified as ‘known’ and ‘un-known’ missing data (Hair et al., 2010).

The aim of this step was to determine the type and cause of missing data and whether the amount of missing values per variable or per case warrant applying remedies techniques. To this end, an assessment of the entire data set was performed and missing data were identified and calculated to provide meaningful data (e.g. amount and percentages of missing data in variables and cases). A total of 2578 out of 22,599 points (11.4%) were identified as missing values. The missing data consisted of missing cases (e.g. not complete responses or respondents who did not answer all questions) and missing variables (e.g. particular questions not been answered by several respondents). Altogether, the missing data were assessed as ‘not ignorable’ on the ground that these missing data force the researcher to proceeds with the examination of missing value. This is because they do not allow multivariate analysis to be executed correctly without applying specific remedies and also have theoretical importance.

Most of the non-ignorable missing data were un-known because they were due to failure to respond to certain questions or because the respondent has insufficient knowledge to answer the question (e.g. the floor space of data centres, data centre annual budget). Few others were identified as known processes because they were due to failure to complete the last parts of the questionnaire (e.g. missing data concentrated in the fourth quarter of the questionnaire). Hence, data examination was performed for each process in step 2.

6.3.2. Step 2: Determining the extent of missing data

After the not-ignorable data were identified, the next step was to examine the pattern and extent of missing data for both cases and variables (Lewis-Beck et al., 2004). This step can be performed by calculating the percentages of variables with missing data for each case and the number of cases with missing data for each variable (Hair et al., 2010). Table 6.1 and 6.2 provide details of missing data by case and by variable respectively.

Table 6.1: Missing data of cases

Number of cases	Variables completed	completion rate	Missing variable	Total missing data points	Decision	Reason
28	23	24.7%	70	1960	Delete	above 10%, and pattern concentration exists
7	51	54.8%	42	394	Delete	above 10%, and pattern concentration exists
3	81	87.1%	12	36	Delete	above 10%, and pattern concentration exists
9	90	96.8%	3	27	Impute	minor with 3.2%
7	91	97.9%	2	14	Impute	minor with 2.1%
6	92	98.9%	1	6	Impute	minor with 1.1%

Table 6.2: Missing data of variables

Construct	Variable ID	No of missing entries	%	Decision	Reason
DC size	DC4	45	18.50 %	Delete	above 15%,
	DC5	96	39.50%	Delete	above 15%,

The rule of thumb proposed by Hair et al. (2010) for deleting cases with above 10% of missing data and variables with above 15% were applied. Table 6.1 shows that a total of 38 cases had missing values of more than 10% and had non-random patterns in the data (concentration in specific questions). Table 6.2 shows that two variables that ask data centre budget (DC 4) and data centre facility size (DC5) had missing values more than 10%. These observations violate the retention criteria and should be deleted without a need to perform the third step of randomness test. Thus a total of 2 variables and 38 cases had to be eliminated from the study. 22 cases were retained for remedies due to very minor missing values <3.2%.

6.3.3. Step 3: Diagnosing the randomness of the missing data process

After we have identified the extent of missing data that need an action, the next step was to determine the degree of randomness, which are either Missing At Random (MAR) or Missing At Completely Random (MCAR) (Allison, 2002; Hair et al., 2010). It is important to note that this step should be performed only when the missing data that warrant action are substantial. If the missing data are not substantial enough, no further diagnoses are needed and the researcher can skip this step directly to the forth step and use some remedies for substitution (Hair et al., 2010). The final decision of assessing what is low and high is a matter for researcher judgment (Hair et al., 2010). The remaining cases with missing data (after deleting cases and variables with high missing data) show that the amount of total points accounting for missing data was 47 out of 19,065 (0.25%), which was very low. In addition, the missing data were not concentrated into one variable. Therefore the substantiation of these values is not likely to create any bias in results. Thus, based on the above justification and by following the rule of thumb of Hair et al. (2010), it was decided that this missing data is not substantial and the data can be imputed directly with no requirement for further diagnosis.

6.3.4. Step 4: Selecting the imputation method

The purpose of imputation is to estimate the missing values based on valid values from other variables or cases. However, the researcher at this step must determine the approach for accommodating the missing data or imputation. Hair et al. (2010) suggest that if the researcher decided during step 2 that the missing data is not substantial (e.g. skipped diagnosis in step 3), but still wanted to substitute the missing value, then the missing data should be handled as MCAR. The imputation methods available for MCAR are divided into two categories: imputation using only valid data and imputation by using replacement values. The decision on determining what is the most appropriate method (complete case approach, all-variable approach, hot or cold deck, case substitution, mean substitution or regression imputation) is a matter of judgment having the nature of missing data in mind. Because the missing data in our sample were mostly characteristics-based items (i.e. number of servers, number of racks), it was decided to use imputation of mean substitution by using only valid data from the same item. This method implies the replacement of missing values using only valid data from observations (Hair et al., 2010). To this end, the mean was calculated and the missing data of the 22 cases was replaced leaving 205 usable responses for further analysis. It was then possible to have a complete data set that is valid for use in statistical packages.

6.4. The Test of Outliers

The detection of outliers, which is a common problem in empirical research, is important to avoid the impact of abnormal values. Abnormal values could lead to invalid representation of the population (Lewis-Beck et al., 2004). An outlier is a unique combination of an observation identifiable as distinctly different from the other observations in the sample (Hair et al., 2010). Outliers occur for a variety of reasons including procedural error, extraordinary events, extraordinary observations, and unique combination of values. Outliers affect the way an observation represents the population (Allison, 2002). A researcher has three methods to detect potential outliers: Univariate, Bivariate or Mutlivariate detection (Hair et al., 2010).

Univariate method examines the distribution of all cases for each variable in the analysis to allow for setting a low and high range for the distribution. Any observation falling beyond the distribution limit is identified as an outlier. This method standardises all the values in the sample. Cases with standard scores of 2.5–4 (based on the sample size) are identified as potential outliers. The Bivariate method (uni-dimensional) is an extension of Univariate. This method focuses on the relationships of specific variables (e.g. the dependant vs independent variables) and typically uses a scatter plot at confidence interval level of 90% or 95%. The Mutlivariate method (Multi-dimensional) is used to assess the distance of observation in multi-dimensional spectrum from the mean centre of the entire cases in the sample. Mutlivariate analysis can generate a single value for each case irrespective of the number of variables included in the analysis through the use of the Mahalanobis distance (D2) measure. Thus, it is best suited for measuring a complete variate such as variables in factor analysis (Hair et al., 2010). The D2 for the complete variate is divided by the number of variables used in the test. The D2 divided by the degree of freedom D2/df with conservative confidence level of .005 or .001 should be used as an indication for potential outliers if D2/df exceeds 2.5 for small samples (i.e. 80 and fewer) and if D2/df exceeds 4 for larger sample size (Hair et al., 2010).

The determination of the best approach for outlier test depends on the size of the sample and the number of variables (Hair et al., 2010). However, the researcher should utilise as many methods as possible to detect any potential outliers. Because our aim was to examine a complete variate with large number of variables, the best method was the Mutlivariate. Based on our sample size (205), a conservative D2/df threshold level of .005 resulting in value 3.5 (degree of freedom) was decided to be a good limit for the study. The Mutlivariate test was performed using SPSS and computation through a function named CDF.CHISQ. The minimum returned value was .011 which was above the conservative threshold of .005. Thus, based on the results, it can be concluded that there are no outliers that deserve the researcher’s attention.

6.5. Response and Non-Response Bias

The non-response bias is a common problem in most empirical studies, especially in the survey-based research (Rogelberg and Stanton, 2007). Non-response can cause sample bias as well as problems in respect to the generalisations of the results. It is based on the assumption that the population is represented by a subset sample of those who responded to the questionnaire (Nesterkin et al., 2010). As the number of non-respondents increases, the chance of non-response bias increases. Rogelberg and Stanton (2007) advocate that non-response bias assessment should be performed regardless of how high the actual response rate is. One way of looking at the effect of non-response bias is by dividing the sample into subsets of teams or groups and then comparing the deviation of the average between them (Nesterkin et al., 2010).

There are different statistical methods to assess the severity of non-response bias in a data (Rogelberg and Stanton, 2007). These include archival analysis, follow-up approach, wave-based analysis, passive non-response analysis, interest level analysis, active non-response analysis, and worst case resistance analysis. Although there are no strict guidelines or norms for concluding whether non-response is causing a serious problem or not, the researcher should utilise at least one of the available methods for assessing non-response bias (Lewis-Beck et al., 2004).

A review of the IS research shows that wave-based analysis appears to be the common method used for assessing non-response bias and hence adopted in this study. To be cautious, in addition to the wave-based analysis, interest level analysis was also performed. Interest level analysis is arguably one of the best techniques for non-response bias assessment (Rogelberg and Stanton, 2007).

6.5.1. Wave-Based Analysis

The data was first examined for potential non-responses bias using the waved-based analysis method. This technique requires splitting the data set into two parts and then testing the differences using appropriate method. For this purpose, the data set was divided into two sub-samples, early respondents (waves one and two) and late respondents (waves three and four). The early respondents accounted for (50.2%) – 103 in total, whereases late respondents were 102 accounting for 102 (49.8%). The statistical independent t-test at 5% significance level was performed through SPSS. This test help to inspect potential non-responses biases that may exist due to differences between early respondents and late respondents by comparing the means of items scores of all constructs between the two sub-samples. The result of the independent t-test is illustrated in Table 6.3.

Table 6.3: Non-response bias test for early respondents and late respondents

Construct	Early Respondents (103)		Late Respondents (102)		T	p	Mean Dff	STD. Error Diff
	Mean	SD	Mean	SD				
SIS Assimilation	0.78	0.43	0.84	0.39	-1.17	0.32	-0.06	0.06
SIS Value	3.66	1.08	3.82	1.01	-1.11	0.31	-0.16	0.15
SIS Compatibility	3.77	1.04	3.78	1	-0.28	0.65	-0.01	0.14
SIS Complexity	3.16	1	3.08	1.13	0.6	0.26	0.07	0.15
SIS Relative Advantage	4.1	0.95	4.24	0.74	-1.06	0.48	-0.14	0.12
SIS P. Uncertainty	3.57	1.05	3.63	1.04	-0.5	0.55	-0.06	0.15
Top management	3.42	1.16	3.58	1.15	-0.99	0.32	-0.16	0.16
Green IT/IS orientation	2.29	0.75	2.38	0.7	-0.8	0.43	-0.08	0.1
DC Energy Governance	3.5	1.42	3.59	1.39	-0.53	0.46	-0.09	0.2
Normative Pressure	2.85	1.3	3.05	1.23	-1.11	0.3	-0.2	0.18
Coercive Pressure	3.54	1.52	3.35	1.49	0.9	0.46	0.19	0.21
Energy Pressure	4.58	1.34	4.49	1.39	0.42	0.67	0.09	0.19
Environment Preservation	3.65	1.5	3.91	1.58	-1.23	0.3	-0.26	0.21
Knowledge Stock	3.2	1.22	3.37	1.09	-1.02	0.36	-0.16	0.16

The analysis shows that there is no significant difference between the two subsamples of early respondents and late respondents at confidence interval of 95% (p-values above 0.05) This implies that the effect of non-response is not statistically significant to the level that affects the data.

6.5.2. Interest Level Analysis

The interest level analysis method assumes that results become biased if the respondents' interest level is related to the attitudinal standing on the area making up the questionnaire preferences. In this study all respondents were offered the option to receive a summary report of the findings of the study. Out of the 205 responses, 84 requested to receive the report and this group was taken as 'interested' data centre managers. It was expected that the interested data centre managers may overrate SIS usage and value. Thus, the sample was split into two groups: interested data centre managers 41% (84) — the group who requested the report — and non-interested data centre managers 59% (121). The SPSS was used and statistical independent t-test at 5% significance level was performed to see if there was a difference between interested and non-interested data centre managers by comparing the means of items scores of all constructs between the two groups. The result of the independent t-test is illustrated in Table 6.4.

Table 6.4: Non-response bias test

Construct	Interested DC Managers (84)		Non-Interested DC Managers (121)		t	p	Mean Dff	STD. Error Diff
	Mean	SD	Mean	SD				
SIS Assimilation	0.65	0.24	0.64	0.26	0.37	0.61	0.01	0.04
SIS Value	3.77	1.02	3.72	1.06	0.33	0.51	0.05	0.15
SIS Compatibility	3.81	1.04	3.75	1	0.4	0.35	0.05	0.14
SIS Complexity	3.36	0.94	3.25	1.12	0.74	0.52	0.11	0.15
SIS Relative Advantage	4.16	0.89	4.18	0.84	-0.19	0.67	-0.02	0.012
SIS P. Uncertainty	3.6	1.05	3.6	1.04	0.036	0.44	0.005	0.15
Top Management	3.2	1.18	3.7	1.09	-3.16	0.007	-0.5	0.16
Green IT/IS Orientation	2.25	0.76	2.4	0.7	-1.49	0.26	-0.15	0.1
DC Energy Governance	3.29	1.45	3.72	1.35	-2.19	0.03	-0.43	0.2
Normative Pressure	2.88	1.3	2.99	1.24	-0.62	0.39	-0.11	0.18
Coercive Pressure	3.2	1.46	3.62	1.53	-1.99	0.06	-0.42	0.21
Energy Pressure	4.13	1.48	4.82	1.2	-3.65	0.006	-0.69	0.19
Environmental Preservation	3.56	1.55	3.93	1.52	-1.72	0.16	-0.38	0.22
Knowledge Stock	3.19	1.21	3.35	1.12	-0.95	0.38	-0.16	0.16

The analysis shows that excepting three variables (top management participation, DC energy governance and energy consumption) there is no difference; this implies that even if non-respondent bias cannot be completely ruled out, it is not to the level that affects the data and as such is not statistically significant.

Hence, based on the two tests for potential non-responses biases, it can be concluded that even if non-response bias cannot be totally ruled out it is not significant to affect the result of the study.

6.6. Descriptive Analysis of Data

The data for this study were collected from a survey of data centres in the second quarter of 2011. The sampling frame was 1500 data centres. The key respondents were 'Data Centre Manager' or managers with equivalent job title who were members of nine professional industry groups that focus on data centre management, listed on LinkedIn (http://www.linkedin.com). Invitation to participate in the survey was disseminated through LinkedIn's internal email system together with the Web address of the questionnaire to the 1500 potential respondents, and 34 were not delivered due to unknown reasons, leaving only 1466 that successfully reached the potential respondents. A total of 243 responses (from 243 separate data centres) were received, resulting in approximately 16.6% response rate. After applying the test for missing data, a total of 38 responses were eliminated, leaving 205 responses that are valid for analysis. Participating data centres come from 22 countries with US (38%), Australia (19%) and UK (7%) being the highest, as shown in Figure 6.1.

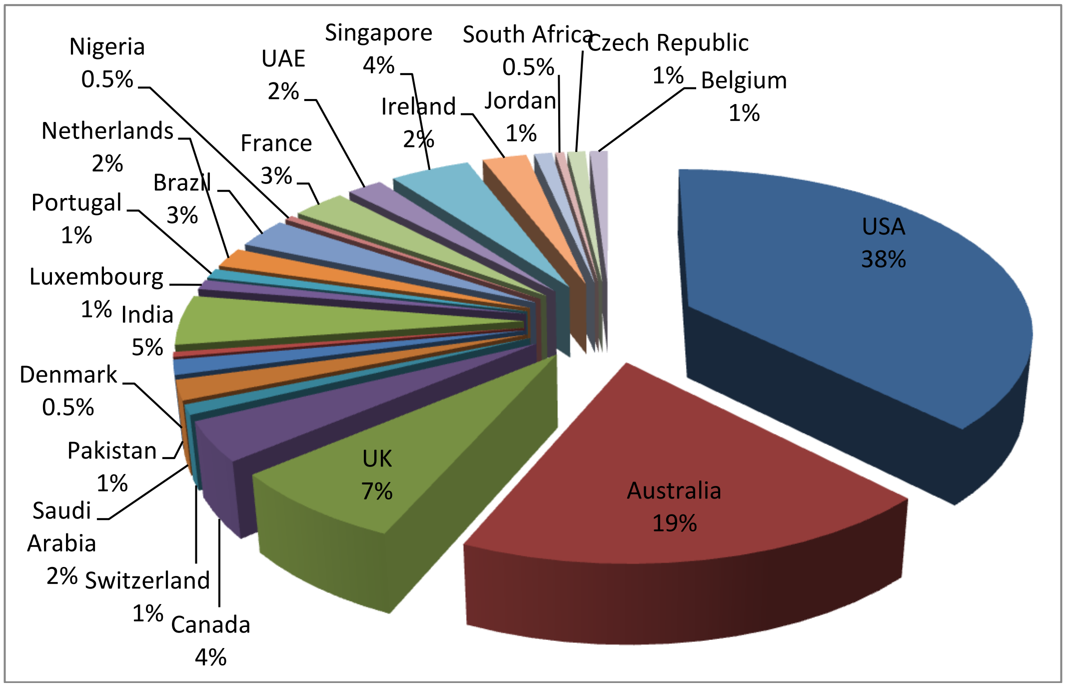


Figure 6.1: Geographic distribution of participating data centres

6.6.1. Profile of participating data centres

In order to identify the common industry type, the Australian and New Zealand Standard Industrial Classification (ANZSIC) is followed. The results in Figure 6.2 show that participating data centres operated in 16 different industry sectors and the majority were from Information Technology and Hosting sectors (32.2%).

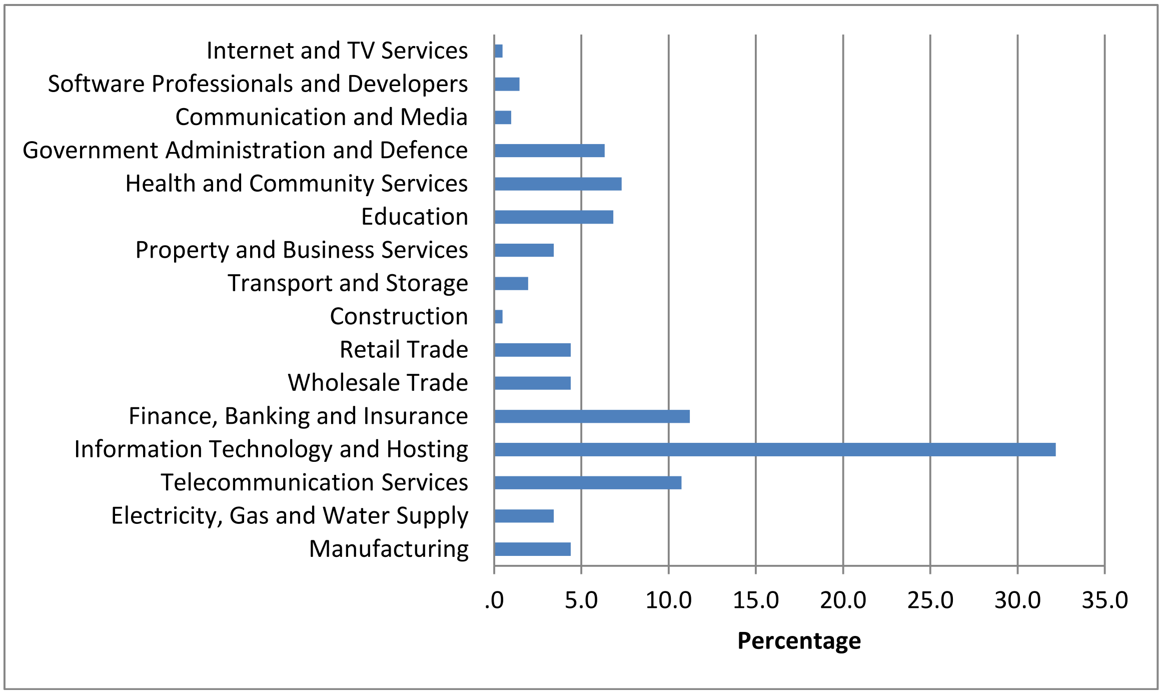


Figure 6.2: Sector profile of participating data centres

In respect to the type of data centre business, 45% of the participating data centres as described in Figure 6.3 were corporate data centres, which represent the IS units of business organisations. Co-located data centres were 20% of the sample whereas the managed data centres accounted for 35% of the sample.

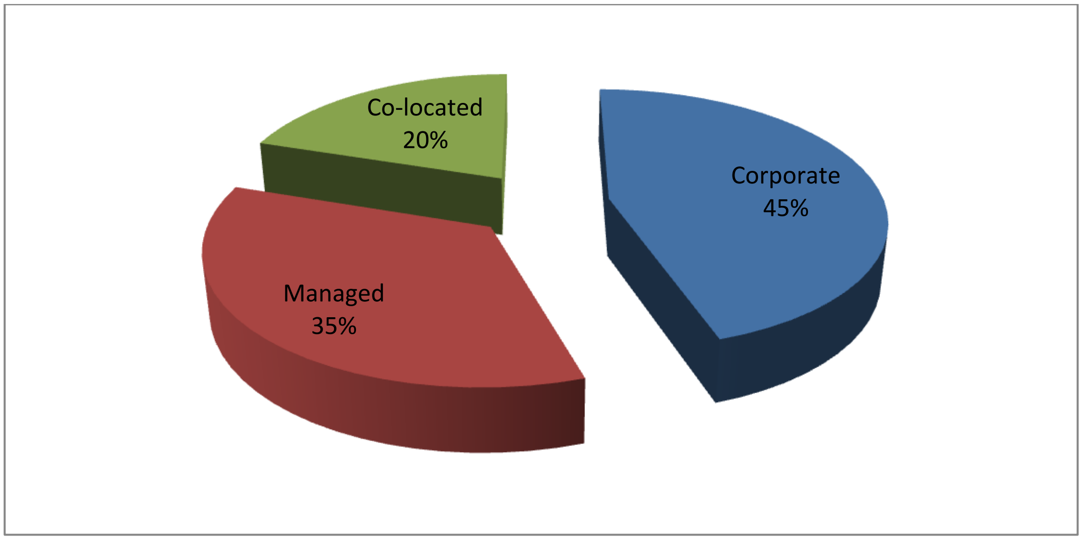


Figure 6.3: Types of participating data centres

In order to understand the differences in the design of data centres and the dissemination of IT infrastructure within the participating organisations, respondents were asked to best describe the configuration of IT infrastructure of their organisation using four classifications. The results in Figure 6.4 show that 44% of participating data centres had multiple dedicated data centre facilities with some other servers or server rooms disseminated in other locations within the organisation, whereas only 15% had one dedicated data centre facility.

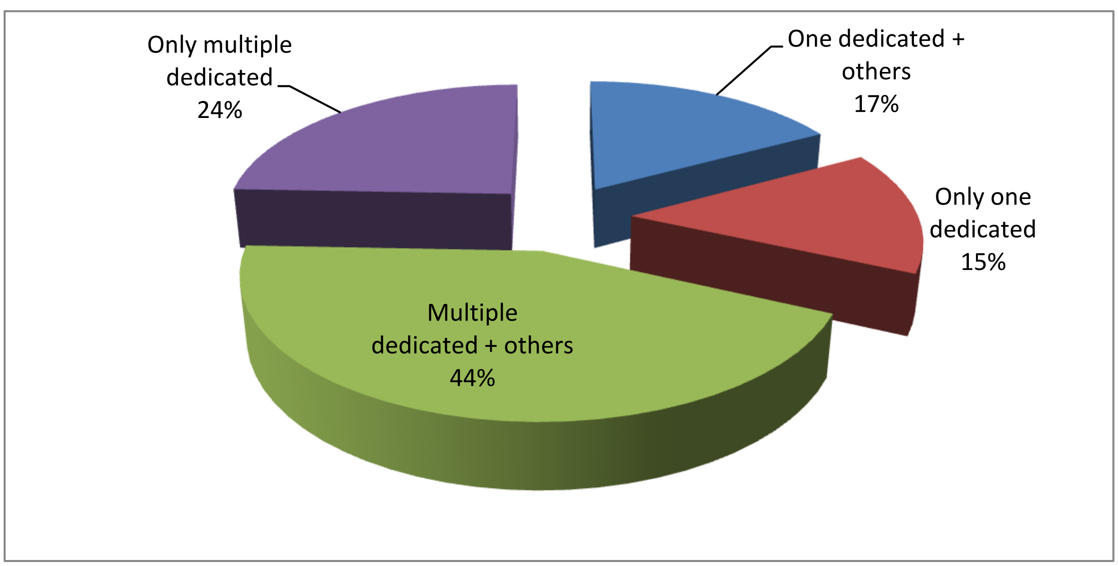


Figure 6.4: Configuration profile of participating data centres

6.6.2. Profile of Respondents

All respondents were at the top management level of their data centres. In most cases the respondent held job titles such as 'Data Centre Manager' or other equivalent job titles such as 'Director of Data Centre' or 'Data Centre Infrastructure Manager'. The results in Figure 6.5 reveal that the majority of Data Centre Managers are experienced professionals. Nearly 61% of respondents had between 11 and 20 years of work experience. Managers with less than 10 years' experience were about 18%, whereas 21% had more than 21 years of experience.

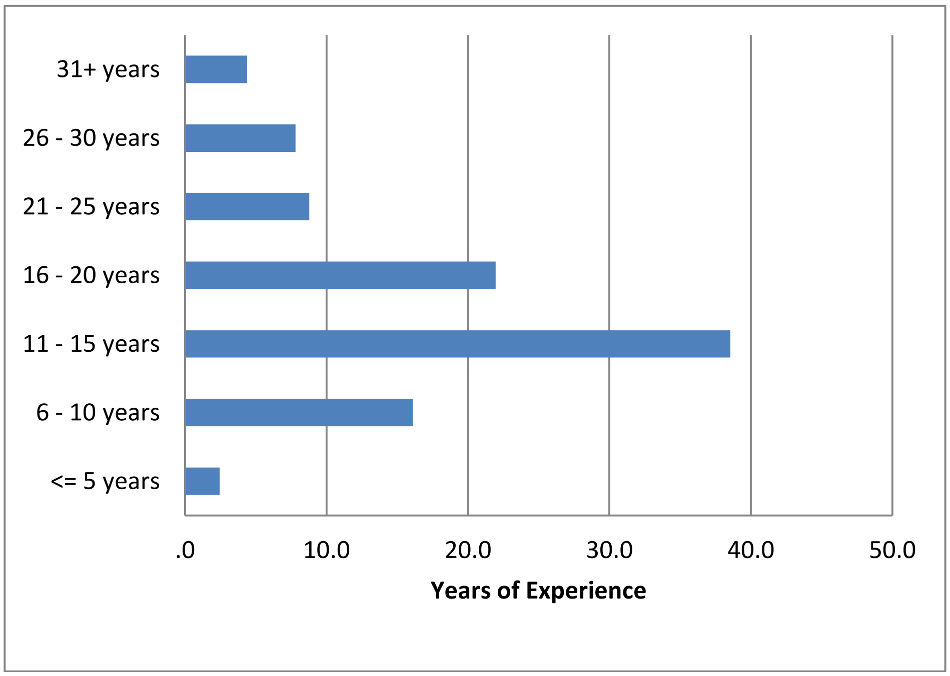


Figure 6.5: Work experience profile of participants

6.6.3. The Extent of SIS use in Data Centres

All of the 243 data centres in the research sample use at least one SIS system to manage some of the data centre operations. However, the type of SIS used in data centres and the extent of their usage differs from one data centre to another. A total of 60 different type of SIS systems were identified from the sample with Building Management Systems, InfraStruXure family products and OpenManage Management tools being the most common systems in use (See Appendix 6a).

SIS volume: As to the volume of SIS, the number of different SIS used in a single data centre was found to be varying. Figure 6-6 shows that almost a third of the sample uses only one SIS, whereas approximately another third uses two SIS brands. While 22% of data centres use three different SIS, the remaining 15% applied more than four different SIS to manage their operations. Although most of the systems identified are commercially-based SIS, some data centres developed an in-house SIS that is tailored to their requirements (See Appendix 6a).

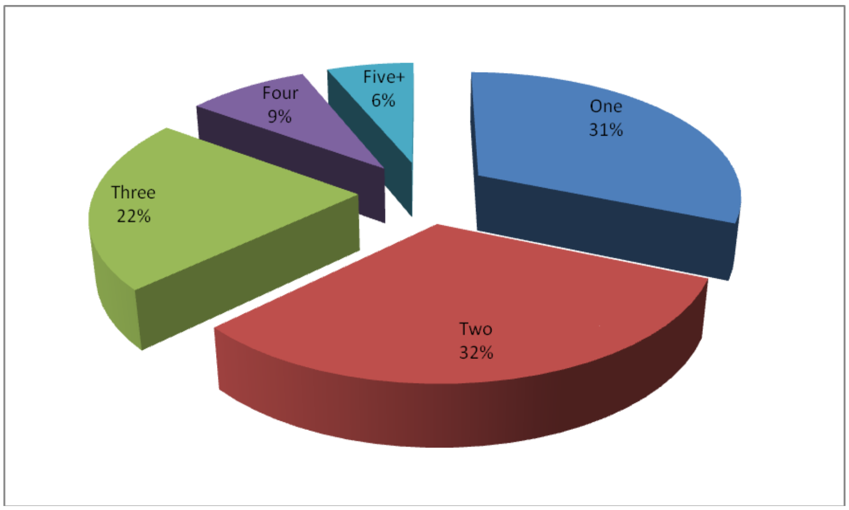


Figure 6.6: Distribution of the number of SIS used is each data centre

SIS diversity: In terms of the functional areas of data centres where SIS is typically applied, the research identified four main functional areas of data centres. The cooling management (e.g. CRAC, HVAC, Chillers, etc) was area where SIS is mostly applied followed by the power management (e.g. PDU, metering, etc).

SIS use-intensity: As to the intensity level of using the various functionalities of SIS, the average of using SIS to *Monitor* the overall processes of facility, cooling, power, and computing platforms in a real time manner was approximately 65%. Whereas the extent of using SIS to *Analyse* and entirely *Automate* the process of data centre platforms was at 58 % and 51% respectively.

SIS integration-intensity: In terms of the level of SIS integration intensity, respondent were asked to evaluate the level of integration using six point Likert scale starting from no integration to high integration. The results reveals that 65% of respondents integrated SIS into critical site support platform (CSSP)- including facility, cooling, and power, whereas 46% of respondents integrated SIS with information and communication technology platform (ICTP)- including servers, network and storage. Forty eight percent of respondents integrated SIS with other IS. In general, the level of both the Use-Intensity and Integration –Intensity reveals that data centres are under-utilising SIS functionalities and capabilities to manage the various processes of data centre platforms. A summary of the findings regarding the extent of SIS use is depicted in table 6.5.

Table 6.5: The extent of SIS use

Assimilation Construct	Area/Function	Extent of usage
Diversity	Facility Management	71.20%
	Cooling Management	96.10%
	Power Management	92.20%
	Computing Management	76.10%
Use-Intensity	Monitoring	65.60%
	Analysing	58.30%
	Automation	51.10%
Integration -Intensity	Level of SIS integration with CSSP	65.40%
	Level of SIS integration with ICTP	45.60%
	Level of SIS integration with other IS	48.20%

6.7. SUMMARY

The objective of this chapter was to examine, prepare and explore the data set that will be used in analysis. A series of procedures and steps was applied to ensure that data is sound and free from errors. This included a check for data transformation and cleaning, missing values, outliers, and response and non-response bias tests. The data set was examined for missing values and data were treated after eliminating 38 responses. The test of outliers using Mutlivariate test reveals that no outliers were detected that require further action. Furthermore, the tests for potential response and non-response bias using wave-based analysis and interest level analysis reveal that response and non-response did not cause any survey biases. After applying these procedures, a total of 205 observations were then ready to be used for multivariate analysis techniques. The chapter briefly reported details about the collected data and the profile of participating data centres, the respondent profiles and concluded providing some statistics about the extent of SIS usage including SIS volume, SIS diversity, SIS use-intensity, and SIS integration-intensity.

CHAPTER 7

7. THE VALIDITY AND RELIABILITY OF THE RESEARCH INSTRUMENT

7.1. Introduction

The rigour of research design is characterised by the extent of data accuracy being a good representative of latent variables drawn from one or more sources that the researcher endeavours to build or test (Coombs, 1976). The purpose of instrument validation is to offer the researchers, their peers, the scientific field, and the entire society a confidence about the positivist method selected and suitability of the method to seek for scientific truth (Nunnally, 1978). The validity of research instruments, that are used to gather data, is the scientific basis that demonstrates the rigour of any empirical research (Starub et al., 2004). This validation process is very important, without which the validity of findings and the interpretation that was initially built upon is threatened. The reliability test is another dimension of measurement purification that helps to assess the measurement error because the measurements of the theorised construct are, often, not free from error. Reliability is concerned with finding true measures that actually express the phenomenon (Starub et al., 2004). Therefore, the ultimate objective of instrument validation and reliability is to establish methods for minimising the errors in the measurement (Starub et al., 2004).

To perform the validity and reliability tests, two seminal guidelines were followed: positivistic research validation (Starub et al., 2004), and criteria to assess partial model structure (Chin, 1998). These guidelines were the basis for numerous PLS-based IS researches (Urbach and Ahlemann, 2010). For more clarity on these guidelines, a further two articles were used as a guide for applying validity assessment in PLS (Gefen and Starub, 2005; Henseler et al., 2009). The criteria for establishing the validity and reliability are performed through two phases: the assessment of measurement model and assessment of structural model (see Figure 7.1).

This chapter is intended to discuss the assessment of the measurement model whereas the assessment of the structural model is discussed in Chapter 8. The chapter starts with an introduction about the Partial Least Squares (PLS) path modelling analysis technique (7.2). Then, another section discuss the criteria used to evaluate the PLS models, with a focus on the evaluation of the reflective measurement model which is relevant to this study (7.3). Then the content validity is being established (7.4). This is followed by the validation and reliability tests (7.5) including the uni-dimensionality, convergent validity, discriminant validity and internal consistency reliability, as well as test for common method bias. The chapter also performs a test to validate the second order construct of SIS value.

7.2. Partial Least Squares (PLS) Path Modelling

The research model used in this study was tested using the Partial Least Squares (PLS) approach (Wold, 1982; Lohmöller, 1989) which has been widely used in IS research (Urbach, and Ahlemann, 2010). The PLS is a second generation modelling technique that evaluates the quality of measurement of research constructs and the interrelationships between the research constructs simultaneously (Fornell, 1982). It assesses the predictive relationships in the research model and tests how well the exogenous latent variables of a model predict values in the endogenous variables (Lohmöller, 1989). The nature of PLS makes it suitable for both theory development and theory testing (Fornell, 1982). In addition, PLS is one of the best techniques suitable for use with small sample sizes and complex exploratory models (Bontis et al., 2002).

Unlike other analysis techniques, such as LISREL in SEM, that has a global Goodness-of-Fit to evaluate how well the observed data fits the theoretical model through assessing the theoretical model and the covariance matrix, the PLS performs two separate stages to evaluate the model structure through assessing quality of relationships between the constructs and their measurement items (i.e. Measurement Model), and interrelationships between the constructs (i.e. Structural Model). In this study, SmartPLS (Ringle et al., 2005) was used as the PLS analysis software. Further, the SPSS, a statistical software package developed by IBM, was also used for performing the Exploratory Factors Analysis.

7.3. The Assessment of the Measurement Model

The assessment of the measurement model is performed through a series of tests including uni-dimensionality, internal consistency reliability, indicator reliability, convergent validity, and discriminant validity (Gefen and Starub, 2005; Henseler et al., 2009). While the uni-dimensionality test is obtained through the Exploratory Factor Analysis in SPSS, the remaining validity and reliability tests are performed through Confirmatory Factor

Analysis (CFA) in PLS. Table 7.1 provides a summary of all the criteria required to meet the validity and reliability of the reflective measurement model.

Table 7.1: Criteria for the assessment of reflective model

Validity/reliability Test	Method	Rule of Thumb	Literature
Content Validity	Literature review; expert panels and pretesting of the instrument	• Survey items should include representative number of items that are relevant and sufficient to measure the content of a construct	Cronbach, 1971; Straub, 1989; Straub et al., 2004).
Uni-dimensionality	Exploratory factor analysis (EFA)	• Each item in the rotated matrix loads with a high coefficient on only one factor. • No item to have cross-loading (more than one significant loading) • Significance factor loading determined based on the sample size (-+.3 to -+.5) • High factor loading > .6 and low <.4 • Eigen value exceeding 1.0. or selecting a number of factors. • Communalities >.40 (low), >.70 (moderate), >.8 (high)	(Hair et al., 2010; Gefen and Starub, 2005; Costello and Osborne, 2005)
Internal consistency reliability	Cronbach's Alpha (CA)	• Value of 1.00 denote to perfectly reliable. • Threshold value should exceed .60, for exploratory • Preferred range for confirmatory between >0.70. to > .90	(Nunally and Bernstein , 1994; Starub et al., 2004; Henseler et al., 2009)
	Composite reliability (CR)	• Value of 1.00 denote to perfectly reliable.. • Threshold value should exceed .60, for exploratory • Preferred range for confirmatory between >0.70. to > .90	Nunally and Bernstein, 1994; Henseler et al., 2009

Table 7.1 (Continued)

Validity/reliability Test	Method	Rule of Thumb	Literature
Convergent validity	Indicator loadings	• Items should load with a significant t-value on its latent construct at least at the 0.05 alpha protection level. • Significant t-values of the Outer Model Loadings are > 1.96.	Gefen and Starub, 2005; Hair et al., 2010
	Average variance extracted (AVE)	• Proposed threshold value: AVE > • 0.500	Fornell and Larcker (1981)
Discriminant validity	Cross-loadings	• Each indicator in the correlation score matrix should load higher on its designated latent variable than on any of the other constructs. • Each of the latent variables loads highest with its own items (e.g. if item loading is =>0.7 then cross loading should be <0.6)	Chin (1998)
	Fornell-Larcker	• the square root of the AVE should be higher than the correlation of that construct with any other construct in the model	Fornell and Larcker (1981)

7.4. Content Validly

Content validity –sometimes called face validity, deals with the issue of instrument representation for the measured constructs (Straub, 1989). The essential concern of content validity is the question of whether the measurement (e.g., survey items) includes representative number of items that are relevant and sufficient to measure the content of a construct (Cronbach, 1971; Straub et al., 2004).

According to Straub et al., (2004: p. 387), establishing content validity is highly recommended 'for assuring that constructs are drawn from the theoretical essence of what they propose to measure'. Content validity can be established through literature review, drawing from already validated instruments, expert panels and pretesting of the instrument (Straub, 1989; Straub et al., 2004). In the current study, the literature review in Chapter 2, discussed the relevant IS studies that have contributed to the understanding of SIS use and value. It has provided starting point to understand the constructs and theoretical underpinning relevant to the current study.

In addition, the pilot study reported in Chapter 3, which was based on interviews with five data centre managers, provided valuable insights to the study and has contributed to the understanding of research phenomenon. The pilot study helped for identifying and validating the relevant antecedent factors to the SIS assimilation and value as well as providing idea on how to measure them. Moreover, relevant theories were consulted to identify and define the meanings of the research constructs. The instrument development is detailed in Chapter 5 and provided information how the items were pulled.

A panel of expert study was conducted and a total of 14 experts were invited to evaluate the instrument of the research. The measurement instrument was also pilot tested with three data centres managers. The pilot test was conducted face-to-face and allowed for more understanding on how data centre interpret the wording and content of the questionnaire. The above processes ensured the content validity of the measures used in the study.

7.5. The Evaluation of Reflective Measurement Model

Following the criteria for assessing the reflective model as described by Starub et al. (2004), Chin (1998), Gefen and Starub (2005) and Henseler et al. (2009), this section discusses the tests of uni-dimensionality (7.5.1), convergent validity (7.5.2), discriminant validity (7.5.3), validation of the second order construct (7.5.4), internal consistency reliability (7.5.5) and common method variance (7.5.6).

Factorial validity is one of the important assessment requirements in the context of establishing the validity of latent variables (Gefen and Starub, 2005). Because latent variables are considered to be research abstractions that cannot easily be measured through direct means, instead they can be measured indirectly using several items in a research instrument (Anderson and Gerbing, 1988; Churchill, 1979). Establishing factorial validity and reliability in PLS analysis requires the measurement of some elements of factorial validity including uni-dimensionality, convergent validity and discriminant validity as well as internal consistency reliability and common method variance (Starub et al. 2004; Gefen and Starub, 2005; Henseler et al., 2009).

7.5.1. Exploratory Factor Analysis: Test of Unidimensionality

Unidimensionality infers that each measurement item on the research instrument reflects one and only one latent variable that relates to it better than to any other latent variables (Gerbing and Anderson, 1988). Unidimensionality can be assessed using several statistical softwares. Nevertheless, it cannot be measured with PLS- based software (Gefen, 2003; Gefen and Starub, 2005).

One of the common methods that researchers use to test unidimensionality is by conducting Exploratory Factor Analysis (EFA) which is available in SPSS. Factor analysis was popularised in 1904 by Charles Spearman and has been one of the most widely used statistical techniques in social sciences research (Fabrigar et al., 1999; Treiblmaier and Filzmoser, 2010).

The primary purpose EFA is to define the underlying structure among variables in multivariate analysis (Hair et al., 2010). There are two objectives that can be achieved through EFA test: finding a better way to 'summarise' the information that is informed by a number of original variables (test if the items load together to their theorised constructs) and to 'reduce' them into a smaller number of factors that share the dimension underlying the factor without compromising the original data. In the current study the EFA test was used to achieve these two objectives. The researcher was concerned whether the items load together to their theorised constructs and that each group of items shares the dimension underlying the factor they measure. As such, the EFA test identified the underlying factors that explain the parallel correlational pattern among measures within a set of measurement items (Gefen and Starub, 2005). In this process, some of the items could be deleted and some of the constructs might need to be merged.

There are a number of methods in which the EFA test can be performed. These include different extraction methods, different factor rotation methods and different criteria to decide the number of factors to extract (Hair et al., 2010). Table 7.2 provides a summary of the methods and criteria available for EFA test.

Table 7.2: A summary of the criteria used in the EFA.

Criteria/Method	Available Test	
Factor Extraction Method	*Principal Component**	
	Maximum Likelihood	
	Unweighted least square	
	Generalised least square	
	Principal axis factoring	
	Alpha Factoring	
	Image Factoring	
Factor Rotation	***Orthogonal***	***Oblimin***
	Oblique	Quartimin
	*Varimax**	Promax
	Quartimax	Covarimin
	Equamax	McCammon
Number of Factors to extract	*Latent Root Criterion (Eigen value)**	
	A Priori Criterion	
	Scree Plot	
	Percentage of Variance	

**Denote the tests selected in this study*

The three criteria or method shown in Table 7.2 must be performed using only one test of each at once. In other words, for factors extraction, the investigator cannot use two extraction methods simultaneously (e.g. Principal Component and Maximum Likelihood). Although some argue that there is almost no difference between the different extraction methods (Arrindell and van-der-Ende, 1985; Velicer and Jackson, 1990), the decision on selecting the appropriate test should always be to obtain a factor structure with both conceptual and empirical support (Hair et al., 2010).

The EFA's extraction rules in this study were set as the following. First, the principal components analysis (PCA) was selected as the factor extraction method. The PCA test reduces the number of original variables to a smaller number of principal components, which accounts for the important amount of the variance (Preacher and MacCallum, 2003). Thus, the use of PCA helps to achieve the second objective for performing EFA test in this study. Second, the Orthogonal–Varimax rotation was applied as the factor rotation method. Varimax rotation test considers the variances of the squared factor loadings for each factor and maximises the sum of these variances in order to approximate a simpler and more meaningful structure (Treiblmaier and Filzmoser, 2010) and produces stable results (Reimann et al., 2002). Thus it serves as a vehicle to achieve the first EFA test objective. Third, Latent Root Criterion (Eigen value or Kaiser Rule) was used as a criterion to decide on the number of factors to extract. It has been recognised that this criterion leads to fewer errors when estimating factor loadings (Fava and Velicer, 1992; Hair et al., 2010). Although it is difficult to find and justify a single best solution in EFA (Treiblmaier and Filzmoser, 2010), the rules applied above are believed to be the most applied methods by researchers for the same objectives of the current study (Costello and Osborne, 2005; Hair et al., 2010).

Before proceeding with an EFA test, the researcher should assess the conceptual and empirical assumptions of factor analysis (Hair et al., 2010). The measurements items used in this study were theorised from a conceptual framework which had been developed through a methodologically sound process, as has been reported in prior sections. Thus, the conceptual assumption of factor analysis is assumed to be valid.

Factorability of the data can be assessed by examining the intercorrelations of the entire matrix, which can be done through Kaiser-Meyer-Olkin (KMO) (Lewis et al., 2005) and Bartlett's Test of Sphericity test (Hair et al., 2010). Bartlett's Test of Sphericity provides evidence that there is a significance correlation among the variables (in the correlations matrix) or at least some them. As a rule of thumb, this test should yield below 0.05 significance level in order to demonstrate the presence of sufficient correlation among variables (factorability of the data) (Hair et al., 2010). The KMO test provides evidence that the sampling is adequate. As a rule of thumb, the result of this test should be above 0.5 to demonstrate sampling adequacy (Lewis et al., 2005).

To establish sufficient correlation among variables (factorability of the data) and sample adequacy, Kaiser-Meyer-Olkin and Bartlett's Test of Sphericity tests were performed through SPSS and results are illustrated in Table 7.3.

Table 7.3: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.813
Bartlett's Test of Sphericity	Approx. Chi-Square	11539.946
	Df	2346
	Sig.	.000

The result shows that Bartlett's Test was (0.00) which indicates the presence of significant correlation among variables. The test of KMO yielded a good value that provides support about the sampling adequacy. Thus, it can be informed that the conceptual and empirical assumption of factor analysis was met, and the EFA can be performed.

7.5.1.1. Steps and criteria followed to perform the EFA test

To validate the unidimensionality of our instrument measurement through EFA, the five-step procedures proposed by Hair et al. (2010) were followed (see Appendix 7b for more details). These included examining the factor of matrix loading, identifying the significant loading, assessing the communalities of the variables, respecifying the factor loading and labelling the factors.

Given the sample size of 205, a factor loading of 0.4 and above is considered to be significant (Hair et al., 2010). All variables with more than one significant loading on two factors are an indication of cross-loading and should be deleted. In addition, setting the PCA test at Eigen >1 is a common method for identifying the optimum number of factors that need to be extracted (Costello and Osborne, 2005).

As to the communalities, although some textbooks suggest that items with communalities above 0.5 should be retained (Hair et al., 2010); others propose that items with communalities less than 0.40 should be eliminated (Costello and Osborne, 2005). Nevertheless, the final decision depends on the researcher’s discretion. Furthermore, the Total Variance Explained table (from the output of PCA test) allows the examination of the Eigen values and looking at the factors that load with Eigen values >1 (Costello and Osborne, 2005).

Based on the above, the following rules were applied to execute the EFA test using PCA extraction with Varimax rotation and the Latent Root Criterion (Eigen value) for factor retention. In particular factors at Eigen value >1 were considered, items with significance factor loading above 0.4 were kept, items with communalities above 0.4 were kept, and any items with cross-loading >0.4 were eliminated.

The five steps of EFA test were conducted for each context of the research model separately (factors of the research instrument that share the same context were included in a single EFA test). In other words, the test were conducted for SIS assimilation construct, SIS value constructs, technological constructs, organisational constructs, and external constructs (including institutional and environmental context- both are external forces and share the underlying concept) separately. The test applied the five steps for each context and results of each test are reported in the following sections and in Appendix 7c.

7.5.1.1.1. the SIS assimilation construct

The first test was run by including all of the SIS assimilation items into the EFA test using the criteria discussed earlier. Bartlett's Test of Sphericity yield $p<0.001$ significance level and KMO were showed above 0.5 (.872). These have demonstrated the sufficient correlation among variables and sampling adequacy. All of the items had factor loadings above .4 with no cross-loading and communalities were above 0.4, except for one item (SB_ICTP), which loaded with communalities of (0.382). However, because it represents a conceptual importance for the measurement instrument and to allow further inspection of it using another test (Hair et al., 2010), the item was retained. Overall, all of the items of SIS assimilation construct have loaded together into one factor, and hence no rotation was needed (more details can be found in Appendix 7c). The explained variance by SIS Assimilation construct was 61.4%. Table 7.4 illustrates the structure of the SIS assimilation construct.

Table 7.4: Component matrix of SIS assimilation

Item ID	Component
	SIS Assimilation
Aut	.866
Mon	.848
Anz	.836
SB_IS	.798
SB_CSSP	.794
SDavr	.778
SB_ICTP	.506

*SVO1- (number of SIS used) was not included in the test as it was a count item

7.5.1.1.2. *the SIS value construct*

Similar to the SIS assimilation, the items of the SIS value construct have loaded into one factor, and therefore the EFA test did not run the rotation. Both the Bartlett's Test (p<.001) and KMO (.878) were at acceptable levels. All criteria were met as factor loadings were (>0.4), no cross-loading and communalities were (>0.4). The explained variance by SIS value construct was 58.3%. Table 7.5 illustrate the final structure of SIS value

Table 7.5: Component matrix of SIS value

Item ID	Component
	SIS Value
SV3	.826
SV2	.809
SV5	.807
SV1	.785
SV6	.734
SV8	.723
SV4	.722
SV7	.690

7.5.2.1.1. *the knowledge stock construct*

The items of managers' SIS knowledge stock construct, which is one of the value facilitating latent variables, have loaded into one factor and criteria were met (Bartlett's Test [p<.001] and KMO [.851]) (more details can be found in Appendix 7c). The explained variance by SIS value construct was 58.3% and knowledge stock construct was 83.4%. Table 7.5 and 7.6 illustrate the final structure of SIS value and knowledge stock.

Table 7.6: Component matrix of SIS knowledge stock

Item ID	Component
	Knowledge Stock
KS3	.925
KS2	.918
KS1	.910
KS4	.899

7.5.2.1.2. the technological constructs

The test of technological constructs that is relative advantage, SIS compatibility, SIS complexity and perceived SIS uncertainty, was completed through three rounds of rotation. The result of the Bartlett's Test and KMO tests was at acceptable level in all of the three rounds and was ($p<.001$) and (.797) respectively in the final structure. In the first run, three factors loaded with one item (TM4- using SIS fits into our data centre management practice) having cross-loading between factor 1 and 3. This item was deleted and the test was run again. In the second round, a violation was detected in one of the items (PTU1- SIS technology would not be standardised in the data centres industry in the future) of the second factor due to low communalities <0.4 (0.363), thus the item was deleted and the test re-ran. The result of the round three test shows that three factors were present and all criteria met (more details can be found in Appendix 7c). More details about the converged items and those which did not hold can be found in Tables 7.10 and 7.11. The explained variance by technological constructs was 62%. Table 7.7 illustrates the final structure of technological constructs.

Table 7.7: Rotated component matrix of technological constructs

Item ID	Component		
	Relative Advantage	Perceived SIS Risk	SIS Compatibility
RA1	.842		
RA3	.772		
RA2	.767		
RA4	.737		
TC3		.752	
PTU4		.726	
TC1		.690	
TC2		.687	
PTU2		.632	
PTU5		.605	
TM2			.811
TM1			.796
TM3			.759

7.5.2.1.3. the organisational constructs

Organisational constructs comprised of top management support, Green IT/IS orientation and data centre energy governance. The criteria for items retention were met after completing four rounds of rotations. Bartlett's Test and KMO tests were significant ($p<0.001$) and (.833). In the first run, four groups of factors loaded and two items (GDO5, GDO6) from the first factor had cross-loading with factor 4. Only one item (GDO5- a policy for measuring the environmental performance of data centre) was deleted at once and the test was ran again to see how the items would load.

In the second rotation, all criteria met except for (DCG3- we have targets to reduce the energy consumption of our data centre) from factor 1, which had cross-loading with factor 4, thus the item was deleted. One violation was detected in the third run, which was communalities <0.4 (0.337) of GDO4 (a policy to allocate annual IT budget for purchasing management software [e.g., SIS] to improve the operation of data centre) from factor 4. After the deletion of GDO4, the items of organisational constructs have met the criteria and loaded into three theoretical variables (more details can be found in Appendix 7c). The explained variance by organisational constructs was 59%. Table 7.8 illustrates the final structure of organisational constructs.

Table 7.8: Rotated component matrix of organisational constructs

Item ID	Component		
	Top Management Support	Green IT/IS Orientation	Energy Governance
TMS1	.841		
TMS3	.809		
TMS4	.795		
TMS2	.768		
GDO2		.799	
GDO6		.777	
GDO3		.771	
GDO1		.742	
DCG4		.420	
DCG2			.890
DCG1			.857

7.5.2.1.4. the external constructs (institutional and environmental context)

Similar to the organisational constructs, the test of EFA for the external constructs required four rounds of rotations. External constructs combined both institutional and environmental factors and included coercive pressure, normative pressure, energy pressure and environmental preservation. Bartlett's Test ($p<0.001$) and KMO (.832) tests were significant. The result of the first round of rotation shows that there were five groups of factors and three items (NC1, EC4 and NP2) had cross-loading violation. One item (NC1-consumption volume of non-renewable energy sources) was deleted and the test was ran again. In the second attempt, there were four groups of factors and two items (NP2, NP1) with cross-loading problem. NP2 (SIS use by other data centres) was deleted and the third round of test showed that all of the items met the criteria except for one item (NC3- the need to increase the lifecycle of IT hardware in data centre), which had low communalities <0.5 (0.375). After deleting NC3 and running the test for the fourth round, the criteria were established and four distinct groups of factors were present (more details can be found in Appendix 7c). The explained variance by external constructs was 72.5%. Table 7.9 illustrates the final structure of external constructs.

Table 7.9: Rotated component matrix of external constructs

Item ID	Component			
	Energy Pressure	Environmental Preservation Pressure	Normative Pressure	Coercive Pressure
EC2	.869			
EC1	.829			
EC3	.744			
EC4	.707			
EC5	.599			
CP2		.903		
CP1		.879		
NC2		.723		
NP4			.828	
NP3			.727	
NP1			.610	
CP4				.866
CP3				.793

Table 7.10 provides a summary of all items deleted in the above steps, and Table 7.11 provides details of the factors that emerged as a consequence of the EFA test.

Table 7.10: Items deleted from EFA test

	Construct	**Variable**	**Order of PCA test**	**Loading**	**Comm-unality**	**Decision**	**Reason**
1	Compatibility	TM4	Round 1	0.5	0.584	delete	cross loading >.4
2	Perceived Uncertainty	PTU1	Round 2	0.539	0.363	delete	communality <.4
3	Green IT/IS Orientation	GDO5	Round 1	0.569	0.646	delete	cross loading >.4
4	DC Energy Governance	DCG3	Round 2	0.605	0.655	delete	cross loading >.4
5	DC Green Orientation	GDO4	Round 3	0.431	0.337	delete	communality <.4
6	Environmental Preservation Pressure	NC1	Round 1	0.595	0.739	delete	cross loading >.4
7	Normative Pressure	NP2	Round 2	0.504	0.624	delete	cross loading >.4
8	Environmental Preservation Pressure	NC3	Round 3	0.474	0.375	delete	communality <.4

Table 7.11: New labels and deleted constructs

	New Emerging Factors	Items	Original Factors label	Original Factors status
1	Perceived SIS Risk	TC1	Complexity	Removed
		TC2	Complexity	Removed
		TC3	Complexity	Removed
		PTU2	Perceived Uncertainty	Removed
		PTU4	Perceived Uncertainty	Removed
		PTU5	Perceived Uncertainty	Removed

As a result of EFA test, a new factor has emerged (by converging the items of Complexity and Perceived Uncertainty into one construct) and was labelled based on best description that represents the underlying dimension 'Perceived SIS Risk'. On the other hand, two factor labels were removed due to consolidation into the above new factor. The final result of EFA is presented in Table 7.12 after a total of nine iterations.

Table 7.12: Final EFA result

		Factors													
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	
	Indicators	**SIS Assimilation**	**SIS Perceived Risk**	**SIS Perceived Risk**	**SIS Compatibility**	**Green IT orientation**	**Top management support**	**Knowledge Stock**	**DC Energy Governance**	**Energy Pressure**	**Environment Pres. Pressure**	**Normative Pressure**	**Coercive Pressure**	**SIS Value**	**Communality**
1	Mon	0.85													0.72
	Anz	0.84													0.70
	Aut	0.87													0.75
	SDavr	0.78													0.61
	SBI_IS	0.80													0.64
	SBI_CSSP	0.79													0.63
	SBI_ICTP	0.51													0.26
	SVO1	NA													NA
2	RA1		0.84												0.74
	RA3		0.77												0.69
	RA2		0.77												0.70
	RA4		0.74												0.58
3	TC3			0.75											0.58
	PTU4			0.73											0.59
	TC1			0.69											0.56
	TC2			0.69											0.53
	PTU2			0.63											0.47
	PTU5			0.61											0.47
4	TM2				0.81										0.74
	TM1				0.80										0.74
	TM3				0.76										0.68
5	GDO2					.0.80									0.74
	GDO6					0.78									0.68
	GDO3					.0.78									0.65
	GDO1					0.74									0.62
	DCG4					0.42									0.45
6	TMS1						0.84								0.73
	TMS3						0.81								0.80
	TMS4						0.80								0.81
	TMS2						0.77								0.73

Table 7.12 (Continued)

	Factor													
	indicators	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Comm**
7	KS2							0.92							0.85
	KS3							0.93							0.86
	KS1							0.91							0.84
	KS4							0.90							0.81
8	DCG2								0.89						0.85
	DCG1								0.86						0.77
9	EC2									0.87					0.82
	EC1									0.83					0.77
	EC3									0.74					0.71
	EC4									0.71					0.62
	EC5									0.60					0.47
10	CP2										0.90				0.92
	CP1										0.88				0.89
	NC2										0.72				0.67
11	NP4											0.83			0.73
	NP3											0.73			0.71
	NP1											0.61			0.52
12	CP4												0.87		0.84
	CP3												0.79		0.77
13	SV3													0.83	0.68
	SV2													0.81	0.65
	SV5													0.81	0.65
	SV1													0.79	0.62
	SV6													0.73	0.54
	SV8													0.72	0.52
	SV4													0.72	0.52
	SV7													0.690	0.48

The factors structure for the remaining 57 factors is now very well defined, representing 13 distinct groups of variables that are now ready for other validation analysis.

7.5.3. Convergent Validity

Convergent validity measures the extent to which variables of the same construct that tend to measure the same phenomenon correlate with each other (Straub et al., 2004). It measures the degree to which an individual variable that reflects a particular construct converges in comparison to variables measuring different constructs. The Convergent Validity in PLS can be demonstrated by Average Variance Extracted (AVE) (Fornell and Larcker, 1981), and Indicator Loading (factor loadings) (Gefen and Starub, 2005). AVE indicates to what extent (percentage) a construct is able to explain the variance of its indicators on average (Fornell and Larcker, 1981). It is a summary indicator of convergence (Hair et al., 2010). As a rule of thumb, AVE should be greater than 0.5, which means that the construct is explaining 50% of variance and suggesting adequate convergence (Fornell and Larcker, 1981; Chin 1998; Hair et al., 2010).

Factor loadings are another way for measuring convergent validity (Straub et al., 2004). The high values of factor loading indicate that they converge on a common point (Hair et al., 2010). Hair et al. (2010) suggest that, as a rule of thumb, all variables should be greater than 0.5 and be statistically significance at 0.05 in order to show adequate convergence validity. However, Gefen and Starub (2005) argue that, unlike the covariance-based SEM analysis, established thresholds for factor loadings do not yet exist to establish convergent in PLS. They contend that the t-values of the factor loadings are equivalent to t-values in least-squares regressions, and thus they suggest that all the t-values of factor loading in the Outer Model Loadings output be above 1.96 (equivalent to p value >0.05) in order to show adequate convergence validity. The factor loadings and t-values can be obtained by running a bootstrap in any PLS-based software (e.g. SmartPLS). The result of convergent validity test is depicted in Table 7.13.

Table 7.13: The Factors loading and loading significance

Factor	Items	Factor Loadings	T Stat	p value	Average Variance Extracted (AVE)
SIS Assimilation	Anz	0.8479	20.311	***	0.549
	Aut	0.8579	17.3239	***	
	Mon	0.8448	14.0378	***	
	SDavr	0.7542	10.014	***	
	SVO1	0.365	4.709	***	
	SB_CSSP	0.7955	14.8831	***	
	SB_ICTP	0.4818	6.305	***	
	SB_IS	0.7964	19.2615	***	
SIS Value	SV1	0.7784	11.877	***	0.583
	SV2	0.7999	10.3279	***	
	SV3	0.8204	11.3946	***	
	SV4	0.7204	11.8587	***	
	SV5	0.8003	9.7801	***	
	SV6	0.7294	12.5407	***	
	SV7	0.6993	11.1414	***	
	SV8	0.7339	14.7841	***	
Relative Advantage	RA1	0.8492	11.0169	***	0.699
	RA2	0.8405	9.7746	***	
	RA3	0.8807	8.7175	***	
	RA4	0.7612	11.678	***	
SIS Compatibility	TM1	0.8654	15.7636	***	0.736
	TM2	0.8627	14.0212	***	
	TM3	0.8407	13.6431	***	
Perceived SIS Risk	PTU4	0.8455	13.4817	***	0.532
	PTU5	0.6327	7.1233	***	
	TC2	0.6593	9.1187	***	
	TC3	0.753	11.3755	***	
Top management support	TMS1	0.74	10.5768	***	0.737
	TMS2	0.8718	20.8286	***	
	TMS3	0.9006	19.6612	***	
	TMS4	0.9031	19.463	***	
Green IT/IS orientation	GDO1	0.7293	10.202	***	0.595
	GDO2	0.8408	17.9981	***	
	GDO3	0.7982	16.1291	***	
	GDO6	0.8095	17.1682	***	
	DCG4	0.6595	10.1767	***	

Table 7.13 (Continued)

Factor	Items	Factor Loadings	T Stat	p value	Average Variance Extracted (AVE)
DC Energy Governance	DCG1	0.9152	25.0073	***	0.826
	DCG2	0.8983	19.022	***	
SIS Knowledge Stock	KS1	0.9144	25.9452	***	0.833
	KS2	0.9238	20.1698	***	
	KS3	0.919	22.0809	***	
	KS4	0.8843	17.6318	***	
Coercive Pressure	CP3	0.8927	16.4317	***	0.821
	CP4	0.9144	22.8875	***	
Normative Pressure	NP1	0.7971	12.8859	***	0.590
	NP3	0.7455	11.0458	***	
	NP4	0.7554	10.9308	***	
Energy Pressure	EC1	0.8605	14.1071	***	0.662
	EC2	0.8907	12.9533	***	
	EC3	0.8313	9.8321	***	
	EC4	0.8061	14.6058	***	
	EC5	0.6484	7.9558	***	
Environmental Preservation Pressure	CP1	0.929	20.6518	***	0.832
	CP2	0.9345	20.9561	***	
	NC2	0.8637	20.2852		

p<0.05*, p<0.01 **, p<0.001 ***

The results show that all the t-values of factor loading in the Outer Model Loadings were very significant and below 0.001 alpha protection level, which indicates high convergent validity. A total of two items, TC1 (SIS are complex to use) and PTU2 (SIS compatible system components would not be easily available from existing vendors), had to be dropped due to the insignificance loading of t-value (p=0.064 and .0.0741) respectively.

7.5.4. Discriminant Validity

Discriminant Validity indicates to what extent a latent variable is truly distinct for other latent variables (Hair et al., 2010). In other words, the measurement items that are deemed to make up a particular construct truly differ from those items that are supposed to reflect other constructs (Straub et al., 2004). Thus, high loading of some measurement items on a particular construct provides evidence that the construct is unique and captures some phenomena other measurement items do not (Hair et al., 2010). As such, any measurement item that loads highly on its assigned construct as well as on other constructs that it is not supposed to measure is an indication that the items are interchangeable, which demonstrates a lack of discriminant validity. There are two commonly accepted criteria for assessing the discriminant validity in PLS path models: Cross-loadings (Chin 1998) and Square root of AVEs (known as the Fornell-Larcker criterion) (Fornell and Larcker, 1981).

Cross-loadings are obtained through item component scores of the correlation matrix of each latent variable. Similar to convergent validity, Gefen and Starub (2005) argue that established thresholds for factors loadings do not yet exist to establish discriminant validity in PLS path models. As a rule of thumb, if all indicators in the correlation score matrix load higher on their designated latent variables than on any of the other constructs and each of the latent variables loads highest with its own items, then it is evidence for discriminant validity (Chin 1998; Gefen and Starub, 2005). The square roots of the AVEs are another way for demonstrating discriminant validity. If the square root of the AVE of each latent variable is much larger than the correlation of the specific latent variable of any of the other latent variables in the model, then it is evidence for discriminant validity (Fornell and Larcker, 1981; Chin 1998). Gefen and Starub (2005) contend that guidelines about 'how much' larger the AVE should be than these in the inter-construct correlations are not established. The results of discriminant validity are depicted in Table 7.14 and Appendix 7d.

Table 7.14: Correlation between major constructs

	1	2	3	4	5	6	7	8	9	10	11	12	13
	Coercive Pressure	**Compatibility**	**DC Energy Governance**	**Energy pressure.**	**Green IT/IS orientation**	**Knowledge Stock**	**Perceived SIS Risk**	**Environmental Preservation**	**Normative Pressure**	**Relative Advantage**	**SIS Assimilation**	**SIS Value**	**Top management**
1	***0.90***												
2	0.13*	***0.86***											
3	0.25***	0.08	***0.91***										
4	0.45***	0.30***	0.28***	***0.81***									
5	0.28***	0.40***	0.35***	0.45***	***0.77***								
6	0.20**	0.46***	0.09	0.22***	0.38***	***0.91***							
7	-0.02	0.29***	0.12	0.02	0.25***	0.41***	***0.73***						
8	0.43***	0.29***	0.23***	0.58***	0.46***	0.30***	0.17*	***0.91***					
9	0.36***	0.31***	0.33***	0.44***	0.56***	0.35***	0.19**	0.44***	***0.77***				
10	0.01	0.52***	0.15*	0.21**	0.41***	0.33***	0.16*	0.16*	0.24***	***0.83***			
11	0.13	0.50***	0.00	0.16*	0.42***	0.47***	0.28***	0.28***	0.38***	0.36***	***0.74***		
12	0.11	0.50***	0.17*	0.22***	0.28***	0.41***	0.31***	0.21**	0.37***	0.43***	0.54***	***0.76***	
13	0.36***	0.27***	0.36***	0.48***	0.56***	0.30***	0.01	0.49***	0.45***	0.32***	0.27***	0.36***	***0.86***

*Square root of AVEs are in ***Italic Bold***

The results in Table 7-15 show that all indicators in the correlation score matrix load higher on its designated latent variables than on any of the other constructs, with no cross-loadings, and each of the latent variables loads highest with its own items, except for one item, SVO1. In addition, the result of loading and cross-loading table from Appendix 7d reveals that all the square roots of AVEs (diagonal) of each construct are much larger than the correlation of the specific latent variable with any of the other constructs in the matrix. Thus, we conclude that our data has sufficient discriminant validity.

7.5.5. The Validations of Second Order Construct

In our model structure, the SIS value was modelled as a second-order construct that is linked with two first order constructs, operational value and environmental value. A second-order factor structure contains two layers of latent variables (Hair et al., 2010). Multiple first order latent variables that cause the measured variables are essentially caused by a second order latent variable. First-order and second-order latent variables can be measured using analysis referred to as higher order factor analysis (Hair et al., 2010). The assessment of the validity of second order construct can be demonstrated by the magnitude and significance of paths from the second-order construct to the first order constructs (Chin 1998) and the efficacy of the second-order model (Marsh and Hocevar, 1985). According to Chin (1998), the path from the second-order construct to the first order constructs should be of a high magnitude at cut-off point of 0.7, and with significant p value. Marsh and Hocevar (1985) suggest that target coefficient (*T* ratio) with an upper bound of 1 can be used to assess the efficacy of the second-order model. Table 7.15 shows the results extracted for the bootstrap in PLS.

Table 7.15: Measurement model: second-order construct

Second-order construct	**First-order constructs**	**Loading**	**t-stat**	**Composite reliability**
SIS value				0.9167
	Impact of Operational performance	0.977***	180.46	0.9107
	Impact on Environmental performance	0.831***	32.36	0.8533

p<0.05*, p<0.01 **, p<0.001 ***

The results show that the paths from the second-order latent variable to the two first-order latent variables are significant and of high magnitude, greater than the suggested threshold of 0.7 (Chin, 1998). It also shows that the model has a high *T* ratio of 0.96 which was comparable to relevant studies (Zhu and Kraemer, 2005) implying that the relationship among first-order latent variables are sufficiently captured by the second-order latent variables (Steward and Segars, 2002). Thus, it can be concluded that, from both theoretical and empirical standpoints, the conceptualisation of SIS value as a higher order construct is justified.

7.5.6. Internal Consistency Reliability

Internal consistency assumes that each block in the measurement is homogeneous (Chen, 1998). It assumes that scores for all variables have the same range and meaning. In other words, various items measuring different constructs deliver consistent scores. Because reliability is independent for each construct, the internal consistency test measures the reliability for each construct independently. The assessment of internal consistency reliability can be informed through the measurement of Cronbach's Alpha (Nunally and Bernstein, 1994) and Composite Reliability (Chin, 1998). A threshold of 1.00 for

Cronbach's Alpha or Composite Reliability denotes to perfect internal consistency reliability which is unlikely to occur (Chen, 1998). Cronbach's Alpha assumes that all indicators are equally reliable (Nunally and Bernstein, 1994). A block is considered homogenous if this index is greater than 0.7 (Nunally and Bernstein, 1994), although a threshold value exceeding 0.60 would be acceptable (Henseler et al., 2009), considering that Cronbach's Alpha, with its assumption of parallel measures, produces a lower bound estimate of internal consistency reliability in the PLS path models (Chen, 1998). Thus, due to the fact that Cronbach's Alpha tends to provide underestimations of internal consistency in PLS path models, some authors (Werts et al., 1974; Chen, 1998) suggest the use of Composite Reliability (CR) indicator which provides better estimate of internal consistency as an alternative measure. Composite Reliability does not assume a tau equivalency among the measures, and takes into account that indicators have different loadings (Chen, 1998; Henseler et al., 2009). The threshold values used to indicate the level of Composite Reliability can be interpreted in the same way as Cronbach's Alpha. In this study, both Cronbach's Alpha and Composite Reliability are calculated using SmartPLS. Because of the nature of our research being early stage research, the threshold of this study was set at 0.7. Any construct that fails to meet the minimum threshold of both the Cronbach's Alpha and Composite Reliability simultaneously was considered not reliable.

Table 7.16: Reliability test result

Factor	No. Items	Composite Reliability	Cronbach's Alpha	Communality
SIS Assimilation	8	0.9018	0.8717	0.5489
SIS Value	8	0.9176	0.897	0.5826
Relative Advantage	4	0.9027	0.8561	0.6993
Compatibility	3	0.8932	0.8214	0.7361
Perceived SIS Risk	4	0.8179	0.7058	0.5323
Top management support	4	0.9177	0.8795	0.7371
Green IT/IS orientation	5	0.8796	0.8279	0.595
DC Energy Governance	2	0.9048	0.7901	0.8262
Knowledge Stock	4	0.9524	0.9335	0.8334
Coercive Pressure	2	0.9014	0.7819	0.8205
Normative Pressure	3	0.8119	0.6592	0.5902
Energy Pressure	5	0.9065	0.869	0.6623
Environmental Preservation Pressure	3	0.9367	0.8982	0.8316

All the constructs used in this study as depicted in Table 7.16 have shown acceptable internal consistency. Composite Reliability values were between 0.8 and 0.9 which indicates strong reliability. Cronbach's Alpha values were all above the desired threshold 0.7 except for one construct (normative pressure) that had a value of 0.65 which is, however, above the minimum level and also has Composite Reliability above 0.7 (0.81). As result, we conclude that the data satisfy the requirements of reliability.

7.5.7. Common Method Variance

Common method bias (CMB), which denotes the bias caused by common method variance, is a common problem in self-reported data such as in the case of most empirical studies (Podsakoff and Organ, 1986). The importance of examining the existence of CMB in the data is because it can be one of the main sources of measurement error, which threatens the conclusion's validity about the relationships between measures of different constructs (Podsakoff et al., 2003). Collectively, method variance can either deflate or inflate the observed relationships between constructs such as correlations, path coefficient and the degree of explained variance (Podsakoff et al., 2003; Straub et al., 2004). The common method bias problem typically results from different aspects. In summary, it arises from collecting data using only one method (e.g. survey), collecting predictor and criterion variables from the same source or rater (e.g. respondent), collecting predictor and criterion variables from the same source at one point in time, due to the characteristics of the measurement items themselves (e.g. item complexity), due to the context of the items within the measurement instrument (e.g. scale length), and/or due to the context in which the measures are obtained (Podsakoff et al., 2003; Straub et al., 2004).

There are different statistical analyses methods to assess the severity of common method bias in the data (Podsakoff et al., 2003). However, due to the lack of strict guidelines for concluding whether CMB is a causing a serious problem (Straub et al., 2004), the researcher should utilise at least one of the available methods for assessing CMB (Podsakoff et al., 2003).

This study used an online survey to collect self-reported data from one source (data centre managers) and at one point in time, which presents a condition where CMB is likely to occur. The researcher decided to apply precautious criteria by using a triple-based approach (that combines more than one approach suggested by different texts) to check for potential CMB in the data.

7.5.7.1. Harman's one-factor approach

First, the extent of CMB was assessed using Harman's one-factor test (Podsakoff and Organ, 1986). This method assumes that when one construct accounts for a substantial amount of the variance among all the constructs (also referred as general construct), then it is evidence for CMB problem. The general construct can be obtained through entering all the principal constructs into the PCA analysis without rotation (e.g. using SPSS) and the first factor that will emerge in Total Variance Explained output is the general construct. We have used SPSS to conduct Harman's one-factor test by entering all the constructs into the PCA. Results from this test showed that 13 factors were present and the most variance explained by the general construct is 25.95 percent, which was comparable to other relevant studies (Liange et al., 2007) and indicates that CMB is not a likely contaminant of our results.

7.5.7.2. Multicollinearity approach

The extent of CMB was secondly assessed using the multicollinearity test (Bagozzi et al., 1991). According to this approach, if two or more independent variables correlate above 0.9, then it is an indication of potential CMB (Bagozzi et al., 1991). The assessment of multicollinearity can be done by looking at the inter-construct correlation matrix (Tabachnick and Fidell, 2007), which can be obtained using SPSS. We have conducted the multicollinearity test and the inter-construct matrix was scrutinised for any extreme correlations above 0.9. The result shows that none was identified above this threshold, indicating no presence of CMB in the research data.

7.5.7.3. Common method factor approach

In addition to the Harman's one-factor and multicollinearity test, we also used a more rigorous statistical approach known as common methods variance (CMV) factor, which is recommended by Podsakoff et al. (2003) and Williams et al. (2003) to check for CMB. In this method, all variables are allowed to load on their theoretically designated constructs as well as on a CMV factor (containing all the indicators of the model). The significance of the structural parameters is then examined both with and without the CMV factor in the model. According to Williams et al. (2003), the researcher should examine the statistical significance of factor loadings of the CMV factor and compare the variances of each observed indicator explained by its substantive construct and the CMV factor. The percentage of indicator variance for CMV factor is represented by calculating the squared values of the CMV factor loadings, whereas the percentage of indicator variance for the substantive constructs is obtained by calculating the squared values of the factor loadings of substantive constructs. If the variance explained by the substantive constructs are substantially greater than their CMV construct variances, and the CMV factor loadings are insignificant, then it can be concluded that the CMB is unlikely to be a serious concern (Williams et al., 2003). To test the CMB using CMV factor approach, the criterion suggested by Podsakoff et al. (2003) and the practical guidelines applied by Liang et al., (2007) to test this approach using PLS were followed.

To perform this test in SmartPLS, we created a first-order construct (single-indicator construct) for each indicator in the measurement model and linked them to their appropriate indicators. Each first-order construct (substantive construct) was then linked with their appropriate designed theoretical constructs. A CMV construct that contained all the indicators of the model was created and linked to each single-indicator construct. As a result, all major constructs of interest and the CMV factor become second-order reflective constructs. Appendix 7e shows the factor loadings for each substantive construct (major construct) and factor loadings for the CMV construct captured through this test.

The results show that the average of variance explained by substantive factors is 0.665, while the average of variance explained by common factors is .007. The ratio of substantive variance to CMV variance is about 95:1 which significantly exceeds the thresholds. The CMV factor loadings were insignificant and the average of loading was very low (-.002) compared to substantive factor loading (0.807). Thus, since the CMV factor loadings are insignificant and variances explained by the substantive constructs are substantially greater than their CMV construct variances, it can be concluded that CMB is unlikely to be a serious concern in our data.

In summary, our measurement model demonstrates reliability and validity by satisfying various reliability and validity criteria. Thus, latent variables developed by this measurement model are valid and reliable for testing the conceptual model and the associated hypotheses proposed earlier. The measurement of the structural model is discussed in the following section.

7.6. SUMMARY

The purpose of this chapter is to evaluate and validate the research instrument through a set of rigorous scientific processes that is applicable to the existing research. This process is called the validation of measurement model. The mean and standard deviation values are provided in Appendix 7f. Following the criteria for evaluating the reflective measurement model in this chapter, the uni-dimensionality, internal consistency reliability, indicator reliability, convergent validity, and discriminant validity was evaluated. Furthermore, the study also validated the second order construct and performed a series of tests to check for Common Method Variance bias. After performing these tests and performing the necessary actions, it can be concluded that the model is a psychometrically sound measure of psychological constructs. The measurement model is now ready for the next step which is structural model evaluation and hypotheses testings.

CHAPTER 8

8. THE ASSESSMENT OF THE STRUCTURAL MODEL

8.1. Introduction

After the validation of the measurement model was established, the next step was to analyse the structural model (Chin, 1998). Thus, this chapter discusses the assessment of the structural model. The aim of the chapter is to evaluate the structural model and test the research hypotheses. This can be accomplished through a series of rigorous tests and processes including the evaluation of the total variance explained, the strength and significance of path coefficients, effect size test and predictive relevance test.

This chapter starts with an introduction about the criteria used for assessing the structural model and hypotheses testing (8.2). This is followed by the application and discussion of four procedures (tests), that is, the assessment of total variance explained (8.3), the strength and significance of path coefficients (8.4), effect size test (8.5) and predictive relevance test (8.6).

8.2. The Evaluation of the Structural Model and Hypotheses Testing

The structural model represents the interrelationships between any two constructs (Hair et al., 2010). The assessment of structural model in PLS can be demonstrated through coefficients of determination (R^2), the significance and magnitude of path coefficients, effect size and predictive relevance (Chin, 1998; Tenenhaus et al., 2005; Henseler et al., 2009). Table 8.1 provides a summary of the typical criteria used in analysing the structural model.

Table 8.1: Criteria for analysing the structural model

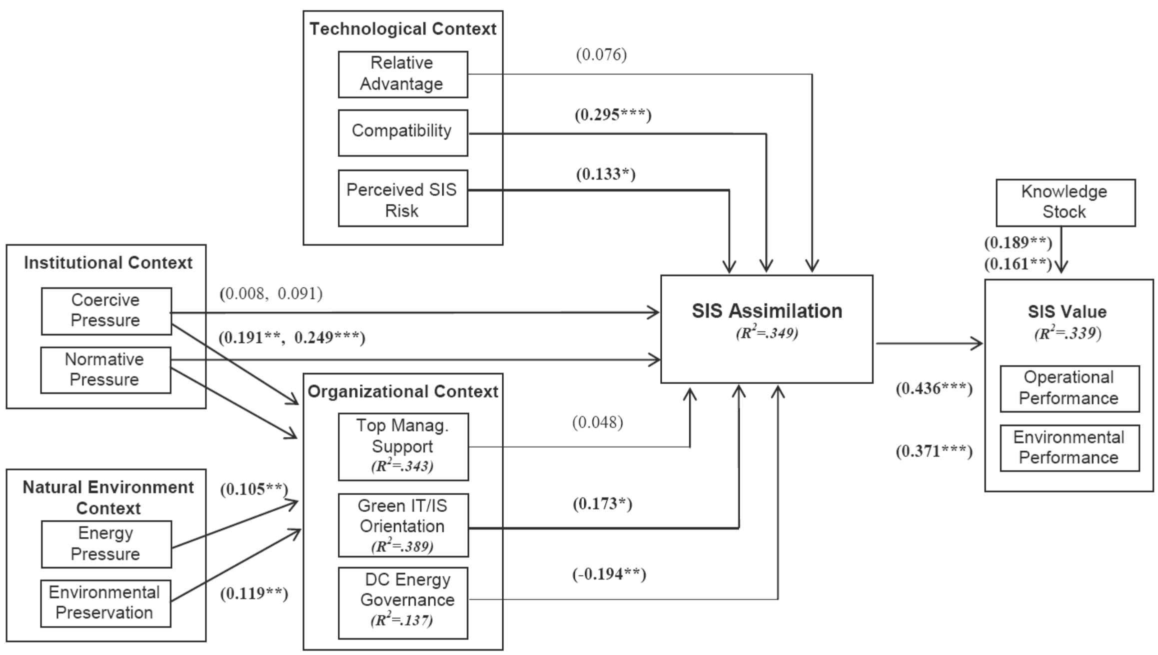
Validity Test	**Method**	**Rule of thumb**	**Literature**
Total Variance Explained (8.3)	Coefficient of determination (R^2) of endogenous constructs	• R^2 values of 0.67 (substantial), 0.33 (moderate), and 0.19 (weak) are used to determine the explanatory power of endogenous constructs	Chin, 1998
Path coefficients (8.4)	Path algebraic sign, magnitude, and significance (t value)	• Algebraic sign should be consistent with the theoretically assumed relationships. • Paths coefficients should reveal strong relationship between two LVs. • The t value of paths coefficients should be significance at least at the .050 level (t>1.96)	Efron and Tibshirani, 1993; Tenenhaus et al., 2005;
Effect size (8.5)	Cohen's (f^2)	• f^2 values of 0.35 (large), 0.15 (medium), and 0.02 (weak) are used to determine the effect of a predictor latent variable at the structural level.	(Cohen, 1988); Chin, 1998; Chin and Todd, 1995
Predictive Relevance (8.6)	Stone-Geisser test (Q^2)	• Q^2-values > 0 give evidence that the observed values are well reconstructed and the model has predictive relevance. • Q^2-values < 0 indicate a lack of predictive relevance	Geisser, 1975; Stone, 1974

In the following, we perform the above typical criteria to analyse the structural model.

8.3. Total Variance Explained

The first criterion for assessing the structural model is the endogenous latent variables' coefficient of determination (R^2). R^2 refers to the proportion of total variation in the dependant variable that can be explained by variation in the independent or predictor variable (Chin, 1998). It measures the relationships of latent variables and provides an estimation of the explained variance of latent variable to their total variance. R^2 of an endogenous latent variable should be at sufficient threshold in order to demonstrate a minimum level of explanatory power. Chin (1998) postulates that R^2 values of 0.67, 0.33 and 0.19 are considered to have substantial, moderate, and weak explanatory power respectively. Lower R^2 values cast doubt about the utility and power of the research model and theory (Henseler et al., 2009) followed in this study to explain the significant variation in the assimilation and value of SIS among data centres.

The R^2 value can be obtained by running the PLS algorithm (Calculate →PLS algorithm) in SmartPLS. The parameters can be viewed through looking at the resulting model structure (which shows the R^2 value inside each endogenous construct) or by extracting *R square* values from the *overview table* (Calculate →PLS algorithm →Default Report). To examine the extent of variance explained for the major endogenous latent variables (SIS assimilation and SIS value) and sub-endogenous latent variables (DC energy governance, green IT orientation, top management support, environmental performance and operational performance), coefficient of determination was estimated by running the PLS algorithm and the results are displayed in Figure 8.1 and Table 8.2.



p<0.05*, p<0.01 **, p<0.001 ***

Figure 8.1: The result of path algorithm: R^2 values, and paths sign and magnitude

Table 8.2: Prediction quality of endogenous latent variables

	Endogenous variables	R Square	Total Variance Explained
1	SIS Assimilation	0.3491	34.9 %
2	SIS Value	0.3389	33.9 %
3	Data Centre Energy Governance	0.1369	13.7 %
4	Green IT/IS Orientation	0.3889	38.9%
5	Top Management Support	0.3425	34.3%

The result from the original model indicates that the left hand side of the model (SIS Assimilation) has a moderate explanatory power of the variance in SIS assimilation (34.9%). The sub-endogenous variables of SIS assimilation also indicate that the model explains 13.7% of the variance in data centre energy governance, 38.9% of the variance in green IT orientation, and 34.3% of the variance in top management support. The right hand side of the model (SIS value) has a good explanatory power of the variance in SIS value (33.9%). The sub-endogenous variables of SIS value also indicate that the model explains 69.1% of the variance in environmental performance and 95.5% of the variance in operational performance. This signifies that the structural model is a good representation of the observed sample data and thus supports the validity of our structural model. The next test was to assess the structural model path coefficients.

8.4. Path Coefficients

8.4.1. Test of the Original Model

One of the common methods for assessing the structural model is by looking at the algebraic sign, magnitude and significance of individual path coefficients between latent variables (Henseler et al., 2009). The structural path coefficients (standardised beta coefficients of ordinary least squares regressions) provide a partial empirical validation of the theoretically assumed associations between the models' constructs (Henseler et al., 2009). This will allow examining which of the hypothesised relationships of SIS assimilation and value are valid. A researcher should first check the algebraic sign of path coefficients against the theoretically assumed relationships. Any paths showing contrary algebraic sign to the theoretical expectation do not support the assumed hypotheses. The second assumption for assessing path coefficients is that each individual path should be of a high magnitude in order to reveal a strong relationship. Although there are no established guidelines on what stands for a high magnitude in PLS path modelling, some postulate that such paths should exceed .100 (Urbach and Ahlemann, 2010). However, researchers argue that irrespective of a path's magnitude, the path coefficients need to be of statistical significance in order to account for a valid impact within the structural model (Thompson et al., 1995; Tenenhaus et al., 2005).

The statistical significance of paths can be obtained through re-sampling techniques such as either bootstrapping (Efron and Tibshirani, 1993) or jackknifing (Miller, 1974) which generate t-values. As a rule of thumb, the t-value of path coefficients should be significance (at least $t>1.96$) in order to meet .050 significance level (Tenenhaus et al., 2005). The sign and magnitude of path coefficients can be visually observed from the above Figure 8-1 by running the PLS algorithm. However, in order to obtain the significance of individual path coefficients (t-values) in SmartPLS, a bootstrapping technique needs to be performed (Jackknifing is not generally used in PLS analysis and SmartPLS does not perform jackknifing). Practically, t-values can be obtained by running the PLS bootstrap (Calculate →Bootstrapping) in SmartPLS software. The parameters can be obtained by extracting *T Statistics* values from the *Path Coefficients* table (Calculate → Bootstrapping →Default Report). To examine path coefficients of our structural models, the sign, magnitude and significance of individual path coefficients between model latent variables was estimated by running the PLS. Table 8.3 illustrates the overall hypotheses supported.

Table 8-3 shows that out of 28 theorised structural paths, 23 were supported at 0.05-0.001 significance levels. This supports the overall assessment of the structural model as an acceptable representation of the observed sample data. Table 8-3 provides statistical estimates for the Structural Path of the original model, but not all the constructs used in our structural model. The model also hypothesises that three constructs of age of data centre, size of data centre, and type of data centre control the SIS assimilation as well as hypothesising that length of use moderate the relationship between SIS knowledge stock and SIS value. Thus, before we conclude about the total number of hypotheses supported, the moderator variables must be examined.

Table 8.3: Hypotheses testing of original constructs

Hypo.	Path	*β*	T Stat	P Value	Sig	Supported?
H1	Relative Advantage -> SIS Assimilation	0.076	0.897	0.371	n.s	No
H2	Compatibility -> SIS Assimilation	0.295	3.567	0.000	***	YES
H3+4	Perceived Risk -> SIS Assimilation	0.133	2.003	0.046	*	YES
H5	Top Management Support -> SIS Assimilation	0.048	0.689	0.492	n.s	No
H6	Green IT/IS orientation -> SIS Assimilation	0.173	2.209	0.028	*	YES
H7	DC Energy Governance -> SIS Assimilation	-0.194	2.841	0.005	**	No
H8a	Coercive Pressure -> SIS Assimilation	0.008	0.126	0.900	n.s	No
H9a	Normative Pressure -> SIS Assimilation	0.191	2.856	0.005	**	YES
H8b	Coercive Pressure -> SIS Assimilation (Indirect)	0.091	1.551	0.122	n.s	No
	Coercive Pressure -> Top Management Support	0.360	6.390	0.000	***	YES
	Coercive Pressure -> Green IT/IS orientation	0.290	4.636	0.000	***	YES
	Coercive Pressure -> DC Energy Governance	0.256	4.085	0.000	***	YES
H9b	Normative Pressure -> SIS Assimilation (Indirect)	0.249	4.215	0.000	***	YES
	Normative Pressure -> Top Management Support	0.447	9.341	0.000	***	YES
	Normative Pressure -> Green IT/IS orientation	0.560	11.999	0.000	***	YES
	Normative Pressure -> DC Energy Governance	0.327	5.542	0.000	***	YES
H10	Energy Pressure -> SIS Assimilation (Indirect)	0.105	2.686	0.008	**	YES
	Energy Pressure -> Top Management Support	0.480	7.506	0.000	***	YES
	Energy Pressure -> Green IT/IS orientation	0.450	7.401	0.000	***	YES
	Energy Pressure -> DC Energy Governance	0.283	4.471	0.000	***	YES
H11	Nat. Pres. Pressure -> SIS Assimilation (Indirect)	0.119	2.938	0.004	**	YES
	Nat. Pres. Pressure -> Top Management Support	0.488	8.723	0.000	***	YES
	Nat. Pres. Pressure -> Green IT/IS orientation	0.470	7.951	0.000	***	YES
	Nat. Pres. Pressure -> DC Energy Governance	0.232	3.532	0.001	***	YES
H12a	SIS Assimilation -> Operational performance	0.436	7.713	0.000	***	YES
H12b	SIS Assimilation -> Environmental performance	0.371	7.228	0.000	***	YES
H13a	Knowledge Stock -> Operational performance	0.189	2.627	0.009	**	YES
H13b	Knowledge Stock -> Environmental performance	0.161	2.643	0.009	**	YES

p<0.05*, p<0.01 **, p<0.001 ***

n.s.= Not Significant

8.4.2. The Test of Control (moderating) Variables for SIS Assimilation

One of the common methods for testing the moderating variables in PLS path modelling research is through multi group analysis (Chin, 2000; Henseler and Fassott, 2009; Eberl, 2010). Multi group analysis is used to examine the heterogeneity of the observation; that is, different subpopulations are likely to have different parameters (Henseler et al., 2009), such as gender, age or country. As such, it allows the interpretation of differences in effects between different groups. The primary approach for group comparison is t-test (Keil et al., 2000). Keil et al. (2000) suggest the use of separate bootstraps for each sub-sample to obtain the standard error that is used to calculate the difference in paths between groups. The significance of differences between groups can be computed using the following statistic developed by Keil et al.,(2000):

$$t = \frac{Path_{sample\_1} - Path_{sample\_2}}{\left[\sqrt{\frac{(m-1)^2}{(m+n-2)} * S.E.^2_{sample1} + \frac{(n-1)^2}{(m+n-2)} * S.E.^2_{sample2}}\right] * \left[\sqrt{\frac{1}{m} + \frac{1}{n}}\right]}$$

Where *Path* denotes sub-sample-specific path coefficients, *n* denotes the sizes of the sub-samples, *se* denotes and the path coefficient standard errors. The formula is asymptotically t-distributed with n(1)+n(2) - 2 degrees of freedom. This approach allows the researcher to examine the difference between the groups based on the difference of magnitude and significance of path coefficient in the groups as well as measuring the significance of difference between the groups. Although this approach is preferred by many researchers (Henseler et al., 2009), Chin and Dibbern (2009) cast doubts on the ability of this formula to be distributional-based to fit the PLS path modelling with its inherent distribution-free nature. To overcome this scepticism, Henseler et al. (2009) propose an alternative simple approach that does not rely on distributional assumptions, as follows

$$P(b^{(1)} > b^{(2)} | \beta^{(1)} \leq \beta^{(2)}) = 1 - \sum_{\forall j,i} \frac{\Theta\left(2\bar{b}^{(1)} - b_j^{(1)} - 2\bar{b}^{(2)} + b_i^{(2)}\right)}{J^2}$$

Where *J* denotes the number of bootstrap samples, b(1) j and b(2) i denote the bootstrap parameter estimates, b-(1) and b-(2) denote the means of the focal parameters over the bootstrap samples, and *O* denotes the unit step function. This approach allows the determination of the probability of whether a population parameter differs across two subpopulations. Furthermore, other researchers postulate the need for more statistical support for the suitability of sub-samples for group comparisons by establishing goodness-of-fit criteria by the means of R^2 and Coefficient Alpha of endogenous constructs having acceptable R^2 value and Coefficient Alpha of => 0.7 (Tenenhaus et al., 2005; Eberl, 2010). Nevertheless, due to the lack of strict guidelines in respect to the established group comparisons practice, the author decided to use the three approaches all together as being acceptable methods in attempts to enhance the validity of findings. The goodness-of-fit criterion (Tenenhaus et al., 2005; Eberl, 2010) is the first approach that provides support for the analysis. Whereas the Henseler et al. (2009) method allows for the estimating of the probability of difference significance between groups, the Keil et al. (2000) method allows for more detailed comparison of differences for each latent variable between the groups. If a difference between groups is supported by the two methods simultaneously, then it is evident that difference is significantly valid.

As a rule of thumb in PLS group-based analysis, the moderating variable used in comparison must be categorical in nature (not continuous) (Rigdon et al., 1998). 'If one or both of the interacting variables is discrete, or can be made so, researchers can apply a "multisample" approach, with the interaction effects becoming apparent as differences in parameter estimates when the same model is applied to different but related sets of data' (Rigdon et al., 1998, p. 1). However, when the moderating variable is metric in nature and the researcher still wants to perform group analysis, a transformation technique can be applied. The prevailing technique used for transforming metric variables into categorical is called dichotomisation and the common method to transform reflective constructs is by using the mean or median split of indicator values (Henseler and Fassott, 2009). In this case, the researcher split the data set into two sub-samples, one above the mean or median (named as high) and the other one below the mean or median (named as low). The decision of whether to select the mean or median for group separation is up to the researcher (Henseler and Fassott, 2009). The study uses the median value because it is known to be more popular in PLS-based group comparison (Henseler and Fassott, 2009). In the structural model, there are two metric moderating variables (size and age) and one categorical (type), thus it was essential to apply transformation for the two metric variables (age of data centre and data centre size). The original model was estimated separately for each group of observations for each control variable at one time and PLS bootstrapping was employed to obtain the data needed for comparison (Henseler and Fassott, 2009). The results are briefly summarised in this section and will be discussed thoroughly in the research discussion section.

8.4.2.1. The age of data centre

The differences in the age of data centre were hypothesised to influence the SIS assimilation and its relationships with technological, organisational, environmental, and natural environment factors (Hypothesis H15). The age of data centre moderating construct is a single metric item that denotes the years elapsed since the establishment of the data centre. Thus, in order to qualify for the group comparison approaches, the item had to be transformed using an appropriate method. The item was transformed using dichotomisation technique based on the median value (Henseler and Fassott, 2009). All observations having values below the median (8.0 years) denoted ‘new’ data centres whereas observations having values above the median are denoted ‘old’ data centres. To check that each sub-PLS path model has an acceptable fit, the goodness-of-fit criterion is firstly applied. The R^2 values of endogenous constructs (that is, the constructs that are influenced by other construct in the model) in age of data centre subgroups was acceptable and Cronbachs Alpha, Composite Reliability is greater than .7 (Tenenhaus et al., 2005; Eberl, 2010). The results are depicted in Table 8.4.

Table 8.4: overview summary of endogenous constructs only, based on the age of data centre groups using goodness-of-fit criteria

Endogenous Construct	Group1: New s=90			Group2: Old s=115			All Groups
	R^2	Composite Reliability	Cronbachs Alpha	R^2	Composite Reliability	Cronbachs Alpha	R^2
DC Energy Governance	0.180	0.8996	0.777	0.142	0.9037	0.790	0.137
Green IT/IS orientation	0.311	0.8804	0.829	0.512	0.877	0.825	0.389
SIS Assimilation	0.223	0.8979	0.867	0.526	0.9058	0.877	0.349
Top management support	0.356	0.9396	0.915	0.416	0.9013	0.852	0.343

Table 8.4 shows that R^2 values, Cronbachs Alpha, and Composite Reliability for the age groups are very acceptable within the threshold of interpretation. The result, reveal that the difference between R^2 values of SIS assimilation among old and new data centre groups are

significant (r= 0.154, p<0.05) at 95% confidence interval. This suggests that the model works better for old data centres (above 8.0 years) in the sample than new data centres and providing support for hypothesis 15.

In order to check that each group differs from other groups, the path coefficients magnitude and significance was estimated for each group using separate PLS bootstraps (Henseler et al., 2009). The results can be found in Appendix 8a-1. By visually estimating the results the difference in the path coefficients magnitude and significance for the majority of the model constructs between the two data centres groups can be easily identified. This provides initial indication that the age of data centre moderates the level of SIS assimilation. Nevertheless, the impact of the age of data centre on SIS assimilation can only be statistically demonstrated by estimating the statistical significance of differences.

The study estimates the statistical significance of difference using the Keil et al. (2000) and Henseler et al.'s (2009) statistical formulas by entering the required values obtained from PLS bootstrapping into a Microsoft Excel sheet. The results are depicted in Appendix 8a-2.

The findings of Keil's Approach test suggest that the variables that are sensitive to the variation of old and new data centres are top management support, coercive pressure, energy pressure environmental preservation pressure This shows that the variation in the explained variance of SIS assimilation based on the age of data centres can be explained by variation between SIS assimilation and its latent variables.

8.4.2.2. The size of data centre

The size of data centre was hypothesised to moderate the SIS assimilation and its relationships with technological, organisational, environmental, and natural environment factors (Hypothesis H16). The size of data centre moderating construct denotes the number of servers that exist in a data centre. Similar to the age of data centre, the size of data centre is also a single metric item and thus the item was transformed using dichotomisation technique based on the median value (Henseler and Fassott, 2009) to qualify for the group comparison test. All observations having values below the median (2600 servers) denoted 'small' data centres, whereas observations having values above the median denoted 'large' data centres. The R^2 values of endogenous constructs in age of data centre subgroups were acceptable and Cronbach's Alpha and Composite Reliability are greater than .7. The results are depicted in Table 8.5.

Table 8.5: Overview summary of endogenous constructs based on the size of data centre groups using goodness-of-fit criteria

Endogenous Construct	Group1: Large, s=103			Group2 :Small, s=102			All Groups
	R^2	Composite Reliability	Cronbachs Alpha	R^2	Composite Reliability	Cronbachs Alpha	R^2
DC Energy Governance	0.177	0.8934	0.777	0.134	0.9027	0.786	0.137
Green IT/IS orientation	0.451	0.9002	0.8587	0.418	0.8551	0.792	0.389
SIS Assimilation	0.375	0.9005	0.8701	0.407	0.9069	0.879	0.349
Top management support	0.321	0.9212	0.8851	0.347	0.9018	0.855	0.343

The above table shows that R^2 values, Cronbachs Alpha, and Composite Reliability for the sub-samples based on the size of data centre are very acceptable within the threshold of interpretation. These findings indicate that difference between small and large data centres can be statistically examined. Despite the difference in R^2 values of SIS assimilation among the two groups, the findings reveal that difference between small and large data centre groups are insignificant (r^2= 0.035, p= 0.617) at 95% confidence interval. This means that the model is not sensitive to differences in data centre size

8.4.2.3. The type of data centre

The differences in the type of data centre were hypothesised to influence the SIS assimilation and its relationships with technological, organisational, environmental, and natural environment factors (Hypothesis H17). The type of data centre moderating construct used in our sample was already categorical in nature, and thus no transformation was required for this construct. The type of data centre was found to have three distinct segments: Corporate, Managed, and Co-located data centres. Because the formulas used for testing the significance of difference between subgroups (i.e. Keil et al.'s (2000) formula; and Henseler et al.'s (2009) formula) can accommodate only two groups at one time, it was essential to come up with an alternative method to resolve this limitation. Thus, the researcher decided to perform three tests for comparing the difference between groups one and two, groups one and three, and groups two and three. The researcher can then use the results from each comparison group to identify the difference. This method is accepted and has been applied by some PLS-based researches (Eberl, 2010).

To check that each sub-sample based on type of data centre has an acceptable fit, we estimated the R^2 values, Cronbachs Alpha, and Composite Reliability for the endogenous constructs. The R^2 values of the endogenous constructs in age subgroups are acceptable and Cronbachs Alpha (CA) and Composite Reliability (CR) are greater than .7. The results are depicted in Table 8.6.

Table 8.6: Overview summary of endogenous constructs based on the type of data centre groups using goodness-of-fit criteria

	Group1: Corporate, s=93			Group2: Managed, s=70			Group3: Co-located, s=47		
	R Square	CR	Cronb Alpha	R Square	CR	Cronb Alpha	R Square	CR	Cronb Alpha
DC Energy Governance	0.132	0.907	0.820	0.455	0.886	0.744	0.199	0.782	0.445
Green IT/IS orientation	0.466	0.873	0.818	0.490	0.882	0.834	0.470	0.890	0.846
SIS Assimilation	0.363	0.905	0.874	0.525	0.890	0.853	0.435	0.906	0.881
Top management support	0.300	0.902	0.855	0.555	0.929	0.897	0.244	0.910	0.869

Although co-located had low Cronbachs Alpha values, it has acceptable Composite Reliability value, which is the indicator preferred by most researchers for estimating the reliability of PLS path models (Werts et al., 1974; Chen, 1998).

The finding reveals that the difference in the SIS assimilation explanatory value between corporate and managed groups are significant (r^2= 0.162, $p<0.05$) at 95% confidence interval, whereas difference between corporate and co-located groups (r^2= 0.072, p= 0.304) as well as between co-located and managed groups (r^2= 0.09, p= 0.198) were insignificant. The result also shows that the research model appears to work better for managed data centres in the sample than co-located or corporate data centres.

To enhance the researcher's understanding about what constitute these differences, the path coefficients magnitude and significance was estimated using separate PLS bootstraps for each subgroup (See Appendix 8a-3). By visualising the path coefficients' magnitude and significance, it can be inferred that the type of data centre plays an essential part in determining the effect of antecedent factors on the SIS assimilation. The difference of path coefficients and p values between the majority of latent constructs among the groups provides empirical support that the type of data centre controls the level of SIS assimilation to a significant level. To demonstrate the actual effect of the type of data centre on SIS assimilation the statistical significance of differences was estimated. The statistical significance of difference between subgroups was estimated using the Keil et al. (2000) and Henseler et al.'s (2009) statistical formula. The results are depicted in Appendixes 8a-3 and 8a-4.

The findings from Keil et al's approach test suggest that a total of five paths of three latent variables, that is, coercive pressure, normative pressure and energy pressure are sensitive to the variation of data centre. The results of Henseler et al.'s Approach (MGA) test confirm the results from Keil's Approach. It suggests that the variables that are sensitive to the variation also include compatibility and green IT/IS orientation. This suggest that the variation in the explained variance of the extent of SIS use is moderated based on data centre type, that is corporate, managed or co-located.

8.4.3. The Test of Control (moderating) Variables for SIS Value

The length of SIS use was hypothesised to moderate the influence of SIS assimilation as well as SIS knowledge stock on SIS value. The effect of length of SIS use was assessed through SmartPLS moderation effect test. Unlike the multi-groups' comparison used earlier, there was no need for applying dichotomisation technique in this test. This method is applicable when testing the moderation effect of a control variable on one latent variable or on latent variables that have the same number of items (Chin et al., 2003). The results of the SmartPLS moderation effect test of length of SIS use on the relationships between SIS assimilation and SIS value as well as between knowledge stock and SIS value are depicted in Table 8.7.

The results suggest that the length of SIS use significantly moderates the ability of SIS managers' knowledge to facilitate the value creation (operational and environmental performance), whereas there is no significance moderation on relationships between the assimilation of SIS and SIS value.

Table 8.7: Moderation effect test of length of SIS use using SmartPLS

Hypo	**Moderation Path**	**Beta**	**T Stat**	**P value**	Supported
14a	SIS Assimilation * Length of Use -> SIS Value	0.136	1.218	0.225	NO
	SIS Assimilation * Length of Use -> Operational	0.133	1.219	0.224	NO
	SIS Assimilation * Length of Use -> Environmental	0.113	1.215	0.226	NO
14b	Knowledge Stock * Length of Use -> SIS Value	0.151	2.142	0.033	YES
	Knowledge Stock * Length of Use -> Operational	0.147	2.140	0.034	YES
	Knowledge Stock * Length of Use -> Environmental	0.125	2.127	0.035	YES

8.5. Effect Size

The effect sizes test is very important in the evaluation of structural models (Cohen, 1988). While it is considered as a good practice in many disciplines for the publication of empirical research findings (Wilkinson, 1999; Shaver, 2006; Ellis, 2010), it is one of fundamental pillars in PLS path modelling (Chin 1998; Henseler et al,.2009). The effect size is one of the measures used to estimates the strength of the relationship between independent and dependent variables in a statistical sense (Cohen, 1988). It refers mostly to the underlying population rather than a particular sample. In general, effect size conveys the magnitude of relationships between latent constructs without making any presumptions about whether those relationships are a true reflection of the relationships in the population (Ellis, 2010). Consequently, the magnitude of effect size has a direct impact on the power of variance explained (Hair et al., 2010). The effect size test estimates the increase in R square values of the latent construct to which the path is linked to (the associated endogenous construct), relative to the latent construct’s proportion of unexplained variance of the endogenous construct (Chin 1998). In doing so, the researcher needs to evaluate the original model and then compare it to a partial model which excludes a particular construct from the model at one time in an attempt to evaluate the impact of that construct on the total variance explained by the original model or the endogenous latent variable. This is commonly measured by the means of Cohen’s f^2 (Cohen, 1988; Chin, 1998). The f^2 is explained as:

$$(R^2_{\text{full model}} - R^2_{\text{partial model}}) \div (1 - R^2_{\text{full model}})$$

Cohen (1988) suggests that a value of f^2 <.02 has no effect, .02 ≤ f^2 < .15 has small effect, .15 ≤ f^2 < .35 has moderate effect, and f^2 ≥.35 has large effect of a predictor latent variable at the structural level. To examine the effect size in our model, we have measured the f^2. for each endogenous construct following Cohen's method. *Full model* denotes the original model (containing all the model constructs). *Partial model* denotes the alternative model (after eliminating a particular construct from the original model at one time). R^2 of the partial model denotes the explained variance of the endogenous construct for which the eliminated latent variable is directly linked to. The results are depicted in Appendix 8b.

The results show that all of the latent constructs contribute to the original model at different levels (f^2>0). The R^2 value of the partial model was always less than the R^2 of the original model. No results from the deletion of latent constructs in partial models have resulted in any decrease in the R^2 values of the original model. The f^2 values suggest that the unexplained variance of the partial model is significant at difference levels for almost all constructs (except for eight beta paths), suggesting the importance of each latent variable to the total explained variance. This implies that all the constructs contribute to the total explained variance at acceptable range and is also constant with the findings of previous structural model tests.

Because the TOIN model consists of antecedents derived from different theoretical underpinnings, we evaluated four context-based models (Technological, Organisational, Institutional and Natural Environmental Context) were evaluated and compared against the integrated TOIN model. The aim of this step was to check if the power of the TOIN theoretical framework explains the variance in SIS assimilation better than the context-based model. The results are exhibited in Table 8.8 and Figure 8.2

Table 8.8: Estimates of difference between context-based and TOIN model

	Context-based model.	**TOIN model.**	**f^2**	**Sig**
Included context	R^2	R^2		
Technological Context	0.285	0.349	0.098	*
Organizational Context	0.196	0.349	0.235	**
Institutional Context	0.157	0.349	0.295	**
Natural Environment Context	0.103	0.349	0.378	***

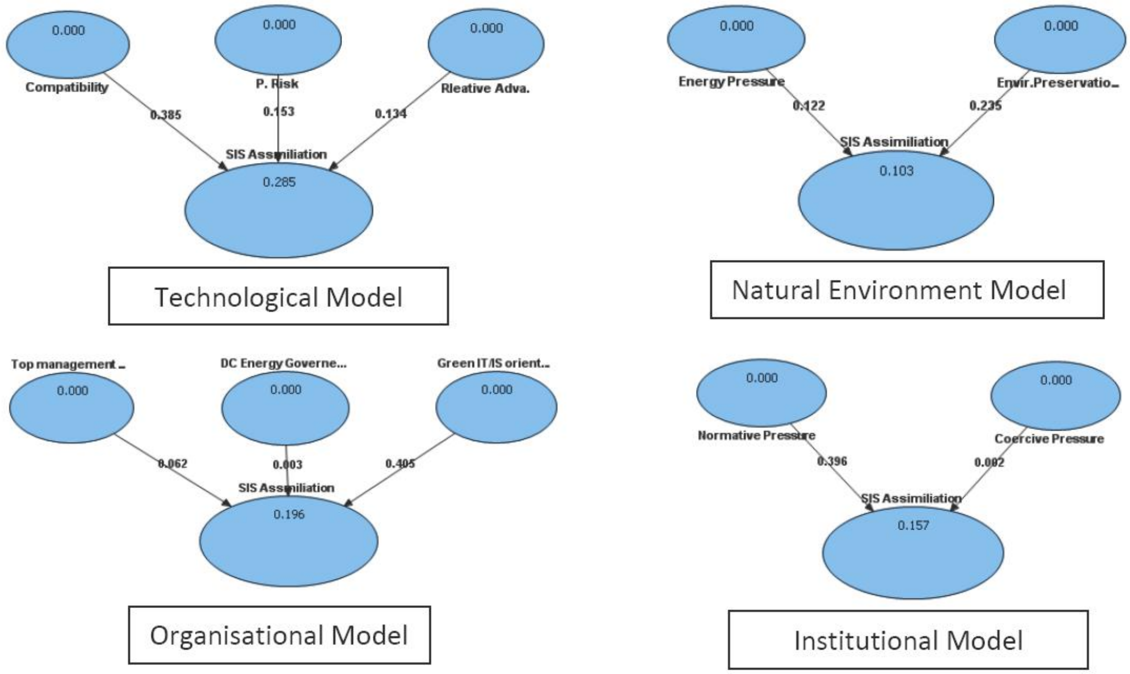


Figure 8.2: Context-based models

By comparing the R^2 values of the four context-based models with the TOIN model, it can be confirmed that the TOIN model is better than any of the context based models in explaining the variance in SIS assimilation. In addition, by using Cohen's method it can be observed that f^2 value is significant for all contexts; thus they all contribute to the original model at significance level.

8.6. Predictive Relevance

Predictive Relevance refers to the assessment of the model's capability to predict the endogenous latent variable's indicators (Stone, 1974). Predictive Relevance can be used as an indication of how well the observed data are reproduced by the structural model and its parameter estimates (Geisser, 1975). This test is of importance in PLS path modelling and can be used as one of the tools for assessing the structural models (Chin, 1998). According to Chin (1998), 'the prediction of observables or potential observables is of much greater relevance than the estimator of what are often artificial construct-parameters' (p. 320). The Stone-Geisser test developed by Geisser (1975) and Stone (1974) is one of the well-known techniques for estimating the predictive relevance. The test generates Q^2 measures of the predictive relevance of a block of manifest variables.

The Stone-Geisser test that generates Q^2 statistics involves omitting one case at a time 'blindfolding', re-estimating the structural model based on the remaining cases after omission, and predicting the blindfolded case values on the basis of the remaining parameters (Sellin, 1995). The blindfolding procedures are only applied to the reflective endogenous latent variables (Henseler et al., 2009). Specifically, in this test the model parameters are estimated and used to predict the omitted values with a systematic assumption that a certain number of cases are missing from the sample. Q^2 is represented by:

$$Q^2 = 1 - \frac{\sum_D E_D}{\sum_D O_D}$$

Where (E) is the sum of square of prediction errors and (O) is the sum of squares of original omitted values.

According to the Stone–Geisser criterion, a Q^2 greater than zero implies that the structural model has predictive relevance, with values being closer to the number one as indicating strong predictive relevance (values ranges between 0 and 1). There are two forms of Q^2: cross-validated communality and cross-validated redundancy (Fornell and Cha, 1994) which are obtainable using blindfolding procedures (Tenenhaus et al., 2005) and are available in common PLS software (e.g. SmartPLS). Cross-validated communality indicates the Q^2 of a single Latent Variable that is associated with a block of Manifest Variables whereas cross-validated redundancy indicates the Q^2 of the entire structural regression (Fornell and Cha, 1994). Wold (1982) postulates that the Stone-Geisser technique well-fits the PLS path modelling approach (especially cross-validated redundancy) (Wold, 1982, p. 30).

The Q^2 value can be obtained by running the PLS blindfolding (Calculate →Blindfolding) in SmartPLS. The parameters can either be visually viewed through looking at the resulting model structure (which shows both the Q^2 of Cross-Validated communality and Cross-Validated redundancy values inside each endogenous construct) or by extracting Q^2 values from the *overview table* (Calculate → Blindfolding →Default Report). We have ran the blindfolding procedures for all of the endogenous variables in our model all together (DC Energy Governance, top management support, green IT orientation, SIS assimilation and SIS value). The omission distance (group factor) was set at threshold of 7 as recommended by Wold (1982). The results are exhibited in Table 8.9.

Table 8.9: Estimates for predictive relevance Q^2

	Predictive Relevance Q^2	
Constructs	**CV Redundancy**	**CV Communality**
SIS Assimilation	0.181	0.505
SIS Value	0.193	0.572
Relative Advantages	0.700	0.700
Compatibility	0.737	0.737
Perceived Risk	0.532	0.532
Top management support	0.250	0.741
Green IT/IS orientation	0.228	0.597
DC Energy Governance	0.121	0.817
Knowledge Stock	0.833	0.833
Coercive Pressure	0.821	0.821
Normative Pressure	0.590	0.590
Energy Pressure	0.662	0.662
Environmental Preservation Pressure	0.832	0.832

From the above results, it can be inferred that our structural model has a good level of predictive relevance. All values are above zero and show high predictive relevance. The next section is the discussion chapter which provides thorough discussion about the findings of our structural analysis.

8.7. SUMMARY

The aim of this chapter was to evaluate the structural model and test the research hypotheses. A series of rigorous criteria and processes using a variety of tests including Total Variance Explained, the strength and significance of Path coefficients, Effect size test and Predictive Relevance was performed. The model explains 34.9% of SIS assimilation and 33.9% of SIS value. The path coefficient test shows that out of 28 developed research hypotheses, a total of 21 hypotheses were supported at 95% confidence interval. The effect size test shows that all the constructs have significant effect size except relative advantage, top management support and coercive pressure constructs. The test of predictive relevance reveals that the structural model has a strong level of predictive relevance. The results also shows that the TOIN model of SIS assimilation and value that combines antecedents from technological, organisational environmental, and natural environment perspective has the best explanatory power compared to the single context perspective. The interpretation and implications of results of this chapter are further discussed in Chapter 9.

CHAPTER 9

9. FINDINGS AND DISCUSSION

9.1. Introduction

Organisations are under increasing pressure to improve the operational and environmental performance of running data centres (Velte et al., 2008; Lefurgy et al., 2003). Some studies emphasise the various advantages of SIS applications. However, to what extent data centres have utilised SIS to support the management of the facility, cooling, power and computing platforms and the factors that determine the extent of use have not been sufficiently studied. In addition, although several industries have already recognised the value of sensor technology, the operational and environmental benefits that SIS can offer to improve the performance of data centres are yet to be investigated. This study was set out to understand how data centres make use of SIS.

Four criteria were developed to evaluate the assimilation of SIS in data centres: volume, diversity, use intensity, and integration of SIS. These criteria were developed Following Massetti and Zmud's (1996) and Ravichandran's (2000) facets of technology assimilation and based on the results of the exploratory study reported in chapter 3. Further, drawing from a number of theories including DOI (Roger, 1983), TOE (Tornatzky and Fleischer, 1990), Institutional (DiMaggio et al., 1983), and NRBV (Hart 1995) and five exploratory case studies of Australian data centres, several determinants of SIS assimilation were identified and evaluated. Building on the RBV (Barney, 1991; Peteraf, 1993) and the NRBV (Hart, 1995), how the utilisation of SIS functionalities that are rare, valuable and sustainable help data centres to improve their operational, and environmental performance was evaluated.

This chapter provides a discussion of the main findings of the study. This process involves the interpretation and implications of results by linking the literature review from chapter 2, the theories on IS assimilation from chapter 4, and data analysis from chapter 8.

The chapter is structured as follows. Firstly, the general model and contribution of TOIN framework on SIS assimilation and value is discussed (9.2). Then, the effect of the variables of TOIN on SIS assimilation and value are discussed in 9.3- 9.6. This is followed by discussion on SIS assimilation and its impact on data centre performance (9.7), as well as SIS knowledge stock effect on SIS value (9.8). The chapter conclude with discussion on the boundary conditions of TOIN (9.3).

9.2. TOIN, SIS Assimilation and Value

Overall, the TOIN theoretical model developed in the current research explains approximately 35% of SIS assimilation in the data centres as well as 34% of SIS value to data centres. This means that 35% of the differences in the volume of SIS a data centre uses, the number of functional areas that are supported by SIS, the extent of utilisation of SIS functionalities and the extent of SIS integration are related to the variables captured in the TOIN framework. Further, 34% of the differences in reducing operational cost and; improving energy efficiency, information accuracy and operation visibility; enhancing infrastructure availability (uptime); reducing energy consumption and; improving compliance with regulatory environmental requirements are related to the use of SIS as well as to the SIS accumulated knowledge of data centre managers.

As there is no prior empirical study on either SIS assimilation or SIS value, the explanatory power of the TOIN model is compared with other studies on IS assimilation and value. For this purpose, relevant articles that were published in recognised IS journals were selected. Table 9-1 illustrates the explained variance by some of the survey-based studies on IS assimilation and value.

The studies illustrated in the Table 9.1, although they were conducted on IS systems other than SIS, examine the assimilation of IS within organisational settings. This means the variance reported in these studies can be used as an acceptable benchmark for comparing the variance explained by the TOIN model. Prior studies reported variance for IS assimilation ranges between 26% and 39% and for IS value (between 17% and 62%). The result of the current study falls within the norms established by previous IS research.

Given that the study is the first to examine the assimilation and value of SIS in data centres, the result represents an important contribution to the future IS research that investigates the factors that influence the use and value of information systems that support environmental as well as operational benefits.

Table 9.1: IS assimilation and IS value explained variance in some relevant IS studies

Authors	Journal title	Endogenous Variable	Explained variance
Fichman 2001	MIS Quarterly	object-oriented programming languages Assimilation	28%
		Database management systems Assimilation	26%
		Computerided software engineering tools Assimilation	27%
Liang et al., 2007	MIS Quarterly	ERP assimilation	39%
Ranganathan et al., 2004	International Journal of Electronic Commerce	Web technologies assimilation	24%
		External Diffusion	58%
		Web technologies value	62%
Rai et al, 2009	Journal of Management Information Systems	Electronic Procurement Innovations assimilation	39%
		Impact on Procurement Productivity	24%
Zhu and Kraemer, 2005	Information Systems Research	E-business use	20%
		E-business value	15%

The theoretical model (TOIN) used in this study was an integrated model developed based on antecedent factors derived from different theoretical underpinnings, namely, technological, organisational, institutional and natural environment contexts. To determine whether the integrated model has more power to explain the variance of SIS assimilation, it was compared against the four context-based models (see chapter 8, table 8.12). The results show that the consolidated model has relatively higher power to explain the variance in SIS assimilation. In addition, the effect size (f^2) for each context-based model reveals that all context-based models have significant effect size on SIS assimilation. This implies that each of the four contexts significantly contribute to the TOIN model. In the subsequent section, the findings of each of the hypotheses will be discussed.

9.3. SIS Technological Factors and SIS Assimilation

Four technological factors, that is, SIS relative advantage, SIS compatibility, SIS complexity and SIS perceived uncertainty, were initially hypothesised to explain differences in the volume, diversity and intensity of SIS use. As a result of the instrument development process, SIS complexity and SIS perceived uncertainty were combined into one factor and re-labelled as perceived SIS risk, producing three technological factors for hypothesis testing. The correlation between the three technological factors and SIS assimilation, the standard effect (i.e., beta values) and p-values are displayed in Table 9.2.

Table 9.2: The correlation, path coefficients and magnitude for technological factors

Constructs	**Correlation**	**Beta**	**P value**	**f^2**
SIS relative advantage	0.356***	0.063	0.45	0.003
SIS compatibility	0.496***	**0.318**	*****	0.100*
Perceived SIS Risk	0.284***	**0.143**	***	0.026*

p<0.05, p<0.01 **, p<0.001 **

The results show that, while SIS compatibility and perceived SIS risk were found to have an impact on the extent of SIS usage, SIS relative advantage has no significant influence on SIS assimilation. In the following sections, each of these constructs is discussed in detail.

9.3.1. The Effect of SIS Compatibility on SIS Assimilation

SIS compatibility was theorised to positively influence the SIS assimilation in data centres. The significant correlation between SIS assimilation and SIS compatibility ($r= 0.496$, $p<0.001$) provides an initial indication that SIS compatibility is closely related to the extent of use and play significant role in explaining the variance in the assimilation of SIS. In addition, 65% of data centre managers agree that SIS use can be facilitated when SIS requirements are compatible with data centre systems and practices. This is consistent with the result from the structural analysis and hypotheses testing in Chapter 8. The significant effect size of SIS compatibility on the model of SIS assimilation ($f^2= 0.100$*), reveals the strength of the relationship between SIS compatibility and the extent of SIS use. In addition, the path coefficient test reveals that SIS compatibility has a positive and significant effect ($\beta= 0.318$, $p <0.001$) on the extent of SIS usage in the data centres. Therefore, hypothesis 2 [*The higher the level of perceived SIS compatibility, the greater the extent of SIS assimilation in data centres*] is supported at a 99% confidence interval.

The finding reveals that the compatibility of SIS with the data centre infrastructure and practice influences the volume of SIS used in data centre and the applications of SIS for managing the facility, cooling, power, and ICT infrastructure. It also influences the intensity of using the SIS to perform various business processes of data centres and the extent of SIS integration. In particular, the level of volume, diversity, and intensity of SIS increases when the technology management requirements of SIS are compatible with the values and norms, and data centre management practices; when the technology is compatible with most components of existing data centre equipment; and when the technical requirements of SIS are similar to the expertise the organisation have developed with other systems.

The infrastructure that make up a particular data centre comprises various equipment (such as servers, racks, network routers and switches, storage drives, and power distribution units), that come from different manufactures (Magoulès and Yu, 2009; Kant, 2009; Mukherjee et al., 2010). Typically, vendors such as IBM, APC, and Siemens develop their own hardware and software in accordance to specific technical standards. Some of these standards are vendor-specific and are not compatible with one another. Likewise, most of the SISs in the market are developed by vendors to exclusively manage each vendor's respective equipment. For example, a SIS developed by IBM is designed based on IBM's technical standards. It can be effective to manage and work on IBM equipment but is incompatible to manage APC equipment. This implies that even if APC's management systems have better features, a data centre might not be able to use an APC system if IBM dominates its hardware infrastructure.

To address SIS compatibility concerns, leading industry players are beginning to introduce standards that can be fitted in new products. For example, the Intelligent Platform Management Interface (IPMI) developed by Intel Corporation allows the monitoring of computer system operation and is supported by more than 200 vendors in the data centre industry.[1] Despite such efforts, the availability of middleware hardware and software that facilitate the compatibly between different systems and the establishment of industry-wide open standards that are required to ensure full interoperability between diverse data centre equipment and sensor-based systems are still at their infancy stage (Magoulès and Yu, 2009; Kant, 2009; Abts, and Felderman, 2012). This implies that compatibility will remain one of the most important factors that could facilitate or restrain the ability of data centres to embrace or extend their usage of SIS.

[1] http://www.intel.com/design/servers/ipmi/adopterlist.htm

The finding of this hypothesis is consistent with the theories of technology use such as DOI (Roger, 1983), and TOE (Tornatzky and Fleischer, 1990) that theorise compatibility as determinant for innovation use. The result also conforms to the findings of Purvis et al.'s (2001) examination of CASE assimilation, Cho and Kim's (2002) study of object-oriented technology, Liao and Lu's (2008) research of continued use of e-learning websites, Lowry's (2002) study on the acceptance of BMS and Hafeez-Baig and Gururajan's (2009) investigation of sensor based healthcare management system. The finding reinforces the importance of compatibility on IT assimilation. It shows that because of data centres' infrastructure diversity, SIS compatibility would continue to have a significant effect on the extent of SIS usage. It also adds to the data centre literature that the compatibility between the equipment populating the different platforms of the data centre and between hardware and software requirements are likely to challenge the effort to modernise data centres (Schulz, 2009; Kant, 2009).

The result has practical implications too. Data centre managers would need to carefully consider the criteria used in the selection of their infrastructure equipment. The criteria should include current and future infrastructure compatibility in general, and the infrastructure interoperability with new IS and SIS in particular. Both hardware and software developers would need to focus on the design of bridging products or systems that facilitate the compatibility between existing infrastructure and new SIS in data centres. Hardware vendors would also need to ensure that their new products adhere to the latest industry standards in respect to the system's interoperability. Finally, leading industry companies and associations (e.g. Gartner, AFCOM, European Data Centre Association etc.) need to take the lead in this area by introducing relevant industry and technical standards that can ensure smooth synchronisation and data exchange between SIS and the equipment in a given data centre.

9.3.2. The Effect of SIS Perceived Risk on SIS Assimilation

Perceived SIS risk was theorised to negatively influence the SIS assimilation. The perceived SIS risk is a construct that has emerged as result of the Exploratory Factor Analysis (EFA) during the instrument validation process. The original indicators that make up the perceived SIS risk construct are perceived SIS uncertainty and SIS complexity. The perceived SIS risk has significant correlation with SIS assimilation ($r= 0.421$, $p<0.001$). In addition, almost half of the respondents reported some sort of complexity issues with SIS technology, SIS use and SIS integration and other technical matters. Further, about 40% of data centre managers were sceptical about the maturity of SIS technology. These statistics provide initial indications about the importance of perceived SIS risk in data centres.

In the same vein, the result from the structural analysis and hypotheses testing in chapter 8 shows that perceived SIS risk has a significant effect size ($f^2= 0.026$*) on the research model. The result of effect size test implies that there is significant relationship between perceived SIS risk and the assimilation of SIS. In addition, perceived SIS risk has a negative and significant path coefficient ($\beta=0.284$; $p<0.001$) on the extent of SIS usage in the data centres (*note: the scores of this construct were reversed for consistency and thus positive values denotes to negative influence*). Hence, hypotheses 3 and 4 (consolidated into one hypothesis) [*The higher the level of perceived SIS risk, the less the extent of SIS assimilation in data centres*] is supported at a 99% confidence interval.

The finding of the hypothesis test conforms to the theories of technology use about the risk of technology such as complexity, trialability and observability (Roger, 1983; Fichman and Kemerer, 1993), and perceived uncertainty (Son et al., 2005). Naturally, risk-related factors have negative association with innovation use. As Fichman and Kemerer (1993) argue, trialability and observability are both related to the risk of a system. Whereas trialability and observability aim to reduce the risk of using a system, complexity and perceived uncertainty have an inverse relationship. This suggests that although some of these risks play an opposite role in the assimilation process, they all have a common nature, which is the risk of technology. The finding is also consistent with Cho and Kim's (2002) study of organisational assimilation of object-oriented technology, Sharma and Yetton's (2007) study of IS implementation success, and Banerjee and Ma's (2011) study of B2B e-market assimilation.

For instance, Cho and Kim (2002) found that the degree of technology maturity affects the extent of use of object-oriented technology. They contend that immaturity of the technology, which leads to the uncertainty about a system, can be a significant risk factor that can inhibit the assimilation of technology. Their findings led to the conclusion that the effect of maturity perception could play dual role; that is, either higher assimilation level is determined by high maturity perception (lower risk perception), or higher assimilation of technology increases the beliefs that the technology is more mature. Banerjee and Ma (2011) found that perceived risk significantly affect firms' ability to assimilate the B2B e-market and to utilise various B2B e-market transactional features.

Likewise, the finding in the current study reveals that perceived SIS risk poses a significant barrier that affects the volume of SIS used in the data centre, the diversity of SIS application within the different functional areas, the intensity of using the various functionalities of SIS to perform various business process of data centre, and the intensity of integration SIS with other systems. In particular, the finding suggests that when SIS are perceived as immature technology; when other technologies are perceived as more promising than SIS technology; when the integration of SIS into data centre infrastructure is perceived as a complex process; and when there are difficulties to understand SIS requirements from a technical perspective, the level of volume, diversity, use intensity and integration intensity of SIS is reduced.

A number of studies have highlighted the complexity of integrating sensors and SIS within the context of data centres (e.g. Raghavendra et al., 2008; Kant, 2009; Watson et al., 2009). Typically, the infrastructure of data centres can be divided into four functional areas: facility, cooling, power and computing systems. Each equipment operating in those four areas are developed in accordance to different technical standards. Therefore, SIS developers tend to design several information management systems that are able to collect sensor data and manage each area separately. Although most of the facility and cooling equipment are standardised, the further integration of power and computing systems to achieve the same objective is a more complex process. This is due to differences in terms of technical specifications, design, objective, and functionalities of the existing infrastructure (Magoulès and Yu, 2009; Kant, 2009). For instance, some of the sensor readings of power supply units that are based on a set number of cycles and phases are not in sync with the speed of cycle changes in CPU sensors. This causes a significant lag and challenges the accurate control of power, cooling and computing systems (Kant, 2009). Therefore, although vendors, developers and researchers are making efforts to find solutions that can resolve these issues, the complexity of integration remains one of the challenges to data centres (Kant, 2009; Watson et al., 2009).

Another dimension of perceived SIS risk is IT professionals or managers' lack of detailed knowledge about the various features and requirements of SIS. Higher knowledge about a system can help to overcome technology complexity barriers (Attewell, 1992; Sharma and Yetton, 2007). Data centres' lack of understanding about the technical, managerial and operational issues poses a barrier to achieving the desired objective of applying a technology (Tschudi et al., 2004). In the current study, only 47% of managers have reported to have good knowledge about the features, advance capabilities, application and technical issues of SIS. Lack of SIS knowledge may influence the data centre managers' risk perception and restrain the extension of SIS applications in the data centres.

The finding of this hypothesis provide empirical support within the data centre context that perceived SIS risk could pose a significant barrier to the extent of SIS usage due to the complexity of data centre infrastructure integration or lack of detailed SIS knowledge. The finding also adds to the literature on the effect of knowledge barriers on technology use (Fichman and Kemerer, 1997; Ravichandran, 2005; Sharma and Yetton, 2007) since it supports that the depth of SIS knowledge may influence the risk perception of SIS.

Further, the finding implies that vendors and developers of SIS would need to work on improving the ease of integration of SIS with data centre platforms. This will help to enhance confidence in SIS performance and reduce the perceived risk of SIS usage. Data centre managers would also need to take positive action and build their know-how of the latest IS developments that are applicable to their operation. Due to the sensitivity of data centre business, it is understandable that the majority of data centre managers tend to be risk averse when it comes to making decisions to apply newly developed systems. The collaboration between data centre managers and developers would be a good starting point to reduce such fears of data centre managers. Moreover, data centre professional associations would need to play a more effective role in the promotion of SIS applications as well as in the dissemination of SIS knowledge about the features and capabilities of SIS for data centre operations management. This effort could help to reduce the level of SIS risk perception.

9.3.3. The Effect of SIS Relative Advantage on SIS Assimilation

SIS relative advantage was hypothesised to positively influence SIS assimilation in data centres. There is significant correlation between the SIS assimilation and relative advantage ($r= 0.356$, $p<0.001$), which provides an initial indication that relative advantage is associated with SIS assimilation. Further, 83% of data centre managers perceive that SIS has more advantages compared to other systems and technologies. In particular:

- 82% of data centre managers perceive that SIS provide improved functionality to manage data centre facility and assets
- 86% perceive that SIS have more capabilities to enhance the efficiency of cooling system
- 93% perceive that SIS provide better visibility of the power activities in data centre
- 68% perceive that SIS provide a more productive way of performing IT operations.

However, contrary to the correlation and descriptive analysis results, SIS relative advantage has no statistically significant effect on SIS assimilation. Firstly, the effect size test (f^2) shows that SIS relative advantage has insignificant effect ($f^2= 0.003$). This suggests that there is a weak relationship between the relative advantage and extent of use. Secondly, the path coefficients test reveals that SIS relative advantage has a weak ($\beta= 0.063$) and insignificant (p 0.45) effect on the extent of SIS usage. Hence, hypothesis 1 [*The higher the level of the perceived SIS relative advantage, the greater the extent of SIS assimilation in data centres*] is rejected at a 95% confidence interval. This finding appears to contradict the theories of technology use such as DOI (Roger, 1983), and TOE (Tornatzky and Fleischer, 1990). It is not also consistent with most of the empirical studies (see Table 9.3) that theorise relative advantage as determinant of innovation use. Thus, it is important to investigate the characteristics of this construct.

As a starting point, the SIS literature (sections 2.5 and 2.6) reveals that SIS provides advanced capabilities to gather real-time information, perform comprehensive monitoring about the activities of an organisation and undertake information analysis about the objects under observation (Chong and Kumar, 2003; Sharma et al., 2005; Fleming, 2008). The literature from section 2.3 shows that data centre industry has also promotes and acknowledges these unique features (Gartner, 2008; Kant, 2009; European Commission, 2010). For example, Gartner (2008) advocates the application of sensors in areas where temperature problems are suspected. They also suggest that this minimal investment in instrumentation provides great visibility of power and cooling activities as well as advanced analytical capabilities. Kant (2009) discusses the essential role of sensors in monitoring power, temperature, and current of modern processors as well as the load of power supply units. He also highlights the fundamental role of temperature, humidity, and fan speed sensors in achieving successful implementation of localised cooling solutions such as direct cooling (built into racks).

Further, the results from the exploratory case study of the five data centres (see chapter 3) indicated that the perception of data centre managers towards the unique advantages of SIS influence their decision to use and the future applications of SIS. All the above premises justify the hypothesis that relative advantage can influence the SIS use. Yet, the hypothesis was not supported in this study.

Although the result is unexpected, it is not unique since some previous studies (see Table 9.3) have also reported similar findings. For example, in Grover and Teng's (1994) investigation of the implementation success of customer-based inter-organisational systems (CIOS), relative advantage has no significant influence on the extent of use and has opposite influence on the perceived usage. They attributed this unexpected result to the unique nature of the CIOS, that is, the system is implemented within another organisation and therefore the influence of relative advantage, as perceptions of organisational members, on the sponsoring organisation at the customer site might be weak. There could be four possible explanations for the mixed result of the literature and the current study's finding about relative advantage.

Table 9.3: A summary of selected IS studies on relative advantage and IS assimilation

.Author	Journal title	Dependant	Beta	P value
Grover and Teng, 1994	Information Systems Journal	Extent of CIOS usage(4): Perceived Usage Transaction Handled by the systems Customers with access to the systems Active user accessing the systems	 -0.042 0.196 0.14 0.085	 N.S N.S N.S N.S
Cho and Kim, 2002	Journal of Management information Systems	Organizational Assimilation of object-oriented technology	0.087	N.S
Hsu et al., 2006	International Journal of Electronic Commerce	E-Business Use (2): Diversity Volume	 0.210 0.249	 ** **
Liao and Lu, 2008	Computers and Education	continued use of e-learning websites	0.470	**
Wu and Chuang, 2009	Electronic Commerce Research and Applications	e-SCM Assimilation	0.26	*

Firstly, the relative advantage construct tends to influence the decision to adopt SIS more than the extent of SIS usage. This is because assimilation and adoption are two different phases of technology innovation. While assimilation refers to the acquisition, fruition, full utilisation, and institutionalisation of a technology (Meyer and Goes, 1988), the adoption of innovation implies the first implementation and initial success of a system (Damanpour, 1991; Agarwal et al., 1997). A meta-analysis of organisational use of technology has found that factors influencing the initiation stage could have inverse conditions on the continued use (Damanpour, 1991b). In addition, the perceptions of organisational members in the adoption stage about the innovation characteristics such as its relative advantage, may not relate significantly to the post-adoption variables (Grover and Teng, 1994). This means that once a system is already adopted and in use, the influence of relative advantage on the extent of use may deteriorate (Adams et al., 1992). This is consistent with Wu and Chuang's (2009) conclusion that technological factors including relative advantage, complexity, ability to provide security, are more important indicators for the adoption phase than the assimilation phase.

Secondly, the use of sensors, either stand-alone sensors devices or integrated with BMS is a common practice in data centres (Davis et al., 2006). In general, SIS can be applied to manage a data centre's facility, cooling, power and ICT infrastructure. Out of these four areas, every data centre has to use some sort of SIS to manage facility systems (e.g. lights, fire, safety) and cooling systems (e.g. heating, ventilation, and air conditioning) (Moore et al., 2004; Baird and Mohseni, 2008). However, the application of SIS for the management of power systems and ICT infrastructure appears to be limited (Watson et al., 2009). There is also a variation among data centres in the extent of SIS use in all the four functional areas (e.g. Raghavendra et al., 2008; Berl et al., 2010; Liu and Terzis, 2012). Therefore, since two out of the four areas of SIS application in data centres are fundamental requirements for operating a data centre, extending SIS use to the other two areas is likely to be influenced by other technological factors such as compatibility and complexity rather than the relative advantage of SIS.

Thirdly, the effect of relative advantage on SIS assimilation can be influenced by the characteristics of the organisation. Cho and Kim (2002) argue that depending on the research context, researchers may end up with different findings about the actual effect of relative advantage on the extent of use. The characteristics of the organisation such as industry, structure, strategy and infrastructure play an important role in facilitating the continued use of innovation (Damanpour, 1991b). The difference in the nature of service or technical infrastructure of an organisation would unequally affect the antecedent factors of innovation as well as the strength of their influence in each organisation context (Daft, 1989; Zaltman et al., 1973). In this vein, the nature of the data centre operation could have an influence on the importance of relative advantage and its strength on the SIS assimilation. Data centres are mission critical facilities that play a significant role in supplying sustainable computation requirements for organisations. Due to the sensitivity of the infrastructure to heat, humidly and water and due to the importance of maintaining security and privacy of the stored data, data centres require a very high level of security and safety standards (Davis et al., 2006).The nature of infrastructure sensitivity in the data centres, and the unique ability of sensors to sense heat behaviours, water leakage, fire, and property breaches might have made SIS become well recognised and their relative advantage to have no additional effect on the assimilation of SIS.

Fourthly, the dominance of innovation affects the importance of relative advantage. An innovation is said to be dominant when different alternative technologies are de-selected until one technology becomes standard (Suarez, 2004). Cho and Kim (2002), after finding an insignificant relationship between the relative advantage and object-oriented technology assimilation, argue that in cases where a particular technology is perceived to be dominant, organisations tend to focus on effective and efficient use of a system rather its relative advantage. In the context of this research, BMS is one of the commonly used SIS for managing the facilities' infrastructure. BMS was first applied in large buildings in the early 1960s for the purpose of monitoring and managing large and distance facilities (Levermore, 2000). Afterwards, the BMS became one of the standard systems for managing the facilities' infrastructure and for monitoring and controlling safety, security and cooling systems (Shabha, 2006). Likewise, in the current study, BMS is used by 62% of the surveyed data centres. In such circumstances, the primary consideration for data centre managers would not likely be on the relative advantage of SIS such as BMS. Instead, it is on how data centres could apply the system to manage different functional areas; how to utilise its capabilities effectively to perform the day-to-day business process; and how to extend its capabilities beyond the traditional use. Thus, data centres might focus on other factors such as integration, customisation, compatibility, system retrofit, or SIS knowledge and skills rather than on SIS relative advantage.

In summary, the result of the testing of this hypothesis aligns with the findings of Cho and Kim (2002) and Grover and Teng (1994). It is also accordant with Wu and Chuang's (2009) argument that relative advantage has low importance in the assimilation stage. The finding implies that high perceptions of SIS relative advantage do not necessarily extend the volume, diversity, use intensity and integration intensity of SIS. Developers of SIS can use this finding to gain an understanding of the important SIS characteristics in the successful SIS implementation and focus more on other facilitating or inhibiting factors in their attempt to widen the SIS market. Nevertheless, despite the above explanations, because this study is the first to test the influence of technological factors on the assimilation of SIS in data centres, further tests need to be undertaken before removing relative advantage from the nomological net of antecedent factors that explain SIS assimilation.

9.4. Organisational Factors and SIS Assimilation

Three organisational factors—top management support, Green IT orientation and data centre energy governance—were identified to influence SIS assimilation. A summary showing the correlation and standardised effect of the three organisational factors on SIS assimilation and their significance are displayed in Table 9.4. The Green IT/IS orientation construct was found to have a positive impact on the extent of SIS usage, whereas data centre energy governance was found to have a negative impact on the extent of SIS usage, contrary to the research hypothesis. Top management support had no significant influence of SIS assimilation.

Table 9.4: The correlation, path coefficients and magnitude for organisational factors

Constructs	**Correlation**	**Beta**	**P value**	**f^2**
Top Management Support	**0.272*** **	0.082	n.s	0.006
Green IT/IS Orientation	**0.421*** **	**0.249**	***	0.052*
Data centre Energy Governance	0.003	**–0.169**	**	0.035*

p<0.05, p<0.01 **, p<0.001 **

9.4.1. The Effect of Green IT/IS Orientation on SIS Assimilation

Green IT/IS orientation was hypothesised to positively influence SIS assimilation. Green IT orientation captures the existence of environmental stewardship policies such as policies to retrofit or replace inefficient systems and techniques into more efficient ones. Fifty per cent of participating data centres currently have Green IT policies, and 34% are planning to adopt them in the near future, which can foster the use of SIS. The significant correlation between SIS assimilation and Green IT orientation ($r= 0.421$, $p<0.001$) indicates that Green IT orientation plays a significant role in explaining the variance in the assimilation of SIS. Further, the effect size test shows that Green IT orientation has a significant effect size ($f^2=$ 0.052*) on the model of SIS assimilation. Likewise, Green IT orientation has a positive and significant path coefficient ($\beta= 0.249$, $p <0.001$) on the extent of SIS usage in the data centres. Therefore, hypothesis 6 [*SIS are likely to be assimilated to a greater extent in organisations that have developed Green IT/IS orientation*] is supported at a 99% confidence interval.

The result of the hypothesis is consistent with the theories on the environmental sustainability of technology (Melville, 2010) and NRBV (Hart, 1995) that theorise environmental considerations to influence the use or misuse of technology innovation. Further, the result is consistent with findings of Green IT and Green IS studies such as Chen et al. (2008), Molla et al. (2009), and Schmidt et al. (2010). For instance, Chen et al. (2008) report that IS can play important role in facilitating the organisations' effort to develop ecological sustainability under different institutional pressures. Molla et al. (2009) report that organisations pay significant attention to the Green IT policy and practice as part of their effort for managing IT to pursue eco-efficiency and eco-sustainability objectives. Schmidt et al. (2010) show that Green IT policies and activities can help organisations to achieve their objectives of efficient internal operations, market competitiveness and reputational management.

The literature on environmental sustainability perspective suggests that organisations with activities that could cause direct environmental impact are more likely to have a greater use of clean and environmentally friendly systems (Sharma, 2000; Aragón-Correa, 2000). Thus, such organisations tend to embrace environmental stewardship policies that incorporate the voice of the natural environment into product purchase, design and development processes (Hart, 1995). Data centres are one of the largest energy consumers, accounting for 1.1% to 1.5% of total global energy use (Koomey, 2011) and significant amount of global CO_2 emissions (EPA, 2007). With energy efficiency and environmental performance of data centres being critical issues for current and future of data centre business (Schulz, 2009), developing Green IT strategies in the form of policies to retrofit or replace inefficient systems and techniques into more efficient ones has become a key consideration in data centre management practice.

Consequently, a Green IT/IS orientation increases the use of SIS as SIS can be regarded as an example of Green IS (Watson et al., 2010). This is because SIS can reduce the energy consumption and the environmental impact of data centres (Moore et al., 2004; Berl et al., 2010; Zimmermann et al., 2012). This implies that SIS usage could have a direct (e.g. by reducing the energy consumption through monitoring and automation of business functions) or indirect (by facilitating the decision maker in evaluating the environmental or economic performance of data centre equipment) contribution. Therefore, the existence of Green IT policies can facilitate the level of SIS usage in the data centres.

The result adds to the literature about the effect of Green IT policies on green technology adoption because it shows that existing Green IT policies of an organisation can facilitate the success of SIS application, which is regarded as one of the Green IS solutions. While the finding of this hypothesis adds to studies of green technology adoption, it is the first to empirically investigate the influence of Green IT orientation on IS assimilation. It suggests that embracing Green IT policies and Green IT technology is important for the continuity of data centre business. Therefore, data centre managers, CIOs, environmental officers and CEOs can increase their organisation's capability to utilise and integrate the latest IS technologies in data centres through the implementation of effective policies that improve the overall efficiency and sustainability of infrastructure operations.

9.4.2. The Effect of Top Management Support on SIS Assimilation

Top management support was theorised to positively influence SIS assimilation. There is a reasonable degree of association between SIS assimilation and top management support ($r= 0.272$, $p<0.001$). Further, 57% of respondents believe that top management provides support for the business needs of data centres and for establishing strategies for improving sustainability. In particular, top management discusses the data centre issues as a priority in 69% of data centres and articulates a vision to improve the operations of 50% of data centre through use of software. In 59% of data centres, top management establishes goals for the sustainability and in 50%, it sets standards for the sustainability.

Nevertheless, top management support has insignificant effect size ($f^2= 0.006$) on the research model and a weak ($\beta= 0.082$) and insignificant ($p=0.249$) path coefficient on the extent of SIS usage. This implies that the top management support is not affecting the assimilation of SIS. Further, the result from the organisational context-specific analysis shows that top management support has insignificant effect ($B= 0.062$, $p =.38$) on the extent of SIS usage in the data centres (see Chapter 8). Hence, hypothesis 5 *[The higher the level of top management support for improving data centre operation, the greater the extent of SIS assimilation in data centres]* is rejected at a 95% confidence interval.

The finding of the top management SIS assimilation hypothesis does not conform to the theories and research of technology use such as IS implementation success (Kwon and Zmud, 1987), leaders and the workforce perspective (Fichman, 1992), and managerial perspective (Damanpour, 1991). It is also inconsistent with the finding of IS studies (Chatterjee et al., 2002; Liang et al., 2007; Rai et al., 2009) that reported top management support as a significant determinant for innovation use. Nevertheless, some previous studies (see Table 9.5) have also reported a mixed result about the role of top management support.

Table 9.5: A summary of selected IS studies on top management support and IS assimilation

Author	Journal Title	Dependant	Beta	P value
Grover and Teng, 1994	Information Systems Journal	Extent of CIOS usage(4):		
		Perceived Usage	0.094	N.S
		Transaction Handled by systems	0.12	N.S
		Customers with access to systems	0.223	*
		Active user accessing the systems	-0.125	N.S
Chatterjee et al., 2002	MIS Quarterly	Web technologies Assimilation	0.39	*
Liang et al., 2007	MIS Quarterly	ERP Assimilation	0.476	*
Rai et al., 2009	Journal of Management Information Systems	EPI Assimilation	0.20	***

The literature on data centres reveals that collaboration and support by senior management is a requirement for the successful adoption of innovative technologies as well as for increasing the awareness of data centre owners and professionals (Brill, 2007; Loper and Parr, 2007; Raghavendra et al., 2008). In addition, the initial finding from the exploratory case studies indicated that the participation of top management is important to disseminate the awareness and acceptance of new technologies (including SIS). Nevertheless, the hypothesis that top management support can facilitate the SIS use was not supported in this study. This could be due to (a) the attention of top management to external-based systems, (b) the nature of data centre under investigation, and (c) top management importance in the initial investment rather than routine use. Each of these points is elaborated next.

In terms of attention of top management, the success of technology assimilation can be influenced by the priority given to a particular technology. For example, in Grover and Teng's (1994) investigation of the implementation success of CIOS, top management support has no significant influence on the extent of CIOs' perceived usage and CIOs' use of the system to handle transactions. Grover and Teng (1994) explain that active top management support implies priority for a system, which translates into an increased funding and widespread implementation. They contend that external-based systems that have direct connections to external clients and customers represent higher priority for top management. Similarly, because data centres are internal operations and SIS are internally focused systems within data centres, the top management may focus its attention to external systems (e.g. customer and supplier relationship management systems), which have perceived higher priority.

As to the nature of data centres, a data centre can be an IS unit within organisations (e.g. in a university or bank) (corporate data centre), or an independent IT company (fully managed or co-located data centre). The IS unit data centre is typically a single-tenant serving the data processing needs of a single organisation. Conversely, the IT company data centre is a multi-tenant business entity that either can be located at a single site or be geographically distributed over several sites to provide data centre hosting services for several organisations (Alger, 2005).

A clear distinction between the two groups is that each has different organisational structures and the data centre operations has a different impact on the business performance. For instance, in IS unit data centres, a data centre manager or IT operation manager is at the middle management level, whereas the CIO, VP of IT and/or CEO represent the top management level. Thus, in the case of IS unit data centres, data centres might not be under pressure by the top management to improve their performance. As such, any decline in the performance of data centre is likely to be handled by the middle management level, which has a better understanding of data centre technical matters. Therefore, the support of top management is not likely to be important for technology assimilation in the IS units data centres. This explanation is in line with Majchrzake et al.'s (2000) research, which reveals that top management support to successfully implement IS innovations is required when the top management believes that there is a critical decline in the performance that could affect business continuity.

However, for IT company data centres, which have a different organisational structure, top management support might have significant influence. To test this explanation statistically, two alternative models were evaluated separately in PLS for both IS units data centres (single tenant) and IT company data centres (multi-tenant). The results show that top management support construct has a weak ($\beta=0.005$) and insignificant ($p=0.959$) effect on SIS assimilation in IS units data centres, but a significant effect ($\beta=.177$, $p<0.05$) on the SIS assimilation for the IT company data centres (see Appendix 9a). This implies that top management support becomes important in SIS assimilation, when a data centre is an independent business (that is multi-tenant) rather than an IS unit (that is single tenant).

As regards to the third explanation, top management support is likely to be more important at the time of investment decision (Prescott and Conger, 1995). Once that decision is made, top management expects the system to be used and typically handled by the middle level management, and shifts its attention to other areas. This is particularly the case in single-tenant data centres where top management support is more important for the adoption than the assimilation stage. This is consistent with the conclusion of Prescott and Conger (1995) and Wynekoop (1992), who advocate that top management support appears to facilitate the decision to adopt, but not necessarily, the decision to use technology in IS units The result is also in line with Rai et al.'s (2009) conclusion that the biggest increase in top management support can be observed between initial evaluation and limited deployment period. This is because the period involves transition and change in work structures of an organisation.

In summary, the result of the testing of this hypothesis aligns with the findings of Grover and Teng (1994), which shows that top management support has a weak effect on the extent of use. It also supports Rai et al.'s (2009) argument that top management support has low importance in the assimilation stage and Wynekoop's (1992) conclusion that top management support is not likely to be important for technology use in IS units. The finding provides evidence regarding how the top management support construct behaves within the data centre context. Top management support facilitates the volume, diversity and intensity of SIS in multi-tenant data centres. Developers of SIS can use this finding to gain an understanding about the role of top management support in technology innovation, which determines the financial resource of organisations that are required to facilitate the purchase of the developers' products.

Overall, despite the above explanations about the weak effect of top management support on SIS assimilation, and because this study is the first to investigate the role of top management in the process of SIS assimilation in data centres, further tests need to be undertaken before excluding top management support from the model of SIS assimilation.

9.4.3. The Effect of Data Centre Energy Governance on SIS Assimilation

Data centre energy governance was hypothesised to positively influence SIS assimilation. The data centre energy governance captures the existence of energy policies for data centre activities and data centre managers energy performance. As such, these policies and procedures are expected to support the usage of SIS. In particular, the current study reveals that:

- 50% of surveyed data centres receive a separate energy bill for their data centre operations
- 62% embed the energy bill of data centre operation into the data centre budget
- 72% have targets to reduce the energy consumption of data centre operations
- 62% have a clear organisational policy for enhancing the visibility of data centre energy consumption to establish better transparency.

The correlation between SIS assimilation and energy governance was insignificant ($r = 0.003$, $p = 0.96$). Nevertheless, the result from the structural analysis and hypotheses testing in Chapter 8 reveals that data centre energy governance has a significant effect size on the research model ($f^2 = 0.035^*$) and its path coefficient turned out to have a significant but negative ($\beta = -0.169$; $p < 0.01$) relationship with the extent of SIS usage. Further, the result from the organisational context-specific analysis (which only evaluates the effect of the three organisational variables on the SIS assimilation model), shows that the data centre energy governance construct has a positive but insignificant effect ($\beta = 0.003$, $p = 0.98$) on the extent of SIS usage in the data centres. Hence, hypothesis 7 *[SIS are likely to be* *assimilated to a greater extent in organisations that have developed data centre energy governance policies]* was not supported.

The finding does not conform to the conventional wisdom that higher energy governance fosters the use of SIS (Loper and Parr, 2007). It is also not consistent with Molla and Cooper's (2010) study on Green IT readiness, which suggests that governance is one of the fundamental pillars that are required to help organisations maturity for green technology adoption. It is not also in support of with Karanasios et al.'s (2010) study, which hypothesised that the adoption of green data centre best practices can be influenced by the organisation's ability to govern its energy activities. Thus, it was important to investigate the characteristics of this construct. The data centre literature reveals that as organisations' demand for data processing is growing, and energy prices and data centre energy consumption is increasing (Schulz, 2009; Zheng and Cai, 2011), the governance of energy activities in the data centres become highly important (Loper and Parr, 2007) for improving both economic as well as environmental performance (Spafford, 2008). This implies that establishing policies to govern energy usage can facilitate the use of SIS because SIS provides energy measurement and tracking. Further, the preliminary finding from the exploratory study of five data centres (see Chapter 3) reveals that the existence of established policies that define the accountability and responsibility of energy consumption enhances the transparency of energy activities and can facilitate the level of volume, diversity and intensity of SIS. Both the literature and case study findings suggest that data centre energy governance can be a determinant for SIS assimilation. Yet, the hypothesis was not supported.

The unexpected effect of data centre energy governance on SIS assimilation could be due to (a) the immaturity of existing policies to govern energy activities, or (b) the nature of managerial structure of the data centres under investigation.

In respect to the immaturity of existing policies, the descriptive analysis shows that only 50% of data centres in the sample receive a separate energy bill for their operations. Forty-two per cent do not measure the particular consumption of the data centres. This implies that although incentives and policies for enhancing and governing the energy consumption do exist, how these incentives and policies have actually enhanced the data centre manager's energy performance and reduced the overall energy consumption are not known or benchmarked against the returned value of business. Separating the measurement of energy consumption of data centre activities from the rest of organisational activities (Loper and Parr, 2007), or separating the consumption of each tenant (in multi- tenant data centres) is one important step to establishing clear responsibility for energy performance. Thus, the lack of such policies would likely weaken the governance over the energy activities of data centres and hence might be one of the possible explanations for the negative relationship between data centre energy governance construct and SIS assimilation.

The energy governance factor might behave differently depending on the organisational structure of the data centres. For instance, in single-tenant data centres, the data centre represents an IS department of an organisation. Governing the energy consumption of the data centre operation has never been a common practice and is only being recently introduced as part of Green IT initiatives. In multi-tenant data centres, the data centre represents an organisation in its own right. Energy governance of the data centre operation is an essential requirement. This implies that the influence of governing the energy performance of data centre activities on SIS assimilation is likely to be more important in single-tenant data centres than in multi-tenant data centres.

To test this explanation, three alternative models were evaluated separately in PLS for corporate (single-tenant), and managed and co-located (multi-tenant) data centres. The reason for separating multi-tenant data centres into managed and co-located in the test was because the managers of managed data centres are responsible for all the energy activities of facility, cooling and ICT, whereas managers of co-located facilities are only responsible for the facility and cooling operations. However, energy performance in co-located data centres depends on the performance of the ICT operations that are operated by the tenants (clients), and therefore they can be in different conditions. The results of the three tests are shown in Appendix 9b.

The results show that the data centre energy governance construct has a weak (β=0.044) and insignificant (p=0.614) effect on SIS assimilation in co-located data centres as well as in managed data centres (β=.188, p=0.07), whereas data centre energy governance has a significant effect (β =.333, $p<0.01$) on SIS assimilation in the corporate data centres. This support the argument that governance of data centre energy through the assimilation of SIS works better for corporate data centres because it serves the requirement of the top management in respect to the governance of the data centre energy activities as well as the performance of data centre managers.

In summary, the finding of the testing of this hypothesis shows that the current practice of data centre energy governance is negatively related to SIS assimilation However, in order to understand the role of energy governance in the success of SIS assimilation, it is important to take into account the nature of the managerial structure of an organisation. That is because energy governance in an IS unit data centres is different from energy governance in an IT company data centre. Overall, the current study is the first attempt to understand the effect of energy governance on SIS use in data centres. Due to the importance of energy to data centres and due to the growing need for effective energy governance, the role of energy governance as an antecedent factor for SIS assimilation requires further investigations before making any conclusion about the actual role of energy governance in the process of SIS assimilation.

9.5. Institutional Factors and SIS Assimilation

In this study, the two institutional factors of coercive pressure and normative pressure were hypothesised to form part of the explanation to differences in the volume, diversity and intensity of SIS use. Further, institutional factors were also hypothesised to indirectly influence SIS assimilation through organisational context including top management support, Green IT/IS orientation and data centre energy governance. The correlations and standardised effect of the two institutional factors on the endogenous variables and their p-values are displayed in Table 9.6. Overall, whereas normative pressure was found to have direct and indirect positive impact on the extent of SIS usage, coercive pressure has failed to influence the SIS assimilation directly, but significantly influences the organisational context for SIS assimilation.

Table 9.6: The correlation, path coefficients and magnitude for institutional factors

	Direct effect		**Indirect effect**							
	SIS Assimilation		SIS Assimilation		Top management support		Green IT/IS orientation		Data centre energy governance	
Constructs	Corr.	Beta	t-value	Beta	Corr.	Beta	Corr.	Beta	Corr.	Beta
coercive pressure	0.13	0.008	1.55	0.091	0.358***	0.360***	0.279***	0.290***	0.246***	0.256***
normative pressure	.383***	0.191**	4.215	0.249***	0.445***	0.447***	0.556***	0.560***	0.326***	0.327***

p<0.05, p<0.01 **, p<0.001 **

9.5.1. The Effect of Normative Pressure

9.5.1.1. Direct effect

The study hypothesised that normative pressure has positive and direct influence on SIS assimilation. There is a significant association between SIS assimilation and normative pressure (r=0.383, p< 0.001). On average, 35% of respondents indicated that institutional norms and peer data centre practice drive the decision to use SIS. In particular, the decision to use SIS is influenced by SIS usage of external and/or internal clients (21%), SIS usage by other data centres (32%), participation in professional and business bodies that promote and disseminate information on SIS (45%), and green data centre certification (41%). In addition, the test of effect size (f^2) (see Chapter 8) reveals that normative pressure has a significant effect on SIS assimilation (f^2=0.037*). Likewise, normative pressure was found to have a significant and positive effect on SIS assimilation (β= 0.191, p <0.01). Further, the findings from the institutional context-specific analysis from Chapter 8 reveals that normative pressure has a significant effect (β= 0.396, p <0.001) on the volume, diversity and intensity of SIS usage in the data centres. Therefore, hypothesis 9a *[normative pressures will have a positive influence on the assimilation of SIS in the data centre]* was supported at a 99% confidence interval.

This finding is consistent with the institutional theory (DiMaggio and Powel, 1983) that theorises the use of innovation to be influenced by normative pressure. It is also in line with empirical studies (e.g. Liang et al., 2007; Kouki et al., 2010) that have investigated the effect of normative pressure on technology use. For example, Liang et al. (2007) investigated the effect of normative pressure on ERP assimilation. Their findings indicate that the normative pressure construct reveals a significant direct effect to the ERP assimilation. Kouki et al.’s (2010) study identifies normative forces as one of the main external factors that can drive organisations in both developed and developing countries to use ERP systems. It is also consistent with Chen et al.’s (2011) finding that normative forces influence the adoption of green policies such as to install software for pollution prevention, product stewardship and sustainable development.

9.5.1.2. Indirect effect through organisational context

Normative pressure was also theorised to have an indirect and positive effect on the assimilation of SIS in the data centre through top management support, Green IT orientation and data centre energy governance constructs. The correlations between normative pressure and the three organisational factors of top management support (r= 0.358, p <0.001), Green IT/IS orientation (r=0.279, p <0.001), and data centre energy governance (r=0.246, p <0.001) were significant. In addition, the test of effect size (f^2) reveals that normative pressure has a significant effect on top management commitment to support green initiatives, organisation’s Green IT/IS orientation and data centre energy governance (f^2= 0.055*; 0.198**; 0.045*) respectively. Likewise, the test of path coefficient reveals that there is significant positive effect of normative pressure on the top management support (β= 0.447, p <0.001), Green IT/IS orientation (β=0.560, p <0.001) and data centre energy governance (β=0.330, p <0.001). Further, normative pressure was found to have a significant and positive ‘indirect effect’ on SIS assimilation through the three organisational factors (β= 0.249 p <0.001). Therefore, hypothesis 9b *[Organisational context (that is top management support, green IT/IS orientation and data centre energy governance) mediates the influence of normative pressure on SIS assimilation]* was supported at a 99% confidence interval.

These findings are in line with empirical studies and theoretical discussion about the mediating role of top management (Reich and Benbasat, 1990), formal monitoring of organisational progress (Garrity, 1963), organisational incentives (Bhattacherjee ,1996), and human agency (e.g. middle level managers, and operational level knowledge workers) (Liang et al., 2007) within the institutional contexts to explain variation in the level of technology use within organisations.

The data centre literature accentuates the importance of industry best practices and standards, and peer data centres in driving the decision to use SIS (Loper and Parr, 2007; Kant, 2009; European Commission 2010). As improving operation cost, energy performance and environmental footprint of data centres become a must for business continuity, leading professional associations and consulting organisations within the data centres industry started to push for greater utilisation of SIS to address these concerns (Greenberg et al., 2006; Gartner, 2008).

SIS-enabled best practices can shape organisational directions and preferences in several ways. Researchers assert that best practices that are promoted and recognised by respected and leading professional industry institutions become standards and benchmark for success (Greenberg et al., 2006; Schulz, 2009; European Commission, 2010). As data centre best practices become common at the industry, or institutional level, they become a source of much of the institutional pressure on an organisation (Liang et al., 2007). This implies that institutional norms about SIS and level of SIS success stories from peer data centres can shape the organisational context for SIS assimilation, and foster and guide data centres managers in making decisions about when and how to improve existing business processes through SIS.

Moreover, in their investigation for the antecedents to Greening Data Centres, Karanasios et al. (2010) found that institutional pressure motivates the decisions to adopt green data centre best practices. As SIS are one of best practices to monitor and improve the energy and environmental performance, it can be considered one of the green data centre best practices and energy governance that is guided by external forces.

In summary, the results of testing the normative pressures hypotheses provide empirical support for the direct and indirect facilitating role of normative pressures in the process of SIS assimilation. As to the direct effect, the findings suggest that green data centre certification and participation in professional, trade and business bodies that promote and disseminate information on SIS adoption are more likely to be the source of normative pressure. This implies that SIS are being recognised by the data centres industry as one of the best practices that help data centre in their green effort. Therefore, it is likely that data centres seeking green practice recognition receive higher level of normative pressure to use SIS.

However, from an indirect effect perspective, normative pressure was fully mediated by the organisational factors. Therefore, it can also implied that as the portion of data centre managers that perceive normative pressure from professional engagement and green data centre certification increases, the use of SIS by external and/or internal clients as well as the use by other data centres increase creating further institutional driver for the use of SIS. This suggests that normative pressure can play double role in SIS assimilation and its aggregative effect can be increased by organisation aspects. The finding provide data centres and organisations that have more focus on sustainability and environmentally friendly actions with more understanding about how institutional norms shape their choice of data centre best practices.

9.5.2. The Effect of Coercive Pressure

9.5.2.1. Direct effect

Coercive pressure was theorised to have both a direct and an indirect positive effect on SIS assimilation. The results from descriptive statistics shows that current and/or foreseeable regulations for reducing the energy consumption and reporting the environmental footprint were perceived to have an influence on the decision to adopt SIS in 46% and 50% of the sample respectively. In addition, whereas 14% of respondents perceived that pressure from data centre suppliers to use SIS influence their decision to adopt SIS, 23% perceived that pressure from competitive conditions could have the same effect. Moreover, there is insignificant (r= 130, p=0.063) correlation between coercive pressure and SIS assimilation. Likewise, the result of effect size test (f^2) from the structural analysis and hypotheses testing in Chapter 8 shows that coercive pressure has insignificant effect on SIS assimilation (f^2=0.002). Moreover, the result shows that coercive pressure has a weak (β=0.008) and insignificant (p=0.90) effect on SIS assimilation. Further, the result from the institutional context-specific analysis reveals that coercive pressure has insignificant effect (β= 0.002, p =.976) on the extent of SIS usage in the data centres (see chapter 8). Hence, hypothesis 8a [*coercive pressures will have a direct and positive influence on the assimilation of SIS in the data centre*] was rejected.

This finding does not conform to institutional theory (DiMaggio and Powel, 1983) that theorises coercive pressure as determinant for innovation use. In addition it is inconsistent with Chen et al.'s (2011) study that reveals significant relationship between coercive forces and the adoption of policies to install software for pollution prevention, product stewardship and sustainable development. Furthermore, it is inconsistent with findings from other IS studies that reveal significant association between the assimilation of innovations such as EDI (Hart and Saunders 1998), e-business use (Zhu and Kraemer, 2005) and ERP assimilation (Linag et al., 2007; Kouki et al., 2010) and the regulatory encouragement and competitive conditions. The government's commitments to encourage the use of technology plays important role in making the use of technology more attractive for organisations (Molla et al., 2010).

The literature also shows that regulatory intervention (e.g. imposing new legislation and initiatives) is required to support, encourage and accelerate the adoption and use of green and clean technologies including SIS (OECD, 2009). Further, the findings from the exploratory study depicted in Chapter 3 reveal that regulatory support can facilitate the use of SIS in data centres. Despite the above findings that justify the hypothesis that coercive pressure can directly and positively influence the assimilation of SIS, the hypothesis was not supported in this study.

Although the result of the test of this hypothesis was surprising, some of the previous studies have also reported an insignificant effect of coercive pressure on technology assimilation. For example, Linag et al. (2007) have found that coercive pressure did not directly affect ERP assimilation. They explain that the effect of coercive pressure is likely to be mediated by members of top management as they are forced to participate in metastructuring activities to support ERP assimilation because they are the focal point of coercive pressures. The literature also shows that the effects of each institutional pressure on different technologies are not clearly identifiable and that each pressure derives from a different process (DiMaggio et al., 1983; Mizruchi et al., 1999).

The result of the test of this hypothesis suggests that current coercive pressure in the form of regulatory intervention, competitive conditions, and other dominant stakeholders such as suppliers are not creating enough drivers to use SIS. One explanation is that some countries enact voluntary or soft regulations in respect to the practice of data centres energy performance. In addition, regulations to specifically use SIS (e.g. to use energy monitoring software) are not yet available. Instead, regulations have set out the broad lines in respect to the environmental performance without intervening with the technologies that are needed to improve the performance such as imposing regulation to improve energy consumption (e.g. OLDP, 2007).

9.5.2.2. Indirect effect through organisational context

Coercive pressure was also hypothesised to indirectly and positively influence the extent of SIS use through top management support, Green IT orientation and data centre energy governance constructs. The correlation analysis result indicates that there is a significant association between coercive pressure and the top management support (r= 0.358**,** p <0.001), Green IT/IS orientation (r= 0.279, p <0.001), and data centre energy governance (r=0.246**,** p <0.001). Nevertheless, contrary to the correlation test, the result of effect size test (f^2) shows that coercive pressure has an insignificant indirect effect on SIS assimilation (f^2=0.002). Moreover, the path coefficients test shows that coercive pressure has a weak (β=0.091) and insignificant (p=0.122) indirect effect on SIS assimilation However, the result shows that coercive pressure has a significant effect on the top management support (β= 0.360, p <0.001), Green IT/IS orientation (β= 0.290, p <0.001), and data centre energy governance (β= 0.256, p <0.001). Hence, hypothesis 8b [*Organisational context (that is top management support, green IT/IS orientation and data centre energy governance) mediates the influence of coercive pressure on SIS assimilation.*] was partially supported at a 95% confidence interval (partial mediation).

The result was partly inconsistent with findings from previous research that have tested the indirect effect of coercive pressure on technology assimilation (e.g. Linag et al., 2007; Molla et al., 2010). For example, the study of Linag et al. (2007) concluded that coercive pressure has a significant direct effect on top management, and indirectly influences ERP assimilation through managerial behaviour. Molla’s et al. (2010) study revealed that institutional forces can create a chain of effects that can alter organisational readiness to invest in technology competence and can indirectly increase the use of e-business.

However, the result was in line with findings from previous research that have investigated the effect of institutional forces on environmental sustainability and Green IT (Chen et al., 2011; Butler, 2011). For instance, the research of Chen et al. (2011) reveals that coercive pressure has a significant effect on pollution prevention, product stewardship (e.g. such in the case of Green IT/IS orientation), and sustainable development. They contend that coercive pressure is an important factor that can drive Green IS and IT practices. Butler (2011) hypothesised that institutional forces including coercive pressure influence the decisions of the managers of IT manufacturers (e.g. top management support) on the design and manufacture of eco-sustainable products.

One possible explanation of the weak indirect effect of coercive pressures in this study is that current regulations are not yet mandatory in some jurisdictions or countries in which the participating data centres operate. Although regulatory policies are placing significant pressure on data centres to adopt sustainable practices (EPA, 2007; Lamb, 2009; European Commission, 2010), such pressure is not generating enough drive to extend the volume, diversity and intensity of SIS.

This implies that other human agency not discussed in this study such as middle level managers, and operational level knowledge workers might mediate the effect of coercive pressures on SIS assimilation. The result also implies that current regulations in some jurisdictions in respect to the practice of data centres in particular can be fulfilled without the need to extend SIS use. In other words, at the time of this study, coercive pressure does not indirectly lead to an increase in the use of SIS. However, coercive pressure is expected to be of more importance in the near future when particular regulations regarding environmental performance and energy monitoring are being enforced. This is consistent with the argument that regulatory actions can affect the behaviour of an organisation that is operating under their jurisdictions (King et al., 1994; Molla, 2009). It is also consistent with the conclusion of Molla and Abareshi (2011) that external institutions within the context of eco-sustainability need to be strong enough in order to drive organisational actions to adopt Green IT.

To sum up, the findings of the tests of the direct and direct hypotheses of coercive pressures imply that the influence of current and/or foreseeable regulations as well as, suppliers and competitors' actions in motivating data centres to extend their usage of SIS has yet to emerge. However, partial mediation of coercive pressures have been discovered in the analysis which suggests that coercive pressures is an important factor in the study of SIS assimilation. This implies that although partial mediation through top management support, green IT/IS orientation and data centre energy governance exist, it is not strong enough to drive the organisations to assimilate SIS in their data centres. The finding can be used to inform regulatory authorities about their significant role in the development of more effective interventions that can drive the use of SIS across data centres industry. Further, suppliers of data centre systems can make use of this finding to strengthen their role in SIS success. Suppliers' role is of high importance, as they can bring in the competitive advantages of SIS into the focus and facilitate their diffusion.

9.6. Natural Environmental Factors and SIS Assimilation

Two natural environmental factors, that is, energy and environmental preservation pressure, were theorised to influence the organisational context (i.e. the top management support, Green IT/IS orientation and data centre energy governance) for the assimilation of SIS. The correlations and standardised effect of the two institutional factors and their p-values are displayed in Table 9.7. Both energy pressure and environmental preservation pressure have positive impact on top management support, Green IT/IS orientation and data centre energy governance. In addition, the two factors significantly and indirectly affect the extent of SIS usage.

Table 9.7: The correlation, path coefficients and magnitude for natural environmental factors

	Indirect Effect		**Direct Effect**					
	SIS Assimilation		Top Management Support		Green IT/IS Orientation		Energy Governance	
Constructs	Corr	Beta	Corr.	Beta	Corr.	Beta	Corr.	Beta
Energy pressure	0.164*	0.105**	0.480***	0.480***	0.447***	0.450***	0.275***	0.283***
Environmental preservation pressure	0.278***	0.119**	0.487***	0.488***	0.462***	0.470***	0.232***	0.232***

p<0.05, p<0.01 **, p<0.001 **

9.6.1. The Effect of Energy Pressure on Organisational Context

Energy pressure was hypothesised to indirectly and positively influence the extent of SIS use. Energy pressure was operationalised by asking respondents to indicate to what extent they are concerned about rising energy price, cost of energy consumption, growth of energy need, current and/or foreseeable accessibility to energy for the data centre operations. About 65% of respondents indicated that they are concerned about the energy-related issues.

The correlations between energy pressure and all the organisational context factors of top management support ($r= 0.480$, $p <0.001$), Green IT/IS orientation ($r=0.447$, $p <0.001$) and data centre energy governance($r=0.275$, p= $p <0.001$) are significant. In addition, the result from the structural analysis and hypotheses testing reveals that energy pressure has a significant positive effect on the top management support ($\beta= 0.480$, $p <0.001$), Green IT/IS orientation ($\beta= 0.450$; $p <0.001$) and data centre energy governance ($\beta= 0.283$, $p <0.001$). Likewise, energy pressure has significant and positive indirect effect on SIS assimilation through the three organisational factors ($\beta= 0.105$**). Therefore, hypothesis 10 [*Organisational context (that is top management support, green IT/IS orientation and data centre energy governance) mediates the influence of energy pressure on SIS assimilation*] is supported at a 99% confidence interval.

The finding is in line with the data centre literature (Schultz, 2009; Loper and Parr, 2007; Schulz, 2009; Zheng and Cai, 2011) that stresses the importance of energy to the survival of data centres businesses. Energy is a fundamental resource to data centres and is becoming a major issue for data centre operations (Brill, 2007; Loper and Parr, 2007; Lamb, 2009). In addition, data centre energy consumption has attracted regulatory attention with new regulations and restrictions coming up to govern how data centres can improve the efficiency of energy use (EPA, 2007). Further, the availability of energy, and the increasing rate of energy price is adding another dimension to the energy paradox (Loper and Parr, 2007; Zheng and Cai, 2011).

All of these issues have made energy consumption, cost of energy, energy efficiency and other related issues top priorities to data centre managers and other business leaders. The pressure is also triggering the organisational action in terms of receiving the commitment of top management for projects that can improve data centre energy performance, formulating Green IT/IS policies and in terms of creating accountabilities and responsibility for energy governance. This pressure is facilitating SIS use as SIS can be one of the technologies that can monitor, trace and reduce the energy consumption of data centres.

In summary, the results of the tests of the hypotheses show that energy pressure indirectly affects the volume, diversity and intensity of SIS. The findings add to the literature on the impact of energy considerations on technology use and Green IT/IS. The findings are original due to the lack of previous study on how energy pressure influences the adoption and assimilation of technology in general, and SIS in particular. This suggests that data centre managers and other senior IS professionals need to understand the specific features of SIS and how to use their features to curb the energy consumption as well as other energy concerns.

9.6.2. The Effect of Environmental Preservation Pressure on Organisational Context

Environmental preservation pressure was hypothesised to have an indirect and positive influence on the extent of SIS use. The environmental preservation construct was measured by asking respondents to indicate to what extent they are pressured to reduce the volume of non-renewable energy sources, and CO_2 emissions and to increase the lifecycle of IT hardware in data centre.

Environmental preservation pressure has significant correlation with the organisational factors of top management support, Green IT/IS orientation and data centre energy governance (r= 0.487, p <0.001; 0.462, p <0.001; 0.232, p <0.001) respectively. Approximately 59% of respondents indicated that environmental concerns have considerable influence on the organisational effort that drives the decisions to use SIS. Likewise, the results from Chapter 8 reveal that environmental preservation pressure has a significant positive effect on the top management support (β= 0.488, p <0.001), Green IT orientation (β= 0.470, p <0.001) and data centre energy governance (β= 0.232, p <0.001). Further, environmental preservation pressure has a significant and positive indirect effect on SIS assimilation through top management support, Green IT/IS orientation and data centre energy governance (β=**.**119**). Therefore, hypothesis 11 [*Organisational context (that is top management support, green IT/IS orientation and energy governance) mediates the influence of environmental preservation pressure on SIS assimilation*] is supported at a 99% confidence interval.

The results of the test of the environmental preservation pressure hypotheses were consistent with the theories on the environmental sustainability such as NRBV (Hart, 1995). According to NRBV's pollution prevention concept (Hart 1995), emission and waste-related issues affect the organisational effort towards adopting sustainable practices. Generally, organisations with activities that could cause direct environmental impact are more likely to have a greater use of clean and environmentally friendly systems (Sharma, 2000; Aragón-Correa, 2000). Data centres are coming under pressure to preserve the environment due to their high-energy consumption and energy-related emissions (Tschudi et al., 2004; EPA, 2007; Schulz, 2009; Zheng and Cai, 2011). The finding implies that those data centres that feel such pressure are developing Green IT policies and energy governance mechanisms that in turn facilitate SIS assimilation. The finding is also in line with other conceptual and empirical studies (e.g. Chen et al., 2011; Molla and Abareshi, 2011) that reported the importance of environmental sustainability in driving the organisational effort towards the use of IS as sustainable and green solution. Overall, the results provide empirical evidence that environmental preservation pressure indirectly affect the volume, diversity and intensity of SIS in the data centre context. Although several studies have investigated the antecedents for the assimilation of IS, very few (Chen et al.,

2008) have reported how environmental preservation considerations impact technology use. Thus, the finding of this hypothesis adds to the literature on the effect of natural environment on technology innovation.

In terms of practice, data centre managers and owners need to pay attention to the exacerbating environmental problems associated with their business and be prepared for changes in both mindset and behaviour.

9.7. SIS Assimilation and its Impact on Data Centre Performance (SIS Value)

SIS assimilation was theorised to positively influence the extent of SIS value. SIS value was modelled as a second-order construct composed of two first-order constructs: operational performance and environmental performance. The standardised effect of the second-order construct and first-order constructs and p-values are displayed in Table 9.8.

Table 9.8: The correlation, path coefficients and magnitude for SIS assimilation and SIS value

Second-order construct	Correlation	Beta	P value
SIS Value	0.543***	**0.448**	***
Impact on Operations Performance	0.520***	**0.436**	***
Impact on Environmental Performance	0.479***	**0.371**	***

$*p<0.05$, $p<0.01$ **, $p<0.001$ ***

The correlation between the second-order construct (SIS value) and SIS assimilation is significant ($r= 0.543$, $p<0.001$). In addition, the correlation between the two first-order constructs, that is operational performance ($r= 0.52$, $p<0.001$) and environmental performance ($r= 0.48$, $p<0.001$) and the SIS assimilation were significant. The structural model results from Chapter 8 as summarised in Table 9.8 show that the paths from the second-order latent variable to the two first-order latent variables are significant and of a high magnitude. The results from 7.5.4 also show a high *T* ratio for first-order latent variables implying that the relationships among first-order latent variables are sufficiently captured by the second-order latent variable.

Further, descriptive statistics reveals that 71% and 51% of respondents recognised an improvement in the operational and environmental performance respectively. Likewise, SIS assimilation has a positive and significant effect (β= 0.448, p <0.001) on the extent of SIS value. In particular, the links between SIS assimilation and operational (β= 0.436, p <0.001) and environmental (β= 0.371, p <0.001) performance are positive and significant. Therefore, Hypothesis 12a [*Greater extent of SIS assimilation is more likely to improve the operational performance of data centres]* and hypothesis 12b [*Greater extent of SIS assimilation is more likely to improve the environmental performance of data centres]* were supported at a 99% confidence interval.

This finding is consistent with the theories of RBV (Barney, 1991; Peteraf, 1993; Penrose, 1995) and NRBV (Hart, 1995). RBV postulate that firms can create value, and achieve long-term performance by developing and acquiring capabilities that are rare and valuable. Conversely, the NRBV focuses on the capabilities that facilitate environmentally sustainable economic activity. The findings of these two hypotheses demonstrate the value of the unique and valuable capabilities that data centres built through the assimilation of SIS improve their operational and ecological sustainability.

The results are also consistent with the findings from previous IS research in section 2.7.3 that have reported a positive connection between the assimilation level and value (e.g. Ranganathan et al. 2004; Raymond et al., 2005; Rai et al., 2009; Setia et al., 2011; Picoto et al., 2012). For example, Ranganathan et al. (2004) found that greater usage of web systems in SCM can improve performance in several areas including customer service, cost reduction, inventory management, cycle-time reduction, supplier relationship management, and overall competitive advantage. Likewise, Zhu and Kraemer (2005) found that higher degree of e-business use is associated with improvement in business performance. They contend that their findings confirm the early research postulation (e.g. Devaraj and Kohli, 2003) that actual use could be a missing link to the payoff of IT.

The findings of these hypotheses have several implications. The results imply that the number of SIS used in the data centre, the number of functional areas supported by SIS, the depth of SIS functionalities utilisation to support different business processes, and the level of SIS integration positively contribute to the realisation of SIS value. This finding adds to the existing knowledge on the connection between technology assimilation and value from section 2.7.3 (e.g. Zhu and Kraemer, 2005; Setia et al., 2011; Picoto et al., 2012).

The results also empirically support the argument about the various advantages of SIS reported in the literature and particularly the potential advantages of SIS for data centre infrastructure. For data centre managers, it showcases the actual impact of SIS usage on the performance of their businesses from operational and environmental perspectives. The empirical evidence provides confidence to data centre executives and investors that investments in SIS technologies for data centres are candidates for generating positive returns and are worthwhile. Developers and vendors of SIS can use the findings to understand how their systems actually improve the performance of data centre operation. They can also use it as a valid means for the evaluation of different SIS functionalities in order to improve the SIS performance.

9.8. SIS Knowledge Stock and SIS Value

Data centre managers' SIS knowledge stock was hypothesised to positively contribute to the operational and environmental performances of data centre. The standardised effect of this construct on SIS value creation and p-values are displayed in Table 9.9.

Table 9.9: The correlation, path coefficients and magnitude for SIS knowledge stock and SIS value

Constructs	**Correlation**	**Beta**	**P value**
SIS value	0.411***	0.188	**
Impact on operations performance	0.380***	0.189	**
Impact on environmental performance	0.400***	0.161	**

***p<0.05, p<0.01 **, p<0.001 ***,**

The correlation between SIS knowledge and SIS value (second-order construct) is significant (r= 0.410, p <0.001). In addition, the correlation between SIS knowledge stock and operational performance (r= 0.380, p<0.001) and environmental performance (r= 0.400, p<0.001) are significant. Moreover, 47% of participants have reported to have a high level of expertise and professional knowledge on SIS in general.

Likewise, SIS managers' knowledge stock has a positive and significant effect (f^2= 0.044, β= 0.188, p <0.01) on the SIS value to the data centres. Moreover, the link between SIS knowledge stoke and operational performance (β= 0.189, p <0.01) as well as between SIS assimilation and environmental performance (β= 0.161, p <0.01) are positive and significant. Therefore, Hypothesis 13a [*Greater extent of managers' SIS knowledge stock is* *more likely to improve the operational performance of data centres*] and hypothesis 13b [*Greater extent of managers' SIS knowledge stock is more likely to improve the environmental performance of data centres*] were supported at a 99% confidence interval.

The findings of these tests of the hypotheses were consistent with the findings from technology use and value research (Ranganathan et al., 2004; Raymond et al., 2005). For example, Ranganathan et al. (2004) integrated a model of use and value to study the web technologies in SCM. They found that good managerial knowledge about the specific IT systems of the business domains in which the firm operates has significant impact on assimilation value. It also consistent with the argument that deeper knowledge of managers is a facilitating condition that allows organisations to absorb valuable capabilities and resources that is important to achieve high level of innovation use (Cohen and Levinthal, 1990). In addition, the literature shows that deeper knowledge of data centre professionals is important for enhancing the performance of data centres (Tschudi et al., 2004).

Further, the results from the exploratory case study of the five data centres in chapter 3 indicate that the depth of data centre managers' knowledge on SIS features and capabilities influence their ability to understand how these systems can best applied to serves the diverse needs of data centres, which in turns impact the overall level of SIS value realisation.

The finding of the test of the hypothesis implies that the depth of knowledge on SIS features, capabilities, technical issues, and areas where they can be applied, is one of the valuable capabilities that can contribute to SIS value realisation. The test of these hypotheses is one of the first attempts to investigate the effect of managerial SIS knowledge stock on the value creation of SIS in data centres, thus the result adds to the body of knowledge on technology value research. The result highlights the importance of maintaining higher levels of managerial SIS knowledge in facilitating firms' ability to harvest the SIS benefits in operational and environmental terms. By focusing on enhancing and improving managerial knowledge and expertise about the use of SIS, organisations can maximise the benefits of SIS applications in their data centres.

9.9. The Boundary Conditions of TOIN

To understand the boundary conditions of the model due to difference in the age, size and the type of data centre, a number of multi-group comparisons were undertaken. The effect of the three variables on the research models are displayed in Table 9.10 (further details can found in chapter 8).

Table 9.10: The moderating factor effect on SIS assimilation determinants

	Control Variables	Group (g)	Sample size(n)	SIS Assimilation (R^2)	Significant Difference between groups	Number of latent constructs having Significance Diff *
1	Age of Data Centre	New	90	*.223*	Significant Diff r=.154, p<.05	Method 1= 4 factors (Coercive Pressure, Energy Pressure, Environmental preservation, Pressure, Top management support) Method 2 = 4 factors (same as above)
		Old	115	*.526*		
2	Size of Data Centre	Large	103	*.372*	Insignificant Diff r=.035, p=0.6	-
		Small	102	*.407*		
3	Type of Data Centre	Corporate	93	*.362*	Significant Diff r=.162, p<.05	Method 1= 3 factors (Coercive Pressure, Energy Pressure, Normative Pressure) Method 2= 5 same as above + Compatibility, Green IT/IS orientation)
		Managed	70	*.524*		
		Co-located	42	*.434*		

**Method 1 = multi group comparison test using Keil's (2000) approach*
**Method 2 = multi group comparison test using Henseler's (2009) approach*

9.9.1. Age of Data Centre

The difference in the age of data centre was theorised to affect the influence of the technological, organisational, institutional, and natural environment factors on the SIS assimilation. The model explains 53% of the variance in the assimilation of SIS in the old and 22% of the variance in the new data centre sample groups. The r^2 difference between the two groups is significant (r= 0.154, p<0.05). This suggests that the research model works better for old rather than new data centres. Thus, providing support for H15 [*The influence of technological, organisational, environmental, and natural environment factors* *on SIS assimilation varies due to differences in data centre age*] at a 95% confidence interval.

To understand the variables that are sensitive to data centre age differences, the significance of each latent variables in the old and new data centre sample groups' models were evaluated (see section 8.2.1.2) using both Keil and Henseler's approaches. The result reveals that there is a significant difference (Diff r=.154, $p<0.05$) at a 95% confidence interval in the effect of four constructs (see Table 9.12). Thus, it can be concluded that differences in the age of data centres can play an important role in moderating the influence of top management support, coercive pressure, energy pressure, and environmental preservation pressure constructs on SIS assimilation. As such, difference in the age makes these factors stronger in the old data centre group (further details can be found in chapter 8).

9.9.2. Size of Data Centre

The difference in the size of data centre was theorised to affect the influence of the technological, organisational, institutional, and natural environment factors on SIS assimilation. Approximately 50% of the sample is small and the remaining is large. The research model accounts for 41% of the variance of SIS assimilation in the small sample group and 37% of the variance in the large sample group. The r^2 difference between the models in the two groups is insignificant (r= 0.035, p= 0.617) at a 95% confidence interval. Thus, H16 [*The influence of technological, organisational, environmental, and natural environment factors on SIS assimilation varies due to differences in data centre size*] is not supported. This shows that the difference among data centre size group has no significant moderating effect on SIS assimilation.

9.9.3. Type of Data Centre

The difference in the type of data centre was hypothesised to affect the influence of the technological, organisational, institutional, and natural environment factors on the SIS assimilation. The data centres were grouped into three categories: co-located (45% of the entire sample), managed (34%) and corporate (21%). As previously described, a corporate data centre is an IS unit of an organisation that is established for the purpose of supplying information processing needs specifically to that organisation. A fully managed data centre is an independent business that runs the entire IT resources, the facility and all other supplementary equipment to provide complete hosting services to other organisations. A co-located data centre runs the facility and the supplementary equipment to rent a space to other organisations that allow them bring in their own IT equipment into the facility.

Three models were run, each representing one type of data centre. The co-located data centre model explains 43% of the variance in SIS assimilation. While the corporate data centres model explains 36% of the variance, the fully managed group model accounted for 52% of variance. The r^2 difference between corporate and managed groups is significant ($r= 0.162$, $P<0.05$) at a 95% confidence interval. However, the differences between corporate and co-located groups ($r= 0.072$, $P= 0.304$) as well as between co-located and managed groups ($r= 0.09$, $P= 0.198$) are insignificant. Thus, H17 [*The influence of technological, organisational, environmental, and natural environment factors on SIS assimilation varies due to differences in data centre type*] is partially supported.

To further understand the difference in the latent variables and SIS assimilation that underlie the differences in r^2 value, a multi-group's comparison was undertaken. The multi-groups comparison using Keil and Henseler's approach shows that the relationships between SIS assimilation and compatibility, Green IT/IS orientation, coercive pressure, energy pressure, and normative pressure are sensitive to differences in data centre types. These differences in the type of data centre makes these factors stronger in the corporate data centre group (further details can be found in chapter 8).

Thus, it can be concluded that differences in the objectives, business scope and nature of infrastructure among the three types can play an important role in moderating the influence of some of the technological, organisational institutional and natural environment to assimilate SIS.

This result provides an interesting contribution to the data centre research because it empirically shows that antecedent to the SIS assimilation within the data centre context could vary due to the type of data centres.

9.9.4. Moderating Variables of SIS Value

Length of SIS usage was hypothesised to moderate linkage between the SIS value and the SIS assimilation as well as the manager knowledge stock construct, which contributes to the creation of SIS value. The results of moderating variables test conducted through SmartPLS shows that length of SIS usage has a positive and significant moderation effect ($\beta = 0.15$, $p < 0.05$) on the manager's SIS knowledge stock. Therefore, hypothesis 14b [*Length of SIS use moderate the influence of SIS knowledge stock on SIS value*] is supported at a 95% confidence interval.

This finding is consistent with the argument found in the technology assimilation literature that postulates that organisations that maintain a particular technology for a protracted period are more likely to have more experience and better insight about how to effectively create the value using an innovation (Chatterjee et al., 2002; Liang et al., 2007). The finding of the test of this hypothesis implies that due to difference in the length of SIS usage in the data centres, the manager's capabilities and contribution of manager's knowledge to the process of SIS value creation could be moderated accordingly.

The result of moderating test also shows that length of SIS usage has insignificant moderation effect (β= 0.1.4, $p=0.22$) on the SIS assimilation. Therefore, hypothesis 14a [*Length of SIS use moderate the influence of SIS assimilation on SIS value*] is rejected at a 95% confidence interval. This implies that the period of SIS usage is unlikely to moderate the effect of SIS assimilation on the value creation of SIS at the time of the study.

Overall, the findings of this research regarding the effect of the moderating variables of age, size, and type of data centres, as well as length of SIS use, is unique and original due to the dearth of previous conceptual studies, case studies and survey-based research on the moderating effect of the three data centre characteristics and length of SIS use on the adoption, assimilation and value of technology in general, and SIS in particular. Given that the current study is the first to examine the influence of the age of data centre, the size of data centre, the type of data centres and length of SIS use within organisational context and SIS assimilation and value, the results represent an important contribution to future IS research that investigates the factors that moderate the use and value of information systems. Overall, the exact role of the age, size and type of data centre in the assimilation and its relationships with other constructs as well as the exact role of length of SIS usage in the SIS value and its relationships with other constructs remain significant and interesting questions for future research.

9.9.5. Further Test: Exploring Possible Country Effect

Although country effect were not hypothesised, the study ruled out further moderation effect analysis to evaluate whether there is a possible effect of cross country effect or regional differences on the research model as well as on the path of each latent variable. It can be argued that such differences may affect the model especially the factors associated with environmental sustainability.

Two tests: country effect (through SmartPLS) and regional differences (multi group comparison) were evaluated. The results of moderating test conducted through SmartPLS shows that country has no significant effect on the R2 value of SIS assimilation. In addition, country difference did not cause any significant effect on the relationships between SIS assimilation and its latent variables, except for Green IT/IS orientation (results reported in Appendix 9c-1).

Furthermore, data centres were group into four regional areas: Americas (United States and Canada) (41.5% of the sample), Australia (19%), Europe (20%) and the rest of the world (19.5%), for the purpose of multi group analysis (Keil et al., 2000). Four models were run, each representing one regional area (see appendix 9c-2). The r2 difference (see table 9.11) between the models in the regional groups were found to be significant only between Europe and Americas (U.S. & Canada) ($r= .219$, $p= .013$) and between Europe and the Rest of the World ($r= .256$, $p= .020$) groups at a 95% confidence interval. This suggests that there is a partial effect of regional differences.

To further understand the difference in the models that underlie the differences in r2 value, a multi-group’s comparison was undertaken (see appendix 9c-3). The result shows that the relationships between latent variable and SIS assimilation are insignificant due to difference in the r2 value, except for top management support between Europe and the Rest of the World groups. This difference makes top management support stronger in the Europe regional.

Table 9.11: The differences in the R2 value between regional groups

Multi-Group (Regional) comparison	**r^2 (diff)**	**Significance of Diff (r^2)**
U.S. & Canada Vs. Australia	0.121	0.179
U.S. & Canada Vs. Europe	0.219	**0.013***
U.S. & Canada Vs. Rest of the World	0.037	0.681
Australia Vs. Europe	0.098	0.384
Australia Vs. Rest of the World	0.158	0.159
Europe Vs. Rest of the World	0.256	**0.020***

However, the result of cross-country and regional difference cannot be claimed to be a good representative for the actual role of country differences in the model for several reasons. First, the intent of the research for taking a global sample was to learn as much as possible about the research phenomenon, rather than looking at the difference between countries. Therefore, neither the hypotheses nor the survey items were designed to specifically measure differences that may exist across countries (except merely knowing the location of data centre). Second, the majority of countries in the sample had only a few respondents (less than 10), while some countries had a large number of respondents (US and Aus). This variation would affect the result of the country analysis and render its findings to be an untrue reflection of the differences across countries. Third, multi-group comparison group requires larger sample sizes to account for true differences. As the regional areas were divided into four groups, three groups had relatively small sub-samples (e.g. 39). Therefore, country effect was acknowledged in the study as a limitation (section 10.3) and a suggestion were made for future researchers in this regards (section 10.6).

9.10. Summary

This chapter has provided a more detailed discussion about the key findings of this research. The findings of data analysis and tests of the hypotheses from chapter 8 were triangulated by comparing the findings with the literature on Green IT/IS, sensor application, SIS and IS assimilation and value from chapter 2 as well as with the classical theories of IS assimilation and value from chapter 4.

The research model has explained 35% of SIS assimilation and 34% of SIS value, which is accepted and comparable with relevant studies from IS literature. In particular, this research has shown that antecedents including SIS compatibility, SIS perceived risk, Green IT/IS orientation and normative pressure were significant determinants of SIS assimilation and the value model. The chapter also discussed how normative pressure, energy pressure, and environmental preservation pressure have indirectly affected the assimilation of SIS through top management support, Green IT/IS orientation, and data centre energy governance constructs.

The variation in the assimilation as well as linkage between latent variables and SIS assimilation when the age and type of data centre are taken into account were also observed and discussed. The discussion of the second-order model showed how the level of actual usage as well as the level of SIS managers' knowledge has improved the operational and environmental performance of data centre operations including facility, cooling and power, and computing platforms. The interpretation and implications of results were discussed in depth for all factors including those that were not supported. Further, the discussion has shown the research findings were of importance to the theories as well as to industry practice. In the next chapter, the study will discuss how the research questions were answered, the theoretical and practical contribution of the study, as well as limitations of the study, which opens the path for future research.

CHAPTER 10

10. SUMMARY AND CONCLUSION

10.1. Introduction

This chapter highlights the key findings and contribution of the current thesis. In particular, it provides discussion on how the research questions that were introduced in Chapter 1 have been addressed, how the research gaps were filled, and how the current study contributes to the body of knowledge and industry practice. These cover the efforts made throughout the entire thesis in an attempt to answer the research questions, evaluate the extent of SIS usage in data centres, identify the determinants of SIS assimilation, gauge the impact of SIS on data centre performance, and identify factors that facilitate the value creation of SIS.

The chapter is organised as follows. Firstly, the discussion starts by outlining the way the research questions were answered (10.2). This will be followed by the theoretical contribution of the current study (10.3). The third section will be devoted to the practical contribution of the study to the data centre industry (10.4). This is followed by acknowledgment of research limitations in section 10.5, which opens the path for future researchers (10.6).

10.2. The Research Questions Revisited

The study began in Chapter 1 by identifying the gaps in the literature of assimilation and value of sensor information systems in data centres. The rationale for this research stemmed from the knowledge gaps identified in three areas of IS research and practice.

The research presented a conceptual framework for investigating the antecedents to SIS assimilation and SIS value in data centres based on the diffusion of innovation, the technology–organisation–environment framework, institutional, resource-based view and natural resource-based view theories as well as an exploratory study of five data centres. A mixed-methods approach consisting of a literature review, a case study and a survey was used. A number of technological, organisational institutional and natural environment factors were identified as antecedents for SIS assimilation and SIS value.

After reviewing the literature, exploring the SIS phenomenon within data centre context through an empirical exploratory study, and building a different theoretical lens, an integrated research model (TOIN) was developed to investigate the assimilation and value of SIS. The TOIN model of SIS assimilation and value combines antecedents from technological, organisational, institutional, and natural environment perspectives.

The result of the original model revealed that compatibility, perceived risk, Green IT/IS orientation and normative pressure directly affect the assimilation of SIS that the data centres use to support the operations of facility, power and cooling and computing processes. The result also showed that normative pressure, energy pressure, and environmental preservation pressure indirectly affect the assimilation of SIS. In addition, SIS assimilation and SIS manager's knowledge stock were found to positively affect the SIS value.

How the age, size and type of data centre influence the assimilation of SIS and how they moderate the linkage between the latent variables were evaluated. The result of this test showed that there are significant variations in SIS assimilation as well as on other latent variables in the model when the age and type of data centre are taken into account. Further, length of SIS use was found to moderate the relationship of SIS manager's knowledge stock with SIS value.

The test of the research model helped to answer the research questions of the current study. The following section will discuss how the research questions were addressed in sequence.

10.2.1. To What Extent Are SIS Assimilated in Data Centres?

The motivation behind this question was guided by the opportunities underlying the use of SIS to resolve data centre problems (e.g. found in section 2.5). The study reviewed the literature of data centres and found that the inefficiency of ICTP and CSSP operations is one of critical areas in which both researchers and practitioners devote their endeavours to improving the operational and environmental performance of ICTP and CSSP.

The literature revealed that various techniques (e.g. efficient cooling techniques), methods (e.g. methods to effectively position IT equipment in data centres) and technologies (e.g. resource management systems) are proposed and used to apply best practice and to overcome some of the data centre issues. It also showed that IS and sensors (as well as the integration of IS and SIS) is one of the technologies used for supporting the management of data centre’s business functions.

The advantage of SIS is recognised in computer science, electrical engineering, and applied science disciplines that were identified in the literature include monitoring, analysing, and automating several tasks such as manufacturing process automation, building environment monitoring and control, irrigation control, and food production and diagnosis. This has led to the assertion that the application of SIS in data centres is one of the technologies that could be applied to manage data centre operations and improve its sustainability (e.g. see sections 2.3 and 2.5).

Although many experimental studies have investigated the application of SIS with the data centre environment (see section 2.5), the status of SIS in data centres through empirical studies is yet to be explored.

To understand the extent of SIS use in data centres, two approaches were followed. Firstly, due to the lack of empirical studies on SIS use and value in data centres, it was important to enhance the researcher’s understanding of the SIS phenomenon and the current state of SIS applications in data centres. In addition, exploring the indicators of SIS assimilation and value was equally important in order to evaluate the extent of use of SIS in the real settings. Firstly, a preliminary evaluation of SIS use in data centres was undertaken. This has revealed that although SIS was used in almost every data centre, there was a variation in the SIS volume, SIS diversity, and SIS intensity (use-intensity and integration-intensity) among data centres.

Secondly, a global survey was used to gauge the extent of SIS use in data centres. The feedback from 205 data centres revealed that SIS was used in the entire surveyed sample but there was a variation in the extent of use among the sample. As to the SIS volume, it was found that third of the sample used only one SIS, whereas approximately another third used two SIS brands. Twenty-two per cent of data centres used three different SISs, while the other 15% used more than four different SISs to manage data centre operations. Although a total of 60 different SIS were identified in the sample, the dominants SIS used in data centre was the BMS, followed by SIS developed by leading vendors such as InfraStruXure, family products by APC, and Tivoli family products by IBM.

In respect to the SIS diversity, SIS is used for managing the function of CSSP (facility [71%], cooling [96%] and power systems [92%]) and ICTP (computing systems [76%]). As for the evaluation of SIS use intensity, three major functionalities of SIS were used: monitoring, analysing and automating. Monitoring temperature, power use and status of IT hardware, appeared to be the most common functionality used with 65%, followed by analysing thermal and power capacity for predictive pro-active activities at 58%. The automation of lighting and workload of cooling systems, power systems and IT resources was 51%. Finally, SIS integration intensity was measured through three indicators. The result revealed that the level of integrating SIS into CSSP averaged at 65%, whereas integrating SIS into ICTP was lower at 46%. The level of SIS integration with other IS used in data centres was 48%.

In conclusion, there is a variation in the assimilation of SIS among data centres. These variations are explained by the volume, diversity, and use intensity and integration intensity of SIS. Cooling and power are the most functional areas in which SIS is applied, followed by computing and facility areas respectively. Despite this, the majority of data centres prefer the use of SIS for monitoring purposes, whereas almost half use SIS to analyse and automate business activities. This suggests that data centres are under-utilising SIS functionalities and capabilities to analyse and automate the processes of data centre platforms. The level of SIS integration appeared to be low especially regarding the integration of ICTP and other IS.

These results are considered novel as far as it is one of the first empirical studies that have defined and tested the indicators of SIS assimilation through a mixed approach to gauge the extent of SIS use in data centres. As such, the results are of genuine value to both researchers and practitioners.

10.2.2. What is the Nomological Net of Antecedent Factors that Explain the Differences in the Assimilation of SIS among Data Centres?

The assimilation of IS implies the absorption of an IS into the routines of an organisation. It helps organisations to leverage the advantages of using IT/IS in their business activities and strategies. Therefore, understanding the factors that influence organisations' ability to leverage the advantages of SIS in the operations of their data centres is very important to achieve higher level of use and successful assimilation.

Previous theories of IS provided a fundamental understanding about the nomological net of antecedent factors that affect the use of SIS in organisational setting. These included insights form diffusion of innovation theory (DOI), the technology–organisation–environment framework (TOE), institutional theory, and natural resource-based view (NRBV). In particular, the DOI is used to conceptually ground the technological attributes of SIS. While the DOI and TOE are used to conceptualise the organisational factors, institutional theory helped to identify the external forces that might influence the assimilation. The NRBV is used to identify the eco-sustainability factors that might influence assimilation, whereas the RBV is used to identify factors that could affect the value of assimilation.

Previous IS research has identified a number of antecedents that could influence the IS use including technological, organisational environmental (usually defined in terms of external force) and institutional (mimetic, coercive and normative forces) factors. Empirical IS research of different IS have built on the above research and found sufficient evidence that these factors affect the organisations' ability to assimilate IS. Further, the growing importance of environmental sustainability entailed the incorporation of this concept in studying the use of IT/IS. Nevertheless, there is a need for theory-driven research that has identified or formulated the antecedent factors (from the above perspectives combined) for the assimilation and value of SIS in data centres. Against the backdrop of literature on SIS assimilation in data centres, the literature review from chapter 2, the exploratory study from chapter 3, and the relevant theoretical lenses from chapter 4, an integrated model (TOIN) of SIS assimilation and value is proposed. The proposed model has two parts: one is the assimilation part, which is discussed in this section, while another part is value, which will be discussed in the next section.

The underlying concept of TOIN postulates that the unique characteristic of the assimilated technology as well as the attribute of managerial knowledge offer valuable and heterogeneous resources and capabilities that facilitate the operational and environmental performance of data centres. In addition, the attribute of technology, the characteristic, structure and strategy of organisation, and the institutional isomorphism create a chain of effects that could drive or inhibit the assimilation of technology innovation. Moreover, it posits that the effects of institutional isomorphism as well as the effect of natural environmental forces that could drive the organisational efforts towards the successful assimilation of technology are mediated by the characteristic, structure and strategy of organisations.

The TOIN framework have allowed for the identification of the most relevant factors that were then justified through discussion in Chapter 4. An appropriate and rigorous research methodology was applied to validate and test the conceptual model and hypotheses as outlined in chapter 5. A research instrument was used to collect data through a survey of data centre managers and a series of procedures and steps were applied in chapter 6 to ensure that data is sound and free from errors. The evaluation of research instruments followed a set of rigorous scientific processes that were applicable to the existing research for evaluating the validity and reliability of reflective measurement models as outlined in chapter 7.

The test of research model using PLS revealed that the model explained 35% of SIS assimilation. The findings of this research have shown that factors including SIS compatibility, SIS perceived risk, Green IT/IS orientation, and normative pressure directly influence the level of SIS usage. The findings have also shown that normative pressure, energy pressure, and environmental preservation pressure indirectly affect the assimilation of SIS through top management support, Green IT/IS orientation, and data centre energy governance constructs. The moderation effects of the age and type of data centre on the assimilation of SIS were supported.

In conclusion, the nomological net of antecedent factors that explain the differences in the assimilation of SIS among data centres are informed by the TOIN framework. The model is capable of explaining 35% of the variance in SIS volume, SIS diversity, SIS use-intensity and SIS-integration intensity, which is an acceptable level.

The integrated TOIN framework is one of the first attempts to identify the nomological net of SIS assimilation since no previous model has been proposed to study the SIS assimilation in data centres. The results provided empirical evidence that SIS assimilation can be influenced by the technological, organisational, institutional and natural environment, as well as the data centre context.

10.2.3. What Are the Operational and Environmental Values of SIS Assimilation to Data Centres and What Drives Those Values?

The literature on data centres (section 2.3), revealed that two areas of performance were of high importance to the continuity of data centres businesses: operational and environmental performance. The operational performance includes cooling and thermal performance, and power and energy performance of CSSP and information processing performance of ICTP. The operations of CSSP and ICTP also involve environmental aspects. Environmental performance therefore refers to the efficiency of energy consumption and associated carbon emissions, water efficiency and e-waste. Energy has two sides, the operational side (cost of energy usage), and the environmental side (energy consumption and its related issues).

The IS literature from chapter 2 (section 2.7.3), also suggested that the conditions by which organisations can observe and harvest the IT value to improve their business performance are positively associated with a higher level of use as well as utilisation in actual circumstances. Thus, researchers argue that connecting the assimilation with the actual impact of technology use is equally important. Previous studies suggested that a resource-based view (RBV), and a natural resource-based view (NRBV), can be used to investigate the factors that can contribute to the value creation in operational and environmental terms. Further, deeper knowledge of managers' was observed as a facilitating condition for the absorption of capabilities that is required to innovate successfully. Nevertheless, there was a lack of empirical research that has tested the connection between SIS assimilation and its impact on data centres performance.

In terms of operational performance, cooling and thermal performance is concerned with the temperature and air distribution, and circulation to match the heat loads of data centres, whereases power and energy performance is concerned with the distribution of power grid within the data centres, and reduction of energy loss during power delivery and power conversion. Information processing performance is concerned with availability, agility and scalability and achieving those objectives while maintaining utilisations of IT equipment and optimum servers capacity.

As to the environmental performance, large energy consumption of non-renewable resources and its associated CO_2 emission is one of the major areas in which data centres need to improve their environmental footprint. The literature (e.g. sections 2.5 and 2.3.3) also show that IS, including SIS, are one of the technologies used for managing the business functions of data centres. A number of experimental studies on SIS application in data centres have shown that utilisations of SIS capabilities including monitoring, analysis and automations can potentially improve operational and environmental performance. These capabilities can help data centres to improve the visibility of data centres' vast operations, improve workload placement, improve energy efficiency, reduce the cost of running data centres, and CO_2 emissions, and improve compliance to regulatory requirements.

To investigate the value of SIS assimilation, understand the impact of SIS assimilation on data centre performance, and identify any other facilitating factors, the concepts of RBV and NRBV are used. While RBV posits that the greater the extent of heterogeneous resources, the most likely the firm is to develop capabilities that are rare, valuable and sustainable, NRBV posits that developing these capabilities is rooted in the heterogeneous resources that facilitate environmentally sustainable economic activity. This implies that through a more extensive usage of SIS capabilities and deeper manager knowledge about SIS, organisations would be able to create operational and environmental values.

A survey was used to gauge the respondents' value recognition from SIS usage to improve operational and environmental performance of data centre operations. For operational performance, the impact of SIS on the improvement of operational costs, information accuracy of data centre activities, energy efficiency, availability (uptime), visibility of activities, and predictive analysis and preventative measures was evaluated. For environmental performance, the impact of SIS on the improvements of data centre's energy consumption and compliance with regulatory environmental requirements was gauged. The results revealed that, on average, 71% of respondents harvested the SIS advantages to improve the operational performance and 51% have recognised the increase in the environmental performance.

A second-order model of value that has shown how the level of actual usage of SIS and SIS managers' knowledge positively impacts the operational and environmental performance of data centre operations including facility, cooling power and computing was tested. The model explained 34% of SIS value and revealed a significant impact on operational and environmental performance. The test also revealed that SIS mangers' knowledge contributes to the SIS value by improving the operational and environmental performance.

These new findings have revealed the actual value of SIS to data centres and have shown the actual impact of SIS on operational and environmental performance. As such, it has provided empirical evidence about SIS capabilities and their contribution to the automation and sustainability of data centres.

10.3. Limitations of the Study

There were some limitations to this study that could affect the interpretation of the results and thus need to be considered in recognising the theoretical and practical contribution of this study. As such, most of these limitations open the path for future research. *Firstly,* the cross-sectional nature of the survey used in the current study has provided a snapshot of the impact of technological, organisational, institutional and natural environment factors on SIS assimilation and value. Despite this, cross-sectional investigation does not allow for the evaluation of the long-term impact. SIS is an under-researched phenomenon, and the antecedents to the SIS assimilation and value in data centres under this status might require more time to be observed using longitudinal study. In particular, the impact of SIS usage on data centre performance would require a long period of time to materialise. Therefore, it recognition of operational and environmental value would take more time to develop and require continued observation. Thus, the interpretation of SIS value should be considered as preliminary.

Secondly, although the data were collected from a global sample, the theoretical and measurement model have not considered the factors that can explain the differences between several countries that exist in the sample. The intent of the research for taking a global sample was to know as much as possible about the research phenomenon, rather than looking at the difference between countries. It might be assumed that data centres residing in countries with soft regulatory intervention or those countries that promote the use of innovative technologies might have different conditions and priorities that could affect the use and value of technology. Thus, the generalisability of the findings to all data centres across different countries should be cautioned.

*Thirdly***,** in the current study, probability sampling techniques including simple random sampling or cluster sampling were not applicable. Thus, a non-probability sampling using purposive sampling was followed to sample the population more efficiently. This technique was used by IS researchers (Kraemer et al., 1991) to study the IS management knowledge (Bennett, 1998), the use of IT (Pijpers et al., 2001), CASE use (Purvis et al., 2001) and the ERP usage (Esteves, 2009). However, purposive sampling is not a probability sampling and should only be selected when the other probability sampling techniques are not applicable. This was explained in detail in Chapter 5. Considering the nature of the data source (LinkedIn), the researcher has carefully designed the criteria that can enhance the sampling validity and representation of the population and reduce the chance of bias by following suggestions from Allen (1971) and Bernard (2002), as discussed in Chapter 5. The carefully designed procedures have captured 1500 potential respondents who accounted for 35% of the entire population in LinkedIn database that hold the relevant job titles (which was 4312 members). This provides a good indication that the sampling technique applied has allowed the researcher to capture almost a third of the population. Despite the researcher having applied careful criteria for sampling in this study, it cannot be assured that the sample was an accurate representation of the entire population due to the limitation of purposive sampling. The researcher does not contend that the sampling was free from self-selection bias because it was carried out based on a non-probability sampling technique. Thus, there should be caution about the generalisation of the findings.

*Fourthly***,** the study used the same data set for evaluating the validity and reliability of the measurement model as well as for evaluating the structural model (estimation sample). It can be argued that setting aside a portion of the data set to evaluate how well the research model performs on the holdout data provide useful method that could provide stronger predictive and test-retest validity. Therefore, more caution is needed in respect to the generalisation of findings.

*Fifthly***,** the study used Partial Least Square (PLS) path modelling to test the research hypotheses. PLS is a structural equation modelling (SEM) tool that is often used by IS researchers as a tool of choice due to its ease of use, its suitability for small sample sizes and its ability to test and validate complex research models (Goodhue et al., 2006; Marcoulides et al., 2009; Albers, 2010). Despite this, some argue that PLS needs more careful attention especially in respect to the accuracy of statistical power at small sample sizes (e.g. 80), the lack of established global goodness-of-fit (GoF), and the misspecification of measurement models (Gefen and Straub, 2005; Henseler et al., 2009). Therefore, it is important for researchers intending to use PLS to opt for carefulness and pay more attention to these aspects. Nevertheless, a number of researchers contended that by keeping its limitations in mind, looking at its advantages with more caution, and following the guidelines of textbooks and seminal articles, PLS can be an adequate technique to accomplish validity and rigor for model evaluations and hypotheses testing (Henseler et al., 2009; Urbach and Ahlemann, 2010). Therefore, although the researcher has applied rigorous methods to test the reliability and validity of the research model, it must be acknowledged that established guidelines for GoF in PLS is developing and thus some might argue that there is a likelihood for very minor errors in the model's measurements.

Sixthly, the research collected the data from one single respondent from each organisation to avoid obtaining two or more responses from one data centre, as explained in chapter 5. There are advantages as well as disadvantages for in using this approach. The key informants were the people who occupy the position of 'data centre manager' who is the most knowledgeable person in relation to the questions being asked in this study. As such, managers of data centres provided a good representation for their organisations to serve the objective of this study. Although collecting data from single source is common in the conduct of empirical research, the views might only represent the opinions of those managers that could lead to Common Method Bias problems. Hence, some might argue that there is a need for multiple respondents. Three CMB tests were applied (see section 7.5.6) and no CMB problem was detected. However, because of the single respondents, the data might not be completely free from CMB.

Seventhly, the study has focused on a generic SIS rather than specific assimilation of particular SIS. Although the literature from section 2.7.2 shows studies that have investigated generic IS, most of the other studies were specific. By focusing on generic SIS, the characteristics of specific SIS on its assimilation and value were not investigated. However, it could be argued that the attribute of a particular SIS (such as BMS) can affect its level of assimilation and value. Thus, this issue need to be taken into consideration in generalising the findings across all types of SIS assimilation in data centres.

*Lastly***,** the indicators of latent variables used in the research instrument of the current study were initially designed as reflective measurements entirely. Thus the evaluation of measurement model of the research was only performed using the assessment of the reflective model. Unlike reflective measurements, formative measurements are typically designed to capture the latent construct in its entirety, and thus a researcher should decide on formative measurements at the very beginning of instrument's design.

It was decided to theorise that the instrument's items are reflective for two reasons. First, the items of each construct were designed in a way that allows them to covary and be correlated, unlike formative measurement. Second, the EFA was intended to be used for finding a better way to 'summarise' the information that is informed by a number of original variables and to 'reduce' them into a smaller number of factors that share the underlying dimension without compromising the original data. This process is likely to involve dropping some items. Unlike formative measurement, dropping an item in reflective measurement does not alter the meaning of the construct.

Although dependant variables including SIS assimilation and SIS value were designed as reflective measurements, they could also be measured formatively. As such, it can be argued that the results of the study including the explained variance and path coefficient values might be slightly different when these variables are considered as formative. Thus, this can be considered as one of the measurement evaluation limitations.

10.4. Theoretical Contributions

The current study has made a number of contributions to the body of knowledge in several ways.

*Firstly***,** the study has made an original contribution to IS assimilation research by proposing and validating the TOIN framework, which can serve as a theoretical foundation for future and related studies. It has synthesised previous work, the theoretical-based model on IS adoption, and studies of IS assimilation and its impact on the performance of data centres. Hence, the study has not only considered the classical IS innovation theories and previous study on the connection between IS assimilation and value (e.g. Ranganathan et al., 2004; Zhu and Kraemer, 2005; Rai et al., 2009), but also integrated emerging perspectives on the relationships between the natural environment and IT as well as the data centre-specific context, into an integrated research model. The study has contributed to the IS assimilation and value literature in section 2.6, as it has developed, validated and tested one of the first integrative frameworks of SIS assimilation and value that helped to identify drivers and challenges to the deployment, use and utilisation of SIS in the data centres industry. The TOIN framework offered an original contribution to the adoption and use theories (e.g. DOI, TOE) because it has extended these theories by incorporating the natural environmental dimension into the innovation use model. As such, IS researchers can use TOIN as a generic framework to investigate other IS in different domains.

*Secondly***,** given the lack of empirical academic research in the area of data centres as well as in the area of SIS, the study has contributed to an understanding of the determinants of SIS assimilation and SIS value. Therefore, the study represents one of the first empirical studies on the use and value of IS within the data centre environment using a more rigorous approach. The TOIN framework developed in this study coupled with global survey can be used to guide research about SIS and IS in general, and particularly in data centres. In addition, researchers can use this framework to investigate both the antecedents to the assimilation of SIS and other information systems used in the data centres as well as the outcome of use.

*Thirdly***,** the study is the first to examine SIS, as an exemplar solution of Green IS, to resolve the issues and problems of IT itself. As such, the study revealed that the application of SIS and use of its functionalities within the context of IT infrastructure management can effectively contribute to the improvement of the sustainability of large IT infrastructure such as data centres. Thus, the study has added to the emerging body of knowledge on Green IS/IT and IT for sustainability. The study has contributed to Green IT/IS literature by responding to the call for research and answering questions in the area of Green IS that utilise the advantage of intelligent sensors, IS and energy informatics. As such, it has conceptualised a framework of SIS use and value that can be used to study the impact of using of Green IS (e.g. SIS) on IT (e.g. data centres) and tested the model through empirical sample. In particular, it has contributed to the research direction (see section 2.2.1), adoption and use (see section 2.2.2) and value (see section 2.2.3) research. It have also explored and validated factors that affect the adoption, use and value of SIS. Thus, it has contributed to the innovation research in section 2.3.3 because it shows how SIS can improve the performance of data centres, and also contributed to the research that has studied factors related to the adoption, use and value of innovations in section 2.3.4.

*Fourthly***,** the study explored SIS, an emerging subfield of IS that have great prospects in respect to the management of large and critical IT infrastructure. It contributed to IS research by demonstrating how IS integrated with sensors can help to tackle some of the operational and environmental challenges of data centres. Thus, the study has added to the emerging body of knowledge on data centre automation.

The theoretical model developed in the current research elucidated the role of SIS usage in improving the performance of data centre operations through the potential of SIS to enhance the management capability of data centres and attain operational and environmental advantages. The result led to the conclusion that SIS has a positive impact on both operational and environmental performance of data centres. The developed model explained 35% of SIS assimilation and 34% of SIS value. Thus, the study has added to the existing body of knowledge on IS value and connection between technology assimilation and value (such as Ranganathan et al., 2004; Zhu and Kraemer, 2005; Rai et al., 2009), as it has provided early empirical evidence within the data centre context that has shown that a higher level of SIS use was associated with a greater level of SIS value. It also showed how the manager's depth of knowledge on SIS and its applications influenced the data centre's ability to realise the value of SIS.

The study has further contributed to the data centre literature (2.3) by extending the knowledge on how SIS as an IS innovation can be used to improve the operational and environmental performance of data centres. It has further contributed to the IS assimilation value literature in section 2.7.3 as it demonstrated the ability of SIS to create value to the business of data centres.

*Fifthly***,** the study has synthesised previous work on the application of SIS in general (section 2.4) and the application of SIS within the context of data centres (section 2.6). Most of that literature, if not all, was more skewed to the computer science discipline with scarce research in the field of information systems. Further, there was a lack of theory-driven research that has identified the antecedent factors to the use and value of SIS. Thus, the study has bridged the research from the computer science discipline and the field of information systems by using an exploratory study and a theoretical foundation from IS research. The study has also contributed to the literature on sensors as it is regarded as one of the sensor applications research in section 2.4.2. It further contributed to the literature of SIS adoption and use, and has investigated the use and value of SIS in data centres, thus contributing to section 2.5.2. It further contributed to the literature on SIS applications in data centres in section 2.6, as it is regarded as one of the first empirical studies that has investigated the utilisation of SIS in facility, cooling, power and computing operation management and SIS's overall impact on the business performance of data centres.

*Sixthly***,** it is one of the first studies that have empirically investigated the natural environment perspective within the context of SIS use and value in data centres. The study has shown how the natural environment (e.g. energy pressure, environmental preservation) and sustainability considerations (Green IT/IS orientation) significantly influence the organisational context to assimilate SIS in data centres. It also showed how organisation's trend towards Green IT/IS orientation increased their level of SIS assimilations. Thus, the research has added to the emerging body of knowledge on the influence of natural environment and sustainability on technology usage.

Seventhly, the study revealed that the age of the data centre can significantly control the assimilation of SIS. It has also reported that the type of data centre played a significant role in moderating the assimilation of SIS in the data centres. Thus, the study provided empirical evidence on the different segments between co-located, managed and corporate data centres with each having a unique characteristic. The findings of the study have contributed to a further understanding of the nature and state of SIS assimilation in data centres and the antecedents of this assimilation.

10.5. Practical Contributions

The research made a practical contribution to data centre management practices by providing some useful information for data centre mangers, IT manufacturers and system developers, industry associations, and regulatory agencies.

Firstly, in respect to data centre mangers, the research revealed success stories and reported how peer data centres utilised SIS to manage the business functions of ICTP and CSSP platforms. It has revealed that data centres managers can leverage the power of SIS to improve the sustainability of existing infrastructure. In addition, the study provided empirical evidence on how SIS applications can enhance the performance of data centres. Such benefits should encourage data centre executives to invest in SIS. Moreover, the study elaborated to the data centre owners and executives some of the important factors that affect the full utilisation of SIS. As such, data centre managers would need to review their overall strategies and criteria in respect to future investment in the types and features of new IT infrastructure, Green IT/IS technology policies, and energy governance policies. These can help to improve the overall efficiency and sustainability of infrastructure operations.

Further, the study provided valuable insights for the evaluation of the risks associated with the future of data centre businesses. It has shown that for data centres to stay competitive in a changing global environment, firms need to be prepared for changes resulting from external conditions. As SIS can be used to support the business of data centres, senior IT professionals in data centres need to understand the specific features underlying SIS and how to use these features more effectively to improve business performance.

*Secondly***,** in respect to the IT manufacturers and system developers, the study implied that there was a need to focus more on designing standardised products as well as bridging systems. By doing so, IT manufacturers and system developers can help to improve compatibility issues among the diversity of data centre infrastructure. In general, the study revealed that manufacturers and developers need to adhere to the latest industry standards in the development of new products.

In addition, the finding of the study can help the designers and developers to gain further understanding about the importance of SIS characteristics and data centre characteristics in the success of SIS adoption. This information would help them to improve some of the engineering aspects of data centres by providing insights about the role of sensors integration as well as the compatibility of hardware/software in the success of SIS market. The data centre managers, hardware manufactures and SIS developers need to establish a higher level of collaboration and information sharing in regard to the process of developing new SIS in a way that maximises the benefit of each party.

Thirdly, the study reported to leading industry associations that their leadership for SIS success in data centres was required. This can be done by taking the lead in the promotion of SIS applications and dissemination of SIS knowledge. Further, industry associations can introduce some of the industry and technical standards that would enhance the synchronisation and data exchange between SIS and diverse IT hardware and software in data centre industry.

Fourthly, the study offered some of the information that can be used by the regulatory agencies in data centre industry. It is expected that the reported findings of the study can be used to inform regulatory authorities about the important role that can be played by them in this regard. As such, the study has shown that developing more effective interventions by regulatory agencies can drive the use of SIS across the data centre industry.

10.6. Opportunities for Further Study

The findings of the study advance the knowledge and provide several opportunities for future studies in the area of the research. In addition, the limitations of the study acknowledged in section 10.3 open the path for future research.

Firstly, the study developed new constructs that were borrowed from the exploratory study (chapter 3) or developed by getting insights from data centres literature (section 2.3) or as a result of the EFA test. These included factors such as perceived SIS risk, data centre energy governance, energy pressure, environmental preservation pressure, and type, age and size of data centre as well as operational and environmental performance. Because these factors are new, they require more investigations. Therefore, future researchers need to further revalidate and retest these new constructs in order to understand their exact role in SIS assimilation and value and make decisions on the importance in the assimilation and value model.

Secondly, the study used cross-sectional approach for collecting the main data, which does not allow for the evaluation of the long-term impact of SIS on operational and environmental performance. However, future researchers, for example, might consider longitudinal observations of the operational and environmental performance to gain a better evaluation of SIS impact.

Thirdly, the data used in the study were collected from a global sample. The objective was to collect as much information as possible about the SIS use and value phenomenon. However, the study has not considered the difference that may exist between different countries. Future researchers have the opportunity to investigate the country-specific constructs and refine the current research model upon which to address these concerns.

Fourthly, due to the shortage of reliable commercial databases that classify the title of data centre managers, the current research had to use an alternative approach such as LinkedIn databases. Thus, probability sampling techniques were not applicable and this could have affected the generalisability of data. Future researchers may have access to databases that allow probability sampling of data centres, which would allow them to use better sampling techniques.

Fifthly, the study used the same data set for evaluating the validity and reliability of the measurement model as well as for evaluating the structural model (estimation sample). Future research can enhance the predictive validity of data by setting aside a portion of the data set to evaluate how well the research model performs.

Sixthly, the PLS path modelling was used in this study for model evaluation and hypotheses testing. The research has used rigorous methods to test the reliability and validity through PLS. However, future researchers can use PLS along with other SEM techniques such as

LISREL (e.g. the use of multiple analysis) to evaluate the research model and compare the results of PLS with LISREL results. This would provide more understanding and support for the usability and accuracy of PLS measurements.

Seventhly, Although all remedies have been employed to check for common method bias, the "consistency motif" (Podsakoff et al., 2003) is likely to be problematic especially when respondents provide retrospective accounts of attitudes and behavior. It can be argued that respondents will try to maintain consistency between motivation of SIS assimilation and the performance impact. Future researchers can reduce this likelihood by measuring the assimilation of SIS and the impact SIS on performance in two different contexts (e.g. avoiding the measurement of the SIS assimilation and the SIS value in the same survey).

Lastly, the TOIN framework is an integrated innovation assimilation model that links the use of innovation and innovation value. It is an extended model that advances the organisational adoption and use of innovation theories such as DOI, TOE as well as value theories such RBV and NRBV. TOIN incorporates the natural environment perspective as an emerging dimension to the success of technology use. Future researchers can re-test the TOIN model for SIS assimilation (focusing on specific type), Green IS assimilation or use it to study other generic or specific IS.

10.7. Final Concluding Remarks

While the sustainability of data centres remains one of the contemporary issues for global society, researchers, practitioners and developers are making a greater effort to develop and apply different innovative technologies to improve the performance of data centres. Through this research, the author investigated SIS as one of the innovative technologies. The study uncovered and examined the opportunities underlying SIS which make it an effective solution for the improvement of data centre performance.

Assimilating SIS into the daily practice of data centres is increasingly important. The findings reveal that data centres can leverage the capabilities of SIS to improve not only their operational performance, but also their environmental footprint. Hence, the contribution of SIS to the sustainability and automation of data centres by improving the operational and environmental performance of their operations is likely to increase in the future. This will provide rich ground for ongoing research on data centre sustainability and automation.

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APPENDIX 2A: DATA CENTRE BEST PRACTICE

A summary of Data Centre Best Practice

Best Practices	**Theme of best practices**							
Theme	**CSSP performance**		**ICTP performance**		**Operational advantages**		**Environmental advantages**	
	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
Air Management								
Optimising air performance	✓	-	-	✓	✓	-	-	✓
Free cooling systems	✓	-	-	-	✓	-	✓	✓
Liquid cooling systems	✓	-	-	-	✓	-	✓	✓
Direct cooling systems	✓	-	-	✓	✓	-	-	✓
Humidity systems and controls	✓	-	✓	-	-	✓	-	✓
Monitoring and control tools	✓	-	✓	-	-	✓	-	✓
Correct set of temperature and humidity	✓	-	-	-	✓	-	-	✓
Matching cooling to heat load	✓	-	-	-	✓	-	-	✓
Power Management								
Optimising UPS systems	✓	-	-	-	✓	-	-	✓
On-site power generation	-	✓	-	-	✓	-	-	-
Lighting efficiency	✓	-	-	-	✓	-	-	✓
Efficient power transformation	✓	-	-	-	✓	-	-	✓
Developing energy metrics	-	✓	-	✓	-	✓	-	✓
Computing Management								
Efficient stand-by power Sys.	✓	-	✓	-	✓	-	-	✓
Optimising power reliability	-	✓	✓	-	-	✓	-	-
Killing Comatose servers and storage	-	✓	✓	-	✓	-	-	✓
Selecting energy efficient IT hardware	-	✓	✓	-	✓	-	-	✓
IT consolidation & virtualisation	-	✓	✓	-	✓	✓	-	✓
Managing computing resources load and demand	✓	-	✓	-	✓	-	-	✓
Facility design								
Right-sizing the design	✓	-	✓	-	✓	-	-	✓
Optimising the central plant	✓	-	-	-	✓	-	-	✓
Zoning in smart-power *parks*	-	-	-	-	✓	-	✓	-
Room & building materials	✓	-	-	-	✓	-	-	✓
Infrastructure design								
Thermally efficient racks	✓	-	✓	-	✓	-	-	✓
Systematic checking and maintenance	✓	-	✓	-	-	✓	-	-
Rack-centric monitoring	✓	-	✓	✓	-	✓	-	-

APPENDIX 2B: A SUMMARY OF SENSOR CLASSIFICATIONS

Function	Signal Domain Class					
	Optical (Radiant) Sensors	**Magnetic Sensors**	**Thermal Sensors**	**Mechanical Sensors**	**Chemical (Biochemical) Sensors**	**Acoustic Sensors**
Sub-category Examples	Image sensors, infrared sensors,	Magnetic field sensors, hall plate sensors, pressure sensors,	Temperature sensors, Thermopile sensors		Electrochemical sensors, pH sensor, DNA sensors, enzyme-based sensors	
Parameters Measurement	Image Color light polarization luminance reflection	Magnetic field Electric field Frequency Movement Position Capacity	Temperature Thermal radiation Thermal expansion Thermal capacity Enthalpy	Acceleration Orientation Height Length Weight Movement Distance Position Pressure Vibration Density	Composition Concentration level Humidity Particle form & size pH-value Polymerization Degree Reaction level	Sound frequency Sound intensity Sound pressure Time of travel
Functionality Examples	Image sensors translate pictures into electrical signal	Magnetic field sensors translate movement activity into electrical signal	Temperature sensors translate weather temperature into electrical signal	Airbag sensors translate mechanical acceleration into electrical signal	DNA sensor translate Biochemical parameters into electrical signal	Radar sensor translate sound parameters into electrical signal
Application Domain	Scientific research Transportation Security Residential Agriculture	Security Scientific research	Industrial Residential Agriculture	Automotive Built Agriculture Industrial	Medical Industrial Agriculture	Scientific research Medical Security
Application Examples	Managing traffic lights Analysing fingerprint	Detecting object movement	Measuring weather temperature	Triggering Airbag safety Failure diagnostic	Analysing blood sample. Analysing toxic level	Analysing animal sound frequency. Measuring distance

APPENDIX 4A: DIFFERENT FACTORS USED IN TECHNOLOGY ASSIMILATION LITERATURE

Factor	Fichman and Kemerer	McGowan and Madey	Purvis et al.,	Ihlsoon and Young-Gul,	Chatterjee et al	Ranganathan et al.	Zhu and Kraemer	Hsu et al.,	Raymond et al.,
Learning-related scale	✓*								
Diversity of organizational knowledge	✓*								
Functional differentiation		✓*							
Training availability		✓*							
Methodology compatibility			✓*						
Knowledge embeddedness			✓*						
Expectation for market trend				✓					
Maturity of technology				✓*					
Intensity of new technology education				✓*					
Satisfaction with existing technology				✓*					
Strategic investment rationale					✓*				
Extent of coordination					✓*				
Supplier interdependence						✓*			
IT activity intensity						✓			
Competitive intensity						✓			
Financial commitment							✓*		
Trading partner pressure								✓*	
Government pressure								✓*	
Regulatory Concern								✓*	
Manufacturing technologies									✓*
Networking intensity									✓*

APPENDIX 5A: INSTRUMENT'S POOL OF ITEMS AND OPERATIONALISATION

Variable	Measure	Number of items & Scale	Reference
SIS Volume	Number of SIS used in the data centre	one item- list of items and open-ended text	Massetti & Zmud 1996; Liang et al.., 2007; Case study
SIS Diversity	Number of data centre functional areas that is supported by SIS	6 items — three point Likert scale)	Massetti & Zmud 1996; Liang et al., 2007 & Case study
SIS Use-Intensity	Respondents were asked to assess the extent to which SIS functionalities are used in performing the business processes of each functional area identified above.	10 items — 6 point Likert scale)	Ravichandran, 2005 and Case Study
SIS Integration-Intensity	Respondents were asked to assess the extent to which existing SIS are integrated with ICTP platform, CSSP platform, and other IS.	6 items — 6 point Likert scale	Ravichandran, 2005 and Case Study
SIS Value	Respondents were asked to evaluate the extent of improvement in the operational and environmental performance of data centre business as a result of SIS use.	8 items — 5 point Likert scale	*Ranganathan, et al., 2004*; Moore et al., 2005; Case Study
Relative Advantage	Respondents were asked to compare the relative advantages of SIS's ability to (a) manage facility and assets, (b) enhance efficiency of cooling system, (c) enhance visibility of power management, and (d) enhance performance of IT operations.	4 items — 5 point Likert scale	Roger (1983); Ihlsoon and Young-Gul, 2001; Liao and Lu, 2008 and Case Study
SIS Compatibility	Respondents were asked to assess the compatibly of SIS with data centre equipment; value and norms; the existing expertise; and management practice	4 items — 5 point Likert scale	Roger (1983); Ihlsoon and Young-Gul, 2001; Liao and Lu, 2008
SIS Complexity	Respondents were asked to assess the complexity of using, integrating and understanding SIS	3 items — 5 point Likert scale	Roger (1983); Ihlsoon and Young-Gul, 2001; Liao and Lu, 2008 and Case Study
Perceived. Uncertainty	Respondents were asked about the uncertainty of SIS in terms of standardisation, compatible system components, experts abundance, and maturity and uniqueness	5 items — 5 point Likert scale	Fichman, and Kemerer (1993); Son et al. (2005) and Ravichandran (2005); Ihlsoon and Young-Gul, 2001
Top Management Support	Respondents were asked to what extent the senior management actively discusses data centre issues, articulates a vision to use smart management software, and establishes goals standards for the sustainability	4 items — 5 point Likert scale	Meyer & Goes, 1988; Attewell, 1992; Chatterjee et al., 2002
Green IT/IS Orientation	Respondents were asked about the existence of some policies in their data centre including purchase of energy efficient systems, upgrade to energy efficient systems, retirement of energy	6 items — 3 point Likert scale	Chen et al., 2009; Case Study

	inefficient systems, measurement of environmental performance and incorporation of environmental considerations in the design.		
Data Centre Energy Governance	Respondents were asked to indicate whether they get a separate energy bill for data cenre; energy bill is part of data centre budget; have targets to reduce the energy consumption, and have a policy enhancing the visibility of data centre energy consumption	4 items — 5 point Likert scale	Case Study
Coercive Pressure	Respondents were asked to what extent the pressure from current and/or foreseeable regulations for reducing the energy consumption and for reporting environmental footprint, pressure from our major data centre suppliers, and pressure from the competitive conditions drive their decision to use SIS	4 items — 6 point Likert scale	Chen et al. (2009); Liang et al., 2007; Case Study
Normative Pressure	Respondents were asked to indicate the level of SIS use by external and/or internal clients, other data centres, the level of participation in professional, trade and business bodies that promote and disseminate information on SIS adoption and level of green data centre certification.	4 items — 6 point Likert scale	Teo et al., 2003 Liang etl., 2007; and Case Study
Energy Pressure	Respondents were asked to what extent the rising energy price, cost of energy consumption, growth of energy need, current and/or foreseeable accessibility to energy and data centre design constraints drive their decision to use SIS	5 items — 6 point Likert scale	Case Study; Loper & Parr, 2007)
Environmental Preservation Pressure	Respondents were asked to what extent the natural environment pressure in respect to the volume of non-renewable energy sources, CO_2 emissions and hardware lifecycle drive their decision to use SIS.	3 items — 6 point Likert scale	Case Study
Knowledge Stock of Manager	Respondents were asked to indicate the level of knowledge about SIS features, technical skills required for SIS, business processes for which SIS can be utilised and technical issues arising from SIS implementation.	4 items — 5 point Likert scale	(Ravichandran, 2005); Attewell, 1992).

APPENDIX 5B: PANEL EXPERT INVITATION LETTER AND QUESTIONNAIRE

Invitation Letter

Dear.

I am a PhD scholar at the school of Business Information Technology and Logistics at RMIT University, Australia. This letter refers to a panel of experts study that aims to validate the research instrument of a PhD research. You have been approached due to your outstanding expertise and knowledge in the information technology discipline. I am writing to you, to ask you to help me with the instrument development by answering my panel of experts questionnaire. I got your contact details from your publications in journals and conferences or your professional profile published in your organisation homepages. I invite you to kindly participate in this study by reviewing some of the items used in our instrument and provide us with your valuable feedback about important aspects including the relevance, quality, measures and the adequacy of items to inform the scales.

The aim of this research is to examine the factors that explain variation in the use of Information Systems, particularly Sensor Information Systems (SIS) and the value of SIS to data centres in order to design theoretical model for SIS use and value. SIS refers to any information system that uses sensors which are directly or indirectly connected to one or more sensors or sensor network in order to automate, inform and/or transform a given task or process or appliance. Due to the lack of literature in this field of knowledge, we have conducted an exploratory study comprising interviews with five Australian data centres managers in order to gain better understanding about this phenomenon. In addition to the use constructs identified from past IS literature, the exploratory study has engendered additional new constructs which have not been tested before. Thus, examining and validating the constructs' scales by knowledgeable academic and practitioners is a must to verify the appropriateness of the proposed items and their measures. Only the new constructs are included in this study.

I believe your expertise to be of valuable input in developing and refining the research instrument. Please kindly visit the short online questionnaire on http://SIS-Experts.questionpro.com and provide us with your valuable feedback. Your inputs and insights to this study are highly appreciated. We thank you in advance for your participation and contribution!

Yours Sincerely

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Panel of Experts Questionnaire

The aim of this research is to examine the factors that explain variation in the use of Information Systems, particularly, Sensor Information Systems (SIS) and the value of SIS to data centres. SIS refers to any information system that uses sensors which are directly or indirectly connected to one or more sensors or sensor network in order to automate, inform and/or transform a given task or process or appliance. A number of variables are identified to explain the variation in the use of SIS and their value. A survey questionnaire is prepared and is now being tested. You are invited to participate in this test survey as you are identified as a knowledgeable person – "expert"- in the area of the study.

In the questionnaire below, the variable of interest and its definition are provided in the first column. The items we propose to use to measure that particular variable are listed in second column. The first sentence under the second column of each variable indicates the scale and instruction I intend to use in the final survey. For each of the items listed, please indicate its relevance (insert Y= relevant or N= Not relevant) as a measurement of the variable as defined in the first column. Please also indicate if the listed items sufficiently cover the variable. If you have any comment, please add those n the space provided.

Variable	**Proposed Items**	**The Expert Feedback**	
		Relevant ? Insert Y or N	**Overall Assessment**
SIS Diversity (SD) (Number of data centre functional areas that is supported by SIS)	**(4 Items. Yes/No)** *Our organisation uses SIS to support the following functional areas of the data centre*		*Do you believe the proposed items are sufficient to measure the variable?* **Yes** ☐ **No**☐ ***Expert Comments:*** ....
	SD1: facility site management		
	SD2: cooling management		
	SD3: power management		
	SD4: IT operations management		
SIS Use-Intensity (SI) (Refers to Breadth and Depth: Breadth represents the extent to which data centres have used a SIS to conduct routine functions and depth refers to the degree of SIS functionalities that has been established in performing the business processes of data centres.)	**(11 Items. Six Likert 0 =not at all, 1 = very low; 5 = very high)** *To what extent do you perform the following data centre functions using SIS*		*Do you believe the proposed items are sufficient to measure the variable?* **Yes** ☐ **No**☐ ***Expert Comments:*** ....
	SI1: Control the operations of lighting, surveillance and other facility equipments	*YES*☐ *No*☐	
	SI2: Get real time information about important and/or time sensitive change in the behaviour of data centre equipments	*YES*☐ *No*☐	
	SI3: Electronically monitor the data centre temperature and humidity and report the information back in real time	*YES*☐ *No*☐	
	SI4: Automate the management of cooling operations.	*YES*☐ *No*☐	
	SI5: Electronically control the security and safety of data centre assets	*YES*☐ *No*☐	
	SI6: Undertake detailed analysis about the thermal activities of the data centre using historical and real-time information	*YES*☐ *No*☐	
	SI7: Measure the power that goes into each equipment.	*YES*☐ *No*☐	
	SI8: Electronically monitor the operations and status of IT hardware including servers, network, and storage devices and report the information back in real time	*YES*☐ *No*☐	
	SI9: Automate the control of the power systems operations including PDU, on-site generator and	*YES*☐ *No*☐	

	other power equipment.		
	SI10: Synchronise the operations and workload between different data centre platforms (i.e. cooling, power and/or computing).	*YES*☐ *No*☐	
	SI11: Automate the management and control of IT operations	*YES*☐ *No*☐	
SIS Integration-Intensity (SBI) (refers to the degree of inter-connectivity, collaboration, exchange and synchronisation between the components of the two data centre platforms- facility cite and IT.)	**(3 Items. Six Likert scale. 0 =not at all, 1 = very low; 5 = very high)** *Please indicate*		*Do you believe the proposed items are sufficient to measure the variable?* **Yes** ☐ **No**☐ ***Expert Comments:*** ....
	SBI1: the extent to which SIS is integrated with the systems of facility platform (i.e. cooling, power, auxiliaries).	*YES*☐ *No*☐	
	SBI2: the extent to which SIS is integrated with the systems of IT platform (i.e. servers, network, storage).	*YES*☐ *No*☐	
	SBI3: The extent to which SIS is integrated with other information systems we use to manage data centre operations	*YES*☐ *No*☐	
SIS Value (SV) (The impact of SIS on operational and environmental performance of data centres)	**(13 Items. Five Likert scale 1= strongly disagree; 5 = strongly agree)** *By using SIS in our data centre*		*Do you believe the proposed items are sufficient to measure the variable?* **Yes** ☐ **No**☐ ***Expert Comments:*** ....
	SVO1: operational costs reduced	*YES*☐ *No*☐	
	SVO2: information quality and accuracy increased	*YES*☐ *No*☐	
	SVO3: Response time and responsiveness of systems improved	*YES*☐ *No*☐	
	SVO4: energy efficiency improved	*YES*☐ *No*☐	
	SVO5: availability (uptime) of data centre increased	*YES*☐ *No*☐	
	SVO6: security and safety of data centre asset increased	*YES*☐ *No*☐	
	SVO7: management and control of operations enhanced.	*YES*☐ *No*☐	
	SVO8: visibility of energy consumption improved	*YES*☐ *No*☐	
	SVO9: effort in overall data centre management reduced	*YES*☐ *No*☐	
	SVO10: energy consumption reduced.	*YES*☐ *No*☐	
	SVO11: eco-sustainability strategy enhanced.	*YES*☐ *No*☐	
	SVO12: environmental footprint reduced.	*YES*☐ *No*☐	
	SVO13: compliance to eco-sustainability requirements improved	*YES*☐ *No*☐	
Green Data Centre Orientation (GDO) (refers to the incorporation of natural environment consideration to use (or upgrade or purchase)	**(7 Items. Y/N)** *Our organisation has*		*Do you believe the proposed items are sufficient to measure the variable?* **Yes** ☐ **No**☐ ***Expert Comments:*** ....
	GDO1: an active strategy or policy to reduce the energy	**YES**☐ **No**☐	
	consumption of IT (i.e. through virtualization, workload management software, etc.)	*YES*☐ *No*☐	
	GDO2: an active strategy or policy to purchase and/or install more energy efficient systems in the data centre(s)	*YES*☐ *No*☐	
	GDO3: an active strategy or policy to upgrade and/or retrofit energy inefficient systems in the data centre(s)	*YES*☐ *No*☐	

technology and/or systems that can improve the overall performance for the aim of minimising the environmental impact of an organisation.	GDO4: an active strategy or policy to retirement of energy inefficient systems in the data centre(s)	*YES*☐ *No*☐	
	GDO5: an active strategy or policy for measuring the energy consumption of the data centre..	*YES*☐ *No*☐	
	GDO6: an active strategy or policy for measuring the environmental footprint of the data centre	*YES*☐ *No*☐	
	GDO7: Environmental factors are always considered as a priority in the design of data centre	*YES*☐ *No*☐	
Data Centre Governance (DCG) (Data centres governance refers to the existing strategies or procedures with respect to the accountability and responsibility of energy efficiency and operations transparency.)	**(7 Items. Five Likert scale. 1= strongly disagree; 5 = strongly agree)**		*Do you believe the proposed items are sufficient to measure the variable?* **Yes** ☐ **No**☐ ***Expert Comments:*** ....
	DCG1: Our IT department is totally responsible for the energy consumption of the Data Centre	*YES*☐ *No*☐	
	DCG2:We get a separate energy bill for the Data Centre	*YES*☐ *No*☐	
	DCG3:Energy bill is part of our data centre budget	*YES*☐ *No*☐	
	DCG4: Our IT Budget is allocated to install software to improve the operation of data centre	*YES*☐ *No*☐	
	DCG5: We have set targets to reduce the energy consumption of data centre	*YES*☐ *No*☐	
	DCG6: Our organization has a clear policy for measuring the environmental footprint of our data centre	*YES*☐ *No*☐	
	DCG7: Our organization has a clear policy for enhancing the visibility of data centre operations to establish better transparency.	*YES*☐ *No*☐	
Energy consumption (EC) refers to the extent to which energy related issues drive the decision to use specialised SIS in the data centre	**(4 Items. Six Likert scale. 0 =not at all, 1 = very low; 5 = very high)** *To what extent the following issues drive the decision to use specialised SIS in your data centre*		*Do you believe the proposed items are sufficient to measure the variable?* **Yes** ☐ **No**☐ ***Expert Comments:*** ....
	EC1: Rising energy price	*YES*☐ *No*☐	
	EC2: Cost of Data Centre energy (power and cool) consumption	*YES*☐ *No*☐	
	EC3: Growth of energy use to power and cool Data Centres	*YES*☐ *No*☐	
	EC4: Availability of energy to power and cool Data Centre	*YES*☐ *No*☐	
Natural Resource (NC) refers to the extent to which natural environmental resource related issues drive the decision to use specialised SIS in the data centre.	**(3 Items. Six Likert scale. 0 =not at all, 1 = very low; 5 = very high)** *To what extent the following issues drive the decision to use specialised SIS in your data centre*		*Do you believe the proposed items are sufficient to measure the variable?* **Yes** ☐ **No**☐ ***Expert Comments:*** ....
	NC1: Data centre contribution to Co2 emissions	*YES*☐ *No*☐	
	NC2: Data centre contribution to non-renewable resources degradation.	*YES*☐ *No*☐	
	NC3:The environmental impact of Data Centres	*YES*☐ *No*☐	
	SBI3: The extent to which SIS is integrated with other information systems we use to manage data centre operations	*YES*☐ *No*☐	
Knowledge Stock (KS)	**(4 Items. Five Likert scale. 1= strongly disagree; 5 = strongly agree)** *My organisation has a very good knowledge about*		*Do you believe the proposed items are sufficient to measure the*
	KS1: the features, capabilities and requirements of SIS.	*YES*☐ *No*☐	

(The knowledge stock refers to the managerial receptivity of know-what, know-how, and know-why which are required to successfully assimilate SIS in the data centres.)	KS3: the type of technical and training skills required to operate SIS	*YES*☐ *No*☐	*variable?* **Yes** ☐ **No**☐ ***Expert Comments:*** ....
	KS3: the type of systems or business process for which SIS can be utilised.	*YES*☐ *No*☐	
	KS4: The technical issues that may arise from the implementation of SIS	*YES*☐ *No*☐	

APPENDIX 5C: PANEL EXPERT TEST RESULTS

Agreement on items relevance to the construct measured

	Resp No.	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	Relevant /Yes	Not Relevant /No	Agreement
SIS Diversity (SD)	SD1	1	1	2	1	2	1	1	1	1	1	1	2	1	1	11	3	78.57%
	SD2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SD3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SD4	1	1	1	1	2	1	1	1	1	1	1	2	1	1	12	2	85.71%
SIS Use-Intensity(SI)	SI1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SI2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SI3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SI4	1	1	1	1	1	1	1	1	1	1	1	1	1	2	13	1	92.86%
	SI5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SI6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SI7	1	1	1	1	1	1	1	1	2	1	1	1	1	1	13	1	92.86%
	SI8	1	1	1	1	1	1	1	1	1	1	1	2	1	1	13	1	92.86%
	SI9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SI10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SI11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
SIS Integration-Intensity (SBI)	SBI1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SBI2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SBI3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
SIS Value(SV)	SVO1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SVO2	1	1	1	1	2	1	1	1	1	1	1	1	1	1	13	1	92.86%
	SVO3	1	1	1	1	1	1	1	2	1	1	1	1	1	1	13	1	92.86%
	SVO4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SVO5	1	1	1	1	1	1	1	2	1	1	1	1	1	1	13	1	92.86%
	SVO6	1	1	1	1	1	1	1	1	1	1	1	1	2	1	13	1	92.86%
	SVO7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SVO8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SVO9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SVO10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SVO11	1	1	1	1	1	1	1	1	1	1	1	2	1	1	13	1	92.86%
	SVO12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	SVO13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
Green Data Centre Orientation(GDO)	GDO1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	GDO2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	GDO3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	GDO4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	GDO5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	GDO6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	GDO7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
Data Centre Governance(DCG)	DCG1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	13	1	92.86%
	DCG2	1	1	1	1	1	1	1	2	1	1	1	1	1	1	13	1	92.86%
	DCG3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	DCG4	1	1	1	1	1	1	1	1	1	1	1	1	2	1	13	1	92.86%
	DCG5	1	1	1	1	1	1	1	1	1	1	1	1	2	1	13	1	92.86%
	DCG6	1	1	1	1	1	1	1	1	1	1	1	1	2	1	13	1	92.86%
	DCG7	1	1	1	1	1	1	1	1	1	1	1	1	2	1	13	1	92.86%
Energy Consumption(EC)	EC1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	EC2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	EC3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	EC4	1	1	1	1	1	1	1	1	1	1	1	1	2	1	13	1	92.86%
7- Natural	NC1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%

Resource(NC)																		
	NC2	1	1	1	1	1	1	1	1	1	1	1	1	2	1	13	1	92.86%
	NC3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
Knowledge Stock(KS)	**KS1**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	0	100.00%
	KS3	2	1	1	1	2	1	1	2	1	1	1	1	1	1	11	3	78.57%
	KS3	1	1	1	1	2	1	1	1	1	1	1	1	1	1	13	1	92.86%
	KS4	1	1	1	1	2	1	1	1	1	1	1	1	1	1	13	1	92.86%
	56																	
		55	56	55	56	49	56	56	52	55	56	56	52	49	55			
		1	0	1	0	7	0	1	4	1	0	0	4	7	1			
Overall Respondent Agreement		98.2%	100.0%	98.2%	100.0%	87.5%	100.0%	100.0%	92.9%	98.2%	100.0%	100.0%	92.9%	87.5%	98.2%			

Agreements on items adequacy to measure the construct

	Adequacy of Variable Items	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	Yes	No	Agreement
1	**SIS Diversity(SD)**	2	1	2	1	2	1	2	1	1	1	2	2	1	1	8	6	57.14%
2	**SIS Intensity(SI)**	1	2	1	1	2	1	1	1	1	1	1	1	1	1	12	2	85.71%
3	**SIS Integration(SBI)**	2	2	1	1	2	1	1	2	1	1	1	1	1	1	10	4	71.43%
4	**SIS Value(SV)**	1	2	1	1	2	1	1	1	1	1	1	1	1	1	12	2	85.71%
5	**Green Data Centre Orientation(GDO)**	1	1	1	1	2	1	1	1	1	1	1	1	1	1	13	1	92.86%
6	**Data Centre Governance(DCG)**	1	1	1	1	2	1	1	1	1	1	1	1	2	1	12	2	85.71%
7	**Energy Consumption(EC)**	2	1	1	1	2	2	1	2	1	1	2	1	1	1	9	5	64.29%
8	**Natural Resource(NC)**	1	1	1	2	2	2	1	2	1	1	2	1	1	1	9	5	64.29%
9	**Knowledge Stock(KS)**	2	1	1	1	2	1	1	1	1	1	1	1	1	1	12	2	85.71%
		5	6	8	8	0	7	8	6	9	9	6	8	8	9			
		4	3	1	1	14	2	1	3	0	0	3	1	1	1			
	Overall Respondent Agreement	55.6%	66.7%	88.9%	88.9%	0.0%	77.8%	88.9%	66.7%	100.0%	100.0%	66.7%	88.9%	88.9%	100.0%			

APPENDIX 5D: PLAIN LANGUAGE STATEMENT AND ONLINE QUESTIONNAIRE

Plain Language Statement

INVITATION TO PARTICIPATE IN A RESEARCH PROJECT

Project Title:
Modeling the Assimilation and Value of Sensor-Based Management Information Systems in Data Centers

Investigators:
Mr. Adel Alaraifi, PhD scholar, School of Business Information Technology and logistics, RMIT University, Adel.alaraifi@rmit.edu.au, (+61 3 9925 5672).

Supervisors,
Assoc. Prof. Alemayehu Molla, Senior Supervisor, School of Business Information Technology and logistics, RMIT University, Alemayehu.molla@rmit.edu.au, (+61 3 99255803),

Prof. Hepu Deng, Second Supervisor, Business Information Technology and logistics, RMIT University Hepu.deng@rmit.edu.au, (+61 3 9925 5823).

Dear Participant

You are invited to complete a 10 minute (approximately) questionnaire for a research project being conducted by RMIT University. This information sheet describes the project in straightforward language. Please read this sheet carefully and ensure that you understand its contents before deciding whether to participate. If you have any questions about the project, please feel free to ask the investigator or his supervisors.

This research is being conducted by Adel Alaraifi, a PhD scholar from the School of Business Information Technology and logistics at RMIT University, Melbourne, Australia. The research is supervised by Associate Professor. Alemayehu Molla and Professor. Hepu Deng. The aim of this research is to contribute to the practice of Data Center Management by developing a road map for the use of Sensor Information Systems (SIS). SIS is a term used to describe diverse types of management software that utilize the data of sensors (e.g., temperature, load, and flow) to support the management and operations of facility, cooling, power, and computing platforms (e.g., Building Management System (BMS), Tivoli Monitoring, and InfraStruXure Central). This research project has been approved by the RMIT University Business College Human Ethics Advisory Network.

The research seeks to explore the extent to which SIS is used in data centers, the value of SIS usage to data centers, and the factors that explain the differences in the use of SIS among data centers. To obtain a rich knowledge about the research phenomenon, and enhance the researcher's understanding of the current state of SIS usage in the data centers, managers of data centers from all over the world will be invited to participate in a survey questionnaire.

You have been approached because you are the most knowledgeable person about the data center management issues. As a participant, you will be asked to kindly answer some questions relevant to the above objectives. The survey comprises three sections (basic information, system use and value, and factors influencing system use). The project will use QuestionPro Survey services, a third-party site, to collect data in a survey format. If you agree to participate in the survey, the responses you provide will be stored on a secure server that is managed by QuestionPro. Once we have completed our data collection, we will import the data we collect to the RMIT server.

The survey is 'anonymous' and will not collect personal data that is identifiable. Your identity and your organization's identity will remain anonymous. No personal information will be collected in the survey, so none will be stored as data. Your responses will be securely stored for a period of five years in the School of Business Information Technology and Logistics, RMIT University and can only be accessed by the principal investigator and his supervisors. After five years, it will be destroyed. The data collected will be analyzed and used anonymously as output for a PhD dissertation. The results may be published in academic journals and conferences without including information that could potentially identify either you or your organization.

As in the case of using any Internet-based services, users should be aware that the World Wide Web is an insecure public network that gives rise to the potential risk that a user's transactions may being viewed, intercepted, or modified by third parties or that data that the user downloads may contain computer viruses or other defects.

There are no foreseen risks associated with your participation in this research project. The benefits of participating in this research include assisting the overall development of SIS technology and developing a sound understanding of the use and value of Sensor-Based Information Systems in data centers. In addition, practitioners and academics would likely benefit from the output of the research. If you require, you will also receive a summary of the results of the study when it is completed. If you chose to do so, please advise the investigator of your interest. After completing the questionnaire, a link leading to the page for a report request will appear, and you will need to click on the link to enter your email address. Your email address will not be used for any purpose other than sending the result summary report.

Any information that you provide can be disclosed by RMIT only if (1) it is to protect you or others from harm, (2) a court order is produced, or (3) you provide the researchers with written permission.

Your participation in this research is voluntary. As a participant, you have the right to withdraw your participation at any time without prejudice; have any unprocessed data withdrawn and destroyed, provided it can be reliably identified and provided that so doing does not increase your risk; and have any questions answered at any time.

If you are unduly concerned about your responses to any of the survey questions or if you find participation in the project distressing, you can contact my supervisors at the address given below as soon as convenient. We will discuss your concerns with you confidentially and suggest appropriate follow-up measures if necessary"

Any complaints about your participation in this project may be directed to the Chair, Business College Human Ethics Advisory Network, College of Business, RMIT, GPO Box 2476V, Melbourne, 3001, Australia. The telephone number is +61 3 9925 5598 or email address rdu@rmit.edu.au. Details of the complaints procedure are available from http://www.rmit.edu.au/browse;ID=2jqrnb7hnpyo

If you need any further information regarding this research, please contact the researchers at the address below. Due to the nature of the data collection process, we do not require written consent from you. Please note that by completing and returning the survey, it is assumed that you consent to participation. If you agree to participate please visit the link http://SIS.questionpro.com and follow the directions to complete the survey. Your participation in this study is highly appreciated.

Yours sincerely

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Online Questionnaire

SVO1: Please indicate which one or more of the following Sensor Information Systems (SIS) are currently used in your data centre (please tick more than one if applicable) *(SIS volume)*

1. Building Management Systems (BMS)
2. Tivoli family products (monitoring/management of power and IT)
3. InfraStruXure family products (Central, Management, Capacity)
4. OpenManage Management tool
5. Insight Power Manager
6. Energy Wise
7. Nimsoft Server Monitoring
8. Data Center Service Management
9. Data Center Automation Center
10. Workload Automation
11. Others, please list

___

Please indicate to what extent your organisation uses SIS to support the following functional areas of the data centre *(SIS diversity- this was used as one ratio item[SDavr] in the analysis by calculating the percentage [1/6])*

Item		Not adopted	Adoption planned	Currently adopted
SDavr	Management of the facility systems (e.g., lighting, racks security).	❑	❑	❑
	Management of cooling systems operation load.	❑	❑	❑
	Management of data centre thermal load.	❑	❑	❑
	Management of power systems load.	❑	❑	❑
	Management of data centre power usage.	❑	❑	❑
	Management of IT resources load.	❑	❑	❑

Please indicate to what extent do you perform the following data centre functions using Sensor-Based Management Information Systems (SIS)? *(SIS use–intensity: this was transformed into percentage [average of use–intensity for each functionality])*

Item		Not used	Very low	2	3	4	Very high
Aut	*Automation:*						
	Automate the operations of lighting in the data centre.	❑	❑	❑	❑	❑	❑
	Automate the workload of cooling systems in the data centre.	❑	❑	❑	❑	❑	❑
	Automate the load of power systems in the data centre.	❑	❑	❑	❑	❑	❑
	Automate the workload distribution of IT resources in the data centre.	❑	❑	❑	❑	❑	❑
Mon	*Monitoring:*						
	Electronically measure the electricity power coming into the data centre.	❑	❑	❑	❑	❑	❑
	Electronically measure the electricity power	❑	❑	❑	❑	❑	❑

	going into cooling and computing systems.						
	Electronically monitor the status of IT hardware in real time.	❑	❑	❑	❑	❑	❑
Anz	*Analysing:*						
	Get real time information about time-sensitive changes in the behaviour of CPU and PDU.	❑	❑	❑	❑	❑	❑
	Perform detailed analysis of the thermal activities of the data centre using real-time information.	❑	❑	❑	❑	❑	❑
	Perform historical analyses of power capacity for predictive pro-active activities.	❑	❑	❑	❑	❑	❑

Please indicate the extent to which SIS are *((SIS integration–intensity: this was transformed into percentage [average of integration –intensity for each platform])*

Item		Not integrated	Very low	2	3	4	Very high
SB_ CSSP	*Integration with CSSP:*						
	Integrated with facility systems (e.g., lighting, racks security).	❑	❑	❑	❑	❑	❑
	Integrated with cooling systems.	❑	❑	❑	❑	❑	❑
	Integrated with power systems.	❑	❑	❑	❑	❑	❑
SB_ ICTP	*Integration with ICTP:*						
	Integrated with computing systems (e.g., server, network, storage).	❑	❑	❑	❑	❑	❑
SB_IS	*Integration with IS:*						
	Integrated with each other.	❑	❑	❑	❑	❑	❑
	Integrated with other information systems used to manage data centre operations.	❑	❑	❑	❑	❑	❑

Please indicate to what extent do you agree or disagree with the following statements. We believe that

Item		Strongly Disagree	2	3	4	Strongly Agree
TM1	Using SIS are compatible with most components of our data centre equipment.	❑	❑	❑	❑	❑
TM2	The requirements of SIS are compatible with the values, norms and practices of our IT organisation.	❑	❑	❑	❑	❑
TM3	SIS's technical requirements are similar to the expertise we have developed with other systems	❑	❑	❑	❑	❑
TM4	Using SIS fits into our data centre management practice.	❑	❑	❑	❑	❑
TC1	SIS are complex to use.	❑	❑	❑	❑	❑
TC2	Integration of SIS into data centre infrastructure is a complex process.	❑	❑	❑	❑	❑

TC3	SIS are difficult to understand from technical perspective.	❑	❑	❑	❑	❑
PTU1	SIS technology would not be standardised in the data centres industry in the future.	❑	❑	❑	❑	❑
PTU2	SIS compatible system components would not be easily available from existing vendors.	❑	❑	❑	❑	❑
PTU3	Technical experts in SIS technology would be abundant in the IT industry.	❑	❑	❑	❑	❑
PTU4	It was too early to invest in SIS, because the technology was still immature.	❑	❑	❑	❑	❑
PTU5	Other management software/platforms would be more promising than SIS.	❑	❑	❑	❑	❑

Our IT department has a very good knowledge of

Item		Strongly Disagree	2	3	4	Strongly Agree
KS1	The features of SIS.	❑	❑	❑	❑	❑
KS2	The technical skills required to operate SIS.	❑	❑	❑	❑	❑
KS3	The business processes for which SIS can be utilised.	❑	❑	❑	❑	❑
KS4	The technical issues that may arise from the implementation of SIS.	❑	❑	❑	❑	❑

Compared to other technologies, Sensor-Based Management Information Systems (SIS) provide

Item		Strongly Disagree	2	3	4	Strongly Agree
RA1	Improved functionality to manage data centre facility and assets.	❑	❑	❑	❑	❑
RA2	More capabilities to enhance the efficiency of cooling system.	❑	❑	❑	❑	❑
RA3	Better visibility of the power activities in data centre.	❑	❑	❑	❑	❑
RA4	A more productive way of performing IT operations.	❑	❑	❑	❑	❑

By using SIS in our data centre

Item		Strongly Disagree	2	3	4	Strongly Agree
SV1	Operational costs have decreased.	❑	❑	❑	❑	❑
SV2	Information accuracy of data centre activities has increased.	❑	❑	❑	❑	❑
SV3	Energy efficiency of data centre has improved.	❑	❑	❑	❑	❑
SV4	Availability (uptime) of data centre has increased.	❑	❑	❑	❑	❑
SV5	Visibility of overall energy consumption has improved.	❑	❑	❑	❑	❑
SV6	Predictive analysis and preventative measures have improved.	❑	❑	❑	❑	❑
SV7	Energy consumption by data centre equipment has decreased.	❑	❑	❑	❑	❑

SV8	Compliance with regulatory environmental requirements has improved.	❏	❏	❏	❏	❏

Please indicate to what extent do you agree or disagree with the following statements. The senior management of our organization

Item		Strongly Disagree	2	3	4	Strongly Agree
TMS1	Discusses data centre issues as a priority.	❏	❏	❏	❏	❏
TMS2	Articulates a vision to improve the operations of data centre through use of smart management software.	❏	❏	❏	❏	❏
TMS3	Establishes goals for the sustainability of data centre.	❏	❏	❏	❏	❏
TMS4	Establishes standards for the sustainability of data centre.	❏	❏	❏	❏	❏

Our organisation has

Item		Not adopted	Adoption planned	Currently adopted
GDO1	A policy to purchase more energy efficient systems in data centre.	❏	❏	❏
GDO2	A policy to upgrade energy inefficient systems in the data centre.	❏	❏	❏
GDO3	A policy to retire energy inefficient systems in data centre.	❏	❏	❏
GDO4	A policy to allocate annual IT budget for purchasing management software (e.g., SIS) to improve the operation of data centre.	❏	❏	❏
GDO5	A policy for measuring the environmental performance of data centre.	❏	❏	❏
GDO6	A policy to embed environmental considerations as a priority in the design of data centre (including new and reconstructed data centre).	❏	❏	❏

Item		Strongly Disagree	2	3	4	Strongly Agree
DCG1	We get a separate energy bill for our data centre.	❏	❏	❏	❏	❏
DCG2	Energy bill is part of our data centre budget.	❏	❏	❏	❏	❏
DCG3	We have targets to reduce the energy consumption of our data centre.	❏	❏	❏	❏	❏
DCG4	Our organization has a clear policy for enhancing the visibility of data centre energy consumption to establish better transparency.	❏	❏	❏	❏	❏

Please indicate to what extent do the following issues drive your organisation decision to use specialised Sensor-Based Management Information Systems (SIS) in the data centre?

Item		No effect	Very low	2	3	4	Very high
EC1	Rising energy price.	❏	❏	❏	❏	❏	❏
EC2	Cost of data centre energy consumption.	❏	❏	❏	❏	❏	❏
EC3	Growth of energy need to power data centre.	❏	❏	❏	❏	❏	❏
EC4	Current and/or foreseeable accessibility	❏	❏	❏	❏	❏	❏

	to energy to power data centre.						
EC5	Data centre design constraints that cause inefficiency of energy usage (including building, floor and structure design).	❑	❑	❑	❑	❑	❑
NC1	Consumption volume of non-renewable energy sources	❑	❑	❑	❑	❑	❑
NC2	Contribution volume to CO2 emissions.	❑	❑	❑	❑	❑	❑
NC2	The need to increase the lifecycle of IT hardware in data centre.	❑	❑	❑	❑	❑	❑
CP1	The pressure from current and/or foreseeable regulations for reducing the energy consumption of our data centre.	❑	❑	❑	❑	❑	❑
CP2	The pressure from current and/or foreseeable regulations for reporting our environmental footprint.	❑	❑	❑	❑	❑	❑
CP3	The pressure from our major data centre suppliers to use SIS.	❑	❑	❑	❑	❑	❑
CP4	The pressure from the competitive conditions.	❑	❑	❑	❑	❑	❑

Please indicate the extent of the following

Item		Very low	2	3	4	Very high
NP1	SIS use by your external and/or internal clients.	❑	❑	❑	❑	❑
NP2	SIS use by other data centres.	❑	❑	❑	❑	❑
NP3	Your participation in professional, trade and business bodies that promote and disseminate information on SIS adoption.	❑	❑	❑	❑	❑
NP4	Green data centre certification.	❑	❑	❑	❑	❑

Please indicate the following
The number of years elapsed since your first implementation of SIS (Length of SIS use)?

The number of years elapsed since your data centre business establishment (the age of data centre)?

Which of the following best describes the purpose and objectives of your organisation's data centre ? (you may select more than one if applicable) [type of data centre]

1. Supplying computation and information functions to your organisation departments.
2. Supplying computation and information functions to external clients (all equipment owned by your organisation).
3. Providing hosting service of the IT equipment owned by external clients (your organisation responsible only for space, cooling, power and security).

Which of the following best describes the configurations of your organisation's data centre?

1. We have one dedicated data centre, and some other servers are distributed across organisational departments.
2. We have only one dedicated data centre– no servers exist in other organisational departments.
3. We have multiple dedicated data centres, and some other servers are distributed across organisational departments.
4. We have only multiple dedicated data centres– no servers exist in other organisational departments.

Which industry best describes the nature of your organisation business?

1. Primary industry including mining
2. Manufacturing
3. Electricity, Gas and Water Supply
4. Communication Services
5. Information Technology and Hosting
6. Finance, Banking and Insurance
7. Wholesale Trade
8. Retail Trade
9. Construction
10. Accommodation, Cafes and Restaurants
11. Transport and Storage
12. Property and Business Services
13. Education
14. Health and Community Services
15. Cultural and Recreational Services
16. Government Administration and Defence
17. Other Services, please list ___________________________________

Please indicate the following

The number of your data centre employees.

The number of servers in your data centre(s). [size of data centre]

The number of racks in your data centre(s).

The approximate total size of the floor space of your data centre (sq. ft).

The approximate annual data centre budget (in millions $).

The number of years of your professional experience.

The country in which your data centre located.

APPENDIX 6A: DIFFERENT TYPES OF SIS SYSTEMS IDENTIFIED FROM THE SAMPLE

	System Name	Per		System Name	Per
1	Building Management Systems (BMS)	**61.7%**	31	Cacti	**0.4%**
2	Tivoli family products (monitoring/management of power and IT)	**9.1%**	32	Nlyte DCIM	**0.4%**
3	InfraStruXure family products (Central, Management, Capacity)	**24.3%**	33	Server Tech Power Management	**2.1%**
4	OpenManage Management tool	**12.3%**	34	Opengate Data Systems	**0.8%**
5	Insight Power Manager	**7.0%**	35	APC probes	**0.8%**
6	Energy Wise	**4.5%**	36	HP Openview	**2.9%**
7	Nimsoft Server Monitoring	**0.8%**	37	Eaton	**0.4%**
8	Data Center Service Management	**5.3%**	38	Smart PDU (MPL)	**0.8%**
9	Data Center Automation Center	**4.9%**	39	Intelli Monitor (Intellidata)	**0.8%**
10	Workload Automation	**5.8%**	40	Avtech RoomAlert	**0.8%**
11	Aperture Vista	**3.3%**	41	Device ManageR	**0.8%**
12	Sinetica kit	**0.8%**	42	in house sensor based fuel management system	**0.4%**
13	SmartSet	**0.4%**	43	ETAP	**0.8%**
14	InteliSite	**0.8%**	44	iTRACS	**0.8%**
15	Prognosis	**0.8%**	45	Seimens EPMS	**2.9%**
16	Power IQ (Raritan)	**2.5%**	46	Active Power Flywheel manager	**0.4%**
17	Honeywell BAS	**0.4%**	47	TREND	**0.4%**
18	In-House monitoring and management app	**6.2%**	48	icinga	**0.4%**
19	Liebert Site scan	**2.9%**	49	SafetyNet	**0.8%**
20	RLE Technologies Falcon system	**0.4%**	50	Autodialers	**0.8%**
21	CFD	**0.8%**	51	Oztech Comminications	**0.4%**
22	Aperture Unite	**0.8%**	52	Rackwise DCM	**2.1%**
23	Automated Logic Controls	**3.7%**	53	Standard SNMP management	**2.5%**
24	Schneider Ion Enterprise	**0.4%**	54	POwer Logic (Schneider)	**1.2%**
25	Avocent Dsview	**1.6%**	55	Teletrol	**0.8%**
26	Honeywell EBI	**1.2%**	56	eLert	**0.8%**
27	Service Now	**0.4%**	57	Power Assure	**0.8%**
28	Cannon Data Centre manager	**0.4%**	58	Sensaphone IMS	**0.4%**
29	Netbotz	**0.8%**	59	Jacarta	**0.4%**
30	Nagios	**2.1%**	60	Custom Application	**0.4%**

APPENDIX 7A: TEST OF NORMALITY

Normality is a fundamental assumption in multivariate analysis (Hair et al., 2010). It refers to the shape of data distribution for a metric variable and its correspondence to the normal distribution, which takes the form of a bell-shape. It is one of the common benchmarking techniques in statistical methods (Tabachnick and Fidell, 2007). The importance for assuming normality is because large variation from normal distribution in multivariate analysis is a sign that the statistical test is invalid. Making judgments on how large a variation is dependant on the size of the sample. Thus, what is considered to be large in a small sample size might not be the case with larger samples. According to Hair et al. (2010), the impact of violating the normality assumption (non-normality) can be assessed through two dimensions: the shape of the offending distribution and the size of sample (Tabachnick and Fidell, 2007; Hair et al., 2010).

Unlike other covariance-based SEM, PLS does not establish normality requirements (Thompson et al., 1995; Chin, 1998; Gefen et al., 2000). PLS is a nonparametric analysis technique and thus does not assume the normal distribution of the data (Chin, 1998). It uses a series of interdependent Ordinary Least Square regressions to minimise the residual variances without making any distributional assumptions. The PLS technique is therefore relatively robust to deviations from multivariate normality (Gefen et al., 2000) which makes it especially suited for data that does not exhibit the multivariate normal distribution (Thompson et al., 1995; Chin, 1998). Thus, based on the above argument, assuming normality in the current dataset was not a requirement that requires any further action. All in all, normality (or non-normality) of data is not likely to warrant PLS-based analysis

APPENDIX 7B: STEPS AND CRITERIA FOLLOWED TO PERFORM THE EFA TEST

To validate the unidimensionality of our instrument measurement through EFA, the five-step procedures proposed by Hair et al. (2010) were followed.

Step1 and step 2: Examining the factor of matrix loading and identifying the significant loading

The rotated loading matrix is typically used for interpretation of EFA. Typically, it arranges the factor as columns with each containing the variables that represent the loading of a single factor. By comparing the unrotated matrix with the rotated one, it can be observed how the rotation process improves the structure. Given the sample size of 205, a factor loading of 0.4 and above was considered to be significant (Hair et al., 2010). As the sample size and number of variables increase, the acceptable level of significance loading decreases. Variables that load below this value were eliminated because they are poorly represented by the factor model (Treiblmaier and Filzmoser, 2010). The process of this test starts by viewing the unrotated matrix by looking at the first factor and moving to the subsequent factors horizontally from left to right in order to check for the highest loading for that variable on a given factor (Hair et al., 2010). Any variable with significant loading is kept and assigned to its designated factor. All variables with more than one significant loading on two factors are an indication of cross-loading and had to be deleted. The Latent Root test criterion using Eigen value was adopted in order to identify the optimum number of factors that need to be extracted. The Total Variance Explained table (from the output of PCA test) allows the examination of the Eigen values and looking at the factors that load with Eigen values >1 (Costello and Osborne, 2005). The number above Eigen values of one can be used as an indication for the factors that should be retained. The process was iterated until the relevant variables had a significant loading only on one factor, items with cross-loading were deleted, and the optimum number of factors was achieved.

Step3: Assessing the communalities of the variables

Following the identification of significant loadings and cross-loading, the next step is to evaluate the communalities of the variables. This process allows the researcher to identify any variable that is not sufficiently accounted for the factor solution (Hair et al., 2010). Some textbooks suggest that items with communalities above 0.5 should be retained (Hair et al., 2010); others propose that items with communalities less than 0.40 should be eliminated (Costello and Osborne, 2005). Nevertheless, the final decision depends on the researcher's discretion. Any communality below acceptable threshold is a warrant that the item does not have adequate explanation. A researcher might decide to retain an item below this value if it represents conceptual importance and for more inspection using further tests, but the researcher, however, should be aware that the item is poorly accounted for by the factor solution (Hair et al., 2010). Hair et al. (2010) suggest a simple approach that researchers can use to evaluate items with insufficient communalities by identifying the items that lack at least one significant factor loading. We adopt this approach, and thus the communalities threshold was set at 0.4 (similar to significance loadings). All items resulting from steps 1 and 2 were further scrutinised for communalities and some items were deleted due to low communalities.

Step4: Respecifying the factor loading

After the examination of the rotated loading matrix, identification of the significant loading and assessment of communalities, a researcher might find one of the following problems that requires an action: (1) variable with insignificant loading, (2) variable has a cross-loading, (3) variable with significant loading but has low communalities. Hair et al. (2010) suggest that when one or more of these situations occur, the researcher can take any combination of the following actions that are listed from least to most extreme. This includes ignoring these problems and reporting them as they are, evaluating these problems for possible deletion in accordance to the acceptable levels, employing different extraction methods, employing different rotation methods, or decreasing/increasing the number of factors retained. In our case, we had variables with cross-loading and variables with significant loading but low communalities and the solution applied was evaluating these problems for deletion in accordance to the acceptable threshold.

Step5: Labelling the Factors

When the researcher obtains an acceptable factors solution — that is, all factor have significant loading with no cross-loading, and all factors have acceptable communalities — the next step is to assign some meaning to the pattern of factor loading (Hair et al., 2010). The aim of this step is to assign a label to the factor that accurately reflects the variables loading. If almost all the variables are loaded into their theoretically designated factors, then no new labelling is required. However, if the researcher finds that some variables are loaded together under a new factor that was not theorised, then the researcher should assign a new label that reflects the new factor in accordance to the EFA results (Field, 2005). In doing so, the researcher should place great emphasis on the variables that have high loadings in order to assign appropriate names that reflect the underlying dimension of that factor.

APPENDIX 7C: EFA TEST SUMMARY

EFA results for SIS Assimilation factor

Round One KMO (.872) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/ Retention**
1	SDavr, Mon, Anz, Aut, SB_CSSP, SB_ICTP, SB_IS,	61.4	no	criteria met

EFA results for SIS value factor

Round One KMO (.878) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/ Retention**
1	TMS1, TMS2, TMS3, TMS4	58.3	no	criteria met

EFA results for SIS Knowledge Stock factor

Round One KMO (.851) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/ Retention**
1	KS1, KS2, KS3, KS4	83.4	no	criteria met

EFA results for technological factors

Round One KMO (.824) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/ Retention**
1	RA1, RA2, RA3, RA4, TM4	21.3	no	criteria met
2	TC1, TC2, TC3, PTU1, PTU2, PTU4, PTU5	21.1	no	criteria met
3	TM1, TM2, TM3, TM4	16.6	TM4	Cross -loading with factor 1
Round Two KMO (.801) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/ Retention**
1	TC1, TC2, TC3, PTU1, PTU2, PTU4, PTU5	22.3	PTU1	Commonalties <0.5 (0.363)
2	RA1, RA2, RA3, RA4	21.3	no	criteria met
3	TM1, TM2, TM3	15.9	no	criteria met
Round Three KMO (.797) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/Retention**
1	RA1, RA2, RA3, RA4	22.6	no	criteria met
2	TC1, TC2, TC3, PTU2, PTU4, PTU5	22.3	no	criteria met
3	TM1, TM2, TM3	17.1	no	criteria met

EFA results for organisational factors

Round One KMO (.837) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/ Retention**
1	GDO1, GDO2, GDO3, GDO6, DCG3, DCG4, GDO5	19.2	no	criteria met
2	TMS1, TMS2, TMS3, TMS4	19.6	no	criteria met
3	DCG1, DCG2	16.6	no	criteria met
4	GDO4, GDO5, GDO6	8.5	GDO5, GDO6	Cross -loading with factor 1, Deleted GDO5 first and re-run
Round Two KMO (.828) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/ Retention**
1	GDO1, GDO2, GDO3, GDO6, DCG3, DCG4	18.7	DCG3	Cross -loading with factor 4
2	TMS1, TMS2, TMS3, TMS4	20.8	no	criteria met
3	DCG1, DCG2	18.3	no	criteria met
4	GDO4, DCG3	8.6	no	criteria met
Round Three KMO (.837) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/ Retention**
1	TMS1, TMS2, TMS3, TMS4	19.6	no	criteria met
2	GDO1, GDO2, GDO3, GDO6, DCG4	18.7	no	criteria met
3	DCG1, DCG2	10.7	no	criteria met
4	GDO4	8.5	GDO4	Commonalties <0.5 (0.337)
Round Four KMO (.833) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/ Retention**
1	TMS1, TMS2, TMS3, TMS4	22.5	no	criteria met
2	GDO1, GDO2, GDO3, GDO6, DCG4	20.97	no	criteria met
3	DCG1, DCG2	15.5	no	criteria met

EFA results for external factors

Round One KMO(.834) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/ Retention**
1	CP1, CP2, NC1, NC2	18.7	NC1	Cross -loading with factor 5, Deleted NC1 first and re-run
2	EC1, EC2, EC3, EC4	18.6	EC4	Cross -loading with factor 5
3	NP1, NP2, NP3, NP4	12.6	NP2	Cross -loading with factor 4
4	NP2, CP3, CP4	12.4	no	criteria met
5	NC3, NC1, EC4, EC5	10.6	no	criteria met
Round Two KMO (.833) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/ Retention**
1	EC1, EC2, EC3, EC4, EC5	22.7	no	criteria met
2	NC2, NC3, CP2,	18.1	no	criteria met
3	CP3, CP4, NP1, NP2,	13.7	NP2, NP1	Cross -loading with factor 5, Deleted NP2 first and re-run
4	NP1, NP2, NP3, NP4	12.8	no	criteria met
Round Three KMO (.830) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/ Retention**
1	EC1, EC2, EC3, EC4, EC5	23.9	no	criteria met
2	CP1, CP2, NC2, NC3	19.4	NC3	Commonalties <0.5 (0.375)
3	CP3, CP4	12.8	no	criteria met
4	NP1, NP3, NP4	12.7	no	criteria met
Round Four KMO (.832) Bartlett's (p<0.001)				
Factor	**Items Loaded**	**Variance %**	**Violation item**	**Reason for deletion/ Retention**
1	EC1, EC2, EC3, EC4, EC5	25.3	no	criteria met
2	CP1, CP2, NC2	20.0	no	criteria met
3	NP1, NP3, NP4	13.8	no	criteria met
4	CP3, CP4	13.4	no	criteria met

SIS assimilation

Round 1:

	Component
	1
(Aut)	.856
(Mon)	.848
(Anz)	.836
(SB_IS)	.798
(SB_CSSP)	.794
(SDawr)	.778
(SB_ICTP)	.506

SIS value

Round 1:

	Component
	1
(SV3)	.826
(SV2)	.809
(SV5)	.807
(SV1)	.786
(SV6)	.734
(SV8)	.723
(SV4)	.722
(SV7)	.690

Knowledge Stock

Round 1:

	Component
	1
(KS3)	.925
(KS2)	.918
(KS1)	.910
(KS4)	.899

Technological factors

Round 1:

Rotated Component Matrix[a]

	Component		
	1	2	3
(RA1)	.817		
(RA3)	.761		
(RA2)	.756		
(RA4)	.727		
(TM4)	.521		.600
(PTU4)		.713	
(TC3)		.706	
(TC1)		.678	
(TC2)		.670	
(PTU2)		.658	
(PTU5)		.610	
(PTU1)		.535	
(TM2)			.819
(TM1)			.783
(TM3)			.745

Round 2:

Rotated Component Matrix[a]

	Component		
	1	2	3
(PTU4)	.718		
(TC3)	.705		
(TC1)	.675		
(TC2)	.666		
(PTU2)	.663		
(PTU5)	.616		
(PTU1)	.539		
(RA1)		.816	
(RA3)		.768	
(RA2)		.763	
(RA4)		.737	
(TM2)			.812
(TM1)			.782
(TM3)			.743

Round 3:

	Component		
	1	2	3
(RA1)	.842		
(RA3)	.772		
(RA2)	.767		
(RA4)	.737		
(TC3)		.752	
(PTU4)		.726	
(TC1)		.690	
(TC2)		.687	
(PTU2)		.632	
(PTU5)		.605	
(TM2)			.811
(TM1)			.796
(TM3)			.759

Organisational factors

Round1:

Rotated Component Matrix[a]

	Component			
	1	2	3	4
(GDO3)	.755			
(GDO2)	.739			
(GDO1)	.713			
(GDO6)	.675			.562
(DCG3)	.637			
(GDO5)	.569			.500
(DCG4)	.561			
(TMS1)		.826		
(TMS3)		.807		
(TMS4)		.794		
(TMS2)		.748		
(DCG2)			.870	
(DCG1)			.852	
(GDO4)				.775

Round2:

Rotated Component Matrix[a]

	Component			
	1	2	3	4
(GDO2)	.788			
(GDO6)	.777			
(GDO3)	.758			
(GDO1)	.743			
(DCG4)	.427			
(TMS1)		.834		
(TMS3)		.805		
(TMS4)		.793		
(TMS2)		.777		
(DCG2)			.896	
(DCG1)			.840	
(DCG3)	.446			.605
(GDO4)				-.602

Round 3:

Rotated Component Matrix[a]

	Component			
	1	2	3	4
(GDO2)	.796			
(GDO6)	.773			
(GDO3)	.768			
(GDO1)	.741			
(DCG4)	.415			
(TMS1)		.846		
(TMS3)		.806		
(TMS4)		.793		
(TMS2)		.758		
(DCG2)			.895	
(DCG1)			.835	
(GDO4)				.431

Round 4:

	Component		
	1	2	3
(TMS1)	.841		
(TMS3)	.809		
(TMS4)	.795		
(TMS2)	.768		
(GDO2)		.799	
(GDO6)		.777	
(GDO3)		.771	
(GDO1)		.742	
(DCG4)		.420	
(DCG2)			.890
(DCG1)			.857

Institutional factors

Round 1:

Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
(CP2)	.879				
(CP1)	.867				
(NC2)	.736				
(NC1)	.595				.461
(EC2)		.878			
(EC1)		.870			
(EC3)		.762			
(EC4)		.554			.487
(NP4)			.752		
(NP1)			.698		
(NP3)			.650		
(NP2)			.564	.474	
(CP4)				.827	
(CP3)				.746	
(EC5)					.770
(NC3)					.525

Round 2:

Rotated Component Matrix[a]

	Component			
	1	2	3	4
(EC2)	.872			
(EC1)	.834			
(EC3)	.745			
(EC4)	.712			
(EC5)	.601			
(CP1)		.851		
(CP2)		.843		
(NC2)		.695		
(NC3)		.516		
(CP4)			.785	
(CP3)			.727	
(NP2)			.576	.504
(NP4)				.762
(NP3)				.698
(NP1)			.447	.648

Round 3

Rotated Component Matrix[a]

	Component			
	1	2	3	4
(EC2)	.877			
(EC1)	.838			
(EC3)	.743			
(EC4)	.708			
(EC5)	.591			
(CP2)		.871		
(CP1)		.868		
(NC2)		.706		
(NC3)		.474		
(CP4)			.837	
(CP3)			.779	
(NP4)				.818
(NP3)				.721
(NP1)				.577

Round 4:

	Component			
	1	2	3	4
(EC2)	.869			
(EC1)	.829			
(EC3)	.744			
(EC4)	.707			
(EC5)	.599			
(CP2)		.903		
(CP1)		.879		
(NC2)		.723		
(NP4)			.828	
(NP3)			.727	
(NP1)			.610	
(CP4)				.866
(CP3)				.793

APPENDIX 7D: DISCRIMINANT VALIDITY TEST

Loading and Cross-Loading

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Anz	0.16	0.42	0.11	0.21	0.37	0.40	0.23	0.30	0.37	0.21	**0.85**	0.58	0.32
Aut	0.13	0.42	-0.01	0.19	0.47	0.36	0.22	0.33	0.36	0.30	**0.86**	0.37	0.28
CP1	0.42	0.35	0.14	0.53	0.45	0.35	0.18	**0.93**	0.40	0.20	0.29	0.18	0.46
CP2	0.38	0.30	0.16	0.52	0.40	0.28	0.18	**0.93**	0.40	0.12	0.28	0.22	0.40
CP3	**0.89**	0.10	0.18	0.40	0.24	0.20	-0.03	0.45	0.31	0.00	0.11	0.12	0.32
CP4	**0.91**	0.13	0.26	0.41	0.26	0.16	-0.02	0.32	0.33	0.01	0.12	0.08	0.33
DCG1	0.27	0.08	**0.92**	0.21	0.26	0.09	0.11	0.20	0.32	0.13	-0.01	0.14	0.33
DCG2	0.17	0.07	**0.90**	0.29	0.37	0.07	0.10	0.22	0.27	0.15	0.02	0.17	0.33
DCG4	0.15	0.17	0.34	0.33	**0.66**	0.26	0.11	0.37	0.45	0.31	0.36	0.33	0.50
EC1	0.38	0.25	0.22	**0.86**	0.32	0.21	-0.03	0.49	0.35	0.21	0.14	0.16	0.39
EC2	0.36	0.31	0.25	**0.89**	0.43	0.19	-0.01	0.47	0.38	0.26	0.14	0.22	0.43
EC3	0.38	0.32	0.08	**0.83**	0.42	0.29	0.10	0.55	0.38	0.23	0.32	0.29	0.40
EC4	0.37	0.15	0.33	**0.81**	0.32	0.13	0.03	0.51	0.36	0.08	0.04	0.13	0.43
EC5	0.36	0.19	0.23	**0.65**	0.31	0.04	0.00	0.33	0.28	0.03	0.02	0.05	0.27
GDO1	0.31	0.30	0.16	0.31	**0.73**	0.34	0.27	0.35	0.36	0.33	0.29	0.13	0.39
GDO2	0.14	0.35	0.34	0.31	**0.84**	0.24	0.13	0.28	0.46	0.34	0.28	0.17	0.47
GDO3	0.19	0.41	0.21	0.38	**0.80**	0.33	0.20	0.35	0.42	0.33	0.34	0.24	0.38
GDO6	0.30	0.29	0.28	0.38	**0.81**	0.28	0.23	0.42	0.45	0.27	0.34	0.19	0.42
KS1	0.19	0.48	0.14	0.24	0.37	**0.91**	0.41	0.32	0.37	0.31	0.43	0.35	0.25
KS2	0.13	0.44	0.03	0.19	0.33	**0.92**	0.44	0.24	0.27	0.35	0.40	0.41	0.23
KS3	0.19	0.40	0.05	0.16	0.35	**0.92**	0.33	0.25	0.34	0.29	0.47	0.40	0.30
KS4	0.22	0.35	0.11	0.20	0.32	**0.88**	0.29	0.30	0.31	0.25	0.41	0.32	0.31
Mon	0.14	0.39	-0.02	0.18	0.40	0.38	0.14	0.19	0.33	0.33	**0.84**	0.47	0.27
NC2	0.36	0.16	0.32	0.53	0.41	0.20	0.12	**0.86**	0.39	0.12	0.19	0.17	0.46
NP1	0.36	0.29	0.28	0.33	0.48	0.27	0.07	0.33	**0.80**	0.23	0.31	0.29	0.45
NP3	0.17	0.33	0.18	0.43	0.41	0.40	0.22	0.37	**0.75**	0.29	0.35	0.37	0.27
NP4	0.27	0.08	0.27	0.25	0.38	0.15	0.18	0.32	**0.76**	0.04	0.22	0.20	0.28
RA1	0.05	0.39	0.16	0.15	0.34	0.26	0.18	0.09	0.21	**0.85**	0.29	0.38	0.24
RA2	0.01	0.49	0.08	0.25	0.34	0.24	0.11	0.15	0.20	**0.84**	0.26	0.39	0.32
RA3	0.00	0.45	0.12	0.19	0.42	0.35	0.11	0.14	0.22	**0.88**	0.34	0.37	0.26
RA4	-0.05	0.38	0.15	0.10	0.24	0.24	0.16	0.16	0.18	**0.76**	0.28	0.27	0.26
PTU4	-0.04	0.30	0.09	-0.04	0.13	0.38	**0.85**	0.06	0.12	0.22	0.27	0.34	0.02
PTU5	-0.04	0.22	0.10	0.05	0.15	0.15	**0.63**	0.13	0.12	0.18	0.21	0.20	0.05
TC2	0.02	0.14	0.03	0.00	0.18	0.27	**0.66**	0.15	0.17	-0.02	0.15	0.15	-0.03
TC3	-0.01	0.17	0.14	0.07	0.27	0.32	**0.75**	0.19	0.15	0.07	0.19	0.17	0.00
SB_CSSP	0.10	0.39	0.13	0.02	0.33	0.36	0.35	0.17	0.32	0.31	**0.80**	0.53	0.21
SB_ICTP	0.04	0.23	-0.20	0.05	0.09	0.27	0.11	0.08	0.19	0.27	**0.48**	0.15	0.00
SB_IS	0.06	0.46	-0.06	0.13	0.26	0.38	0.22	0.27	0.24	0.31	**0.80**	0.42	0.15

SDavr	0.11	0.36	-0.05	0.06	0.27	0.38	0.14	0.14	0.26	0.23	**0.75**	0.30	0.17
SV1	0.12	0.38	0.15	0.15	0.24	0.35	0.32	0.18	0.25	0.34	0.35	**0.78**	0.33
SV2	0.06	0.41	0.23	0.14	0.22	0.39	0.26	0.11	0.26	0.43	0.44	**0.80**	0.32
SV3	0.00	0.46	0.02	0.02	0.17	0.29	0.23	0.05	0.19	0.34	0.45	**0.82**	0.17
SV4	0.10	0.38	0.12	0.20	0.20	0.23	0.08	0.06	0.33	0.38	0.42	**0.72**	0.33
SV5	0.09	0.39	0.16	0.21	0.28	0.26	0.13	0.14	0.30	0.30	0.45	**0.80**	0.24
SV6	0.06	0.35	0.21	0.18	0.17	0.27	0.28	0.13	0.29	0.41	0.35	**0.73**	0.34
SV7	0.03	0.17	-0.03	0.09	0.11	0.32	0.30	0.18	0.21	0.14	0.38	**0.70**	0.15
SV8	0.21	0.45	0.17	0.32	0.28	0.37	0.29	0.39	0.44	0.27	0.44	**0.73**	0.33
SVO1	-0.10	0.18	-0.06	0.08	0.13	0.19	0.27	0.03	0.09	0.16	**0.37**	0.19	0.02
TM1	0.17	**0.87**	0.16	0.30	0.36	0.34	0.17	0.25	0.28	0.49	0.48	0.46	0.31
TM2	0.14	**0.86**	0.05	0.22	0.29	0.44	0.29	0.23	0.26	0.43	0.39	0.47	0.24
TM3	0.03	**0.84**	0.00	0.25	0.37	0.41	0.30	0.27	0.25	0.40	0.40	0.35	0.15
TMS1	0.18	0.23	0.10	0.33	0.29	0.20	-0.02	0.35	0.23	0.37	0.23	0.31	**0.74**
TMS2	0.32	0.33	0.33	0.44	0.49	0.34	0.10	0.48	0.42	0.28	0.25	0.36	**0.87**
TMS3	0.35	0.14	0.38	0.41	0.53	0.24	-0.04	0.41	0.42	0.28	0.22	0.32	**0.90**
TMS4	0.35	0.23	0.38	0.45	0.56	0.21	-0.01	0.41	0.42	0.21	0.24	0.26	**0.90**

APPENDIX 7E: COMMON METHOD BIAS (CMB) TEST USING COMMON METHOD FACTOR APPROACH

Factor loadings for each substantive construct (major construct) and factor loadings for the CMV construct captured through Common method factor approach test.

Analysis Using Method Factor Approach

	Factor	indicators	Substantive Factor loading	$R1^2$	CM factor loading	$R2^2$
1	SIS Assimilation	SVO	0.3775	0.143	-0.0248	0.001
2		Diavr	0.8707	0.758	-0.1383	0.019
3		Anz	0.7328	0.537	0.145	0.021
4		Aut	0.8431	0.711	0.0258	0.001
5		Mon	0.8233	0.678	0.0335	0.001
6		ICTP	0.6214	0.386	-0.1556	0.024
7		IS	0.8197	0.672	-0.0304	0.001
8		CSSP	0.7472	0.558	0.0529	0.003
9	SIS Value	SV1	0.7802	0.609	0.0066	0.000
10		SV2	0.7902	0.624	0.0261	0.001
11		SV3	0.9434	0.890	-0.165	0.027
12		SV4	0.6996	0.489	0.0312	0.001
13		SV5	0.8281	0.686	-0.0299	0.001
14		SV6	0.722	0.521	0.0161	0.000
15		SV7	0.7831	0.613	-0.1299	0.017
16		SV8	0.5394	0.291	0.2589	0.067
17	Relative Advantage	RA1	0.8713	0.759	-0.0224	0.001
18		RA2	0.8473	0.718	0.0128	0.000
19		RA3	0.8432	0.711	0.0409	0.002
20		RA4	0.7831	0.613	-0.0357	0.001
21	SIS Compatibility	TM1	0.8203	0.673	0.0676	0.005
22		TM2	0.8851	0.783	-0.0216	0.000
23		TM3	0.8714	0.759	-0.0485	0.002
24	Perceived SIS Risk	TC2	0.6774	0.459	-0.0473	0.002
25		TC3	0.735	0.540	0.0052	0.000
26		PTU4	0.817	0.667	0.0285	0.001
27		PTU5	0.6863	0.471	0.0053	0.000
28	Top Management Support	TMS1	0.7652	0.586	-0.0182	0.000
29		TMS2	0.797	0.635	0.1054	0.011
30		TMS3	0.9334	0.871	-0.0456	0.002
31		TMS4	0.9306	0.866	-0.0416	0.002
32	Green IT/IS Orientation	GDO1	0.762	0.581	-0.0304	0.001
33		GDO2	0.9549	0.912	-0.1453	0.021

34		GDO3	0.7712	0.595	0.0328	0.001
35		GDO6	0.8338	0.695	-0.0261	0.001
36		DCG4	0.4956	0.246	0.2083	0.043
37	DC Energy Governance	DCG1	0.9159	0.839	-0.0194	0.000
38		DCG2	0.9023	0.814	0.0196	0.000
39	Coercive Pressure	CP3	0.901	0.812	0.0094	0.000
40		CP4	0.9111	0.830	-0.0092	0.000
41	Normative Pressure	NP1	0.6855	0.470	0.093	0.009
42		NP3	0.7093	0.503	0.1244	0.015
43		NP4	0.9219	0.850	-0.2173	0.047
44	Energy Pressure	EC1	0.8887	0.790	-0.0303	0.001
45		EC2	0.8855	0.784	0.0187	0.000
46		EC3	0.7473	0.558	0.1651	0.027
47		EC4	0.8375	0.701	-0.071	0.005
48		EC5	0.7032	0.494	-0.1107	0.012
49	Environmental Preservation Pressure	CP1	0.9133	0.834	0.0442	0.002
50		CP2	0.958	0.918	-0.0177	0.000
51		NC2	0.8644	0.747	-0.0288	0.001
52	SIS Knowledge Stock	KS1	0.8811	0.776	0.0441	0.002
53		KS2	0.9292	0.863	-0.0161	0.000
54		KS3	0.9197	0.846	0.0084	0.000
55		KS4	0.9226	0.851	-0.0369	0.001
Average			**0.807**	**0.665**	**-0.002**	**0.007**

APPENDIX 7F: MEAN AND STANDARD DEVIATION

Descriptive Statistics					
Item	Mean	Std. Deviation	Item	Mean	Std. Deviation
SB_CSSP	4.27	1.733	DCG1	3.09	1.626
SB_ICTP	3.28	1.862	DCG2	3.46	1.548
SB_IS	3.41	1.786	DCG3	3.90	1.213
TM1	3.73	1.067	DCG4	3.74	1.232
TM2	3.81	1.017	EC1	4.41	1.455
TM3	3.63	1.047	EC2	4.69	1.361
TM4	3.92	.936	EC3	4.90	1.242
KS1	3.21	1.222	EC4	4.27	1.433
KS2	3.39	1.113	EC5	4.41	1.317
KS3	3.28	1.171	NC1	3.73	1.499
KS4	3.25	1.138	NC2	3.87	1.655
RA1	4.15	.821	NC3	3.73	1.476
RA2	4.21	.800	CP1	4.00	1.480
RA3	4.45	.743	CP2	4.08	1.533
RA4	3.88	1.066	CP3	2.65	1.449
SV1	3.72	1.033	CP4	3.06	1.578
SV2	4.14	.929	NP1	2.64	1.178
SV3	3.96	1.023	NP2	2.99	1.184
SV4	3.58	1.080	NP3	3.13	1.349
SV5	4.14	.955	NP4	3.03	1.359
SV6	3.75	1.143	TC1	3.40	1.119
SV7	3.33	1.042	TC2	2.85	1.108
SV8	3.30	1.162	TC3	3.63	.933
TMS1	3.91	1.065	PTU1	3.70	1.195
TMS2	3.29	1.192	PTU2	3.49	1.051
TMS3	3.48	1.187	PTU4	3.65	1.054
TMS4	3.30	1.182	PTU5	3.57	.886
GDO1	2.51	.697	Mon	.6559	.26755
GDO2	2.28	.713	Anz	.5831	.27954
GDO3	2.29	.693	Aut	.5115	.25620
GDO4	2.13	.790	SDavr	.8390	.20637
GDO5	2.42	.707			
GDO6	2.38	.780			

APPENDIX 8A: RESULTS FROM GROUP COMPARISON APPROACHES

8a-1: PLS estimates for the age of data centre group-based sample

		Group: New s=90 R2= 0.223			Group Old: s=115 R2= 0.526		
		Path	T Stat	p value	Path	T Stat	p value
1	Coercive Pressure -> DC Energy Governance	0.031	0.262	0.794	0.149	1.314	0.192
2	Coercive Pressure -> Green IT /IS orientation	0.087	0.810	0.420	-0.172	2.259	**0.026**
3	Coercive Pressure -> Top management support	0.241	2.596	**0.011**	-0.084	0.950	0.344
4	Compatibility -> SIS Assimilation	0.164	1.332	0.186	0.403	3.649	**0.000**
5	DC Energy Governance -> SIS Assimilation	-0.152	1.396	0.166	-0.117	1.694	0.093
6	Energy Pressure -> DC Energy Governance	0.208	1.762	0.082	-0.039	0.279	0.780
7	Energy Pressure -> Green IT/IS orientation	**0.033**	0.293	0.771	0.255	2.093	**0.039**
8	Energy Pressure -> Top management support	0.042	0.318	0.751	0.474	3.973	**0.000**
9	Green IT orientation -> SIS Assimilation	0.065	0.468	0.641	0.338	3.726	**0.000**
12	Nat. Envir. Pressure -> DC Energy Governance	-0.157	1.043	0.300	0.215	1.591	0.114
13	Nat. Envir. Pressure -> Green IT/IS orientation	0.082	0.697	0.488	0.280	2.569	**0.011**
14	Nat. Envir. Pressure -> Top management support	0.308	2.441	**0.017**	0.073	0.698	0.486
15	Normative Pressure -> DC Energy Governance	0.360	2.744	**0.007**	0.151	1.446	0.151
16	Normative Pressure -> Green IT/IS orientation	0.468	4.654	**0.000**	0.444	6.345	**0.000**
17	Normative Pressure -> Top management support	0.194	1.776	0.079	0.265	2.847	**0.005**
18	Perceived Risk -> SIS Assimilation	0.257	2.496	**0.014**	0.136	2.038	**0.044**
19	Relative Advantage. -> SIS Assimilation	-0.024	0.139	0.890	0.114	1.086	0.280
23	Top management support -> SIS Assimilation	0.287	2.269	**0.026**	-0.025	0.287	0.774

8a-2: Overview of The Significance of Differences between Data Centre Age Groups Using both Keil Et Al. (2000) and Henseler Et Al. (2009) Approaches

		Keil's Approach		**MGA Approach***		
		Group1 - Group2	**p value**	**Group1 Para.**	**Group2 Para.**	**Error**
1	Coercive Pressure -> DC Energy Governance	0.118	0.409	0.043	0.145	0.484
2	Coercive Pressure -> Green IT/IS orientation	0.259	**0.026**	0.088	-0.167	**0.019**
3	Coercive Pressure -> Top management support	0.325	**0.004**	0.236	-0.081	**0.006**
4	Compatibility -> SIS Assimilation	0.239	0.102	0.159	0.414	0.921
5	DC Energy Governance -> SIS Assimilation	0.035	0.760	-0.163	-0.110	0.602
6	Energy Pressure -> DC Energy Governance	0.247	0.127	0.225	-0.028	0.115
7	Energy Pressure -> Green IT/IS orientation	0.222	0.130	0.026	0.260	0.928
8	Energy Pressure -> Top management support	0.432	**0.006**	0.061	0.487	**0.992**
9	Green IT orientation -> SIS Assimilation	0.273	0.063	0.047	0.322	0.942
12	Nat. Prese. Pressure -> DC Energy Governance	0.372	**0.038**	-0.167	0.225	**0.956**
13	Nat. Prese. Pressure -> Green IT/IS orientation	0.198	0.163	0.089	0.284	0.888
14	Nat. Prese. Pressure -> Top management support	0.235	0.103	0.296	0.080	0.073
15	Normative Pressure -> DC Energy Governance	0.209	0.158	0.389	0.149	0.129
16	Normative Pressure -> Green IT/IS orientation	0.024	0.824	0.489	0.439	0.423
17	Normative Pressure -> Top management support	0.072	0.570	0.214	0.261	0.691
18	Perceived Risk -> SIS Assimilation	0.121	0.265	0.268	0.146	0.186
19	Relative Advantage. -> SIS Assimilation	0.137	0.434	0.013	0.121	0.735
23	Top management support -> SIS Assimilation	0.313	**0.022**	0.288	-0.028	**0.019**

8a-3: PLS estimates for the type of data centre group-based sample

	Group1: Corporate s=93 R2= 0.362			**Group2: Managed: s=70 R2= 0.524**			**Group 3: Co-located: s=42 R2= 0.434**		
	Path	**T Stat**	**p value**	**Path**	**T Stat**	**p value**	**Path**	**T Stat**	**p value**
Coercive Pressure -> DC Energy Gov.	-0.194	1.342	0.183	0.222	1.985	**0.049**	0.037	0.117	0.907
Coercive Pressure -> Green IT orien.	-0.153	1.846	0.068	-0.083	0.763	0.447	0.286	1.601	0.117
Coercive Pressure -> Top manag. Sup.	0.093	0.865	0.389	0.083	0.995	0.322	-0.093	0.444	0.660
Compatibility -> SIS Assmili.	0.370	3.446	**0.001**	0.506	3.978	**0.000**	-0.061	0.250	0.804
DC Energy Gov. -> SIS Assmili.	-0.276	3.134	**0.002**	-0.095	0.596	0.552	-0.058	0.285	0.777
Energy Pressure -> DC Energy Gov.	0.035	0.249	0.804	0.383	2.519	**0.013**	-0.111	0.291	0.772
Energy Pressure -> Green IT orientation	0.355	3.301	**0.001**	0.157	0.932	0.354	-0.160	0.734	0.467
Energy Pressure -> Top manag. Sup.	0.165	1.173	0.244	0.328	2.095	**0.038**	0.179	0.741	0.463
Green IT orien. -> SIS Assmili.	0.358	2.812	**0.006**	0.082	0.730	0.467	0.316	1.357	0.182
Nat. Envir. Pressure -> DC Energy Gov.	0.002	0.012	0.991	0.199	1.461	0.147	-0.202	0.734	0.467
Nat. Envir. Pressure -> Green IT orien.	0.290	2.708	**0.008**	0.018	0.134	0.894	0.231	1.262	0.214
Nat. Envir. Pressure -> Top manag. Sup.	0.326	1.986	**0.049**	0.148	1.206	0.230	0.149	0.538	0.594
Normative Pressure -> DC Energy Gove	0.375	2.734	**0.007**	0.009	0.080	0.937	0.497	2.390	**0.022**
Normative Pressure -> Green IT orien.	0.274	3.186	**0.002**	0.617	7.012	**0.000**	0.387	2.371	**0.023**
Normative Pressure -> Top manag. Sup.	0.094	0.923	0.358	0.358	3.145	**0.002**	0.346	1.716	0.094
P. Risk -> SIS Assmiliation	0.118	0.953	0.343	0.090	0.763	0.447	0.248	1.229	0.226
Relative Adva. -> SIS Assmili.	-0.033	0.343	0.733	0.131	1.020	0.310	0.216	1.142	0.260
Top manag. Sup.-> SIS Assmili.	0.005	0.051	0.959	0.252	1.268	0.207	0.190	0.853	0.398

8a-4: Overview of the Significance of Differences between Data Centre Type Groups Using Keil et Al. (2000) Approach

	Significance Diff G1-G2		**Significance Diff G1-G3**		**Significance Diff G2-G3**	
	| G1 - G2|	**p value**	**| G1 – G3|**	**p value**	**|G2 – G3|**	**p value**
Coercive Pressure -> DC Energy Governance	0.416	**0.031**	0.230	0.438	0.073	0.663
Coercive Pressure -> Green IT/IS orientation	0.070	0.599	0.439	**0.011**	0.089	0.555
Coercive Pressure -> Top management support	0.010	0.942	0.186	0.380	0.167	0.188
Compatibility -> SIS Assimilation	0.136	0.410	0.431	0.059	0.102	0.578
DC Energy Governance -> SIS Assimilation	0.181	0.289	0.218	0.246	0.022	0.916
Energy Pressure -> DC Energy Governance	0.348	0.095	0.146	0.656	0.423	0.059
Energy Pressure -> Green IT/IS orientation	0.199	0.297	0.516	**0.017**	0.098	0.677
Energy Pressure -> Top management support	0.163	0.439	0.014	0.957	0.146	0.509
Green IT/IS orientation -> SIS Assimilation	0.276	0.116	0.042	0.863	0.256	0.110
Nat. Prese. Pressure -> DC Energy Governance	0.197	0.354	0.204	0.487	0.016	0.938
Nat. Prese. Pressure -> Green IT/IS orientation	0.272	0.109	0.059	0.770	0.262	0.173
Nat. Prese. Pressure -> Top management support	0.178	0.409	0.177	0.562	0.075	0.671
Normative Pressure -> DC Energy Governance	0.366	**0.047**	0.123	0.618	0.142	0.376
Normative Pressure -> Green IT/IS orientation	0.343	**0.006**	0.113	0.500	0.173	0.167
Normative Pressure -> Top management support	0.264	0.084	0.253	0.210	0.092	0.571
Perceived Risk -> SIS Assimilation	0.028	0.872	0.130	0.567	0.047	0.770
Relative Advantage. -> SIS Assimilation	0.164	0.294	0.248	0.190	0.017	0.926
Top management support -> SIS Assimilation	0.248	0.218	0.186	0.353	0.278	0.294

8a-5: Overview of the Significance of Differences between Data Centre Type Groups Using Henseler et Al. (2009) Approach

	MGA 1-2*			MGA 1-3*			MGA 2-3*		
	G1 Para.	**G2 Para.**	**Error**	**G1 Para**	**G3 Para**	**Error**	**G2 Para**	**G3 Para**	**Error**
Coercive Pressure -> DC Energy Gov.	-0.187	0.221	**0.992**	-0.187	0.067	0.746	0.221	0.067	0.311
Coercive Pressure -> Green IT/IS orien.	-0.165	-0.068	0.699	-0.165	0.309	**0.991**	-0.068	0.309	**0.970**
Coercive Pressure -> Top manag. Sup.	0.091	0.093	0.464	0.091	-0.070	0.219	0.093	-0.070	0.227
Compatibility -> SIS Assmili.	0.383	0.478	0.789	0.383	0.007	**0.045**	0.478	0.007	**0.025**
DC Energy Gov. -> SIS Assmili.	-0.255	-0.080	0.833	-0.255	-0.049	0.873	-0.080	-0.049	0.551
Energy Pressure -> DC Energy Gov.	0.026	0.383	**0.960**	0.026	-0.118	0.371	0.383	-0.118	0.119
Energy Pressure -> Green IT/IS orient	0.358	0.130	0.154	0.358	-0.150	**0.013**	0.130	-0.150	0.129
Energy Pressure -> Top manag. Sup.	0.169	0.319	0.784	0.169	0.175	0.525	0.319	0.175	0.317
Green IT/IS orien. -> SIS Assmili.	0.327	0.119	**0.050**	0.327	0.279	0.438	0.119	0.279	0.828
Nat. Prese. Pressure -> DC Energy Gov.	0.013	0.215	0.826	0.013	-0.183	0.259	0.215	-0.183	0.100
Nat. Prese. Pressure -> Green IT/IS orie	0.302	0.038	0.061	0.302	0.180	0.418	0.038	0.180	0.828
Nat. Prese. Pressure -> Top manag. Sup.	0.323	0.175	0.192	0.323	0.097	0.285	0.175	0.097	0.546
Normative Pressure -> DC Energy Gove	0.377	0.008	**0.026**	0.377	0.454	0.720	0.008	0.454	**0.961**
Normative Pressure -> Green IT/IS orie	0.285	0.620	**0.996**	0.285	0.384	0.750	0.620	0.384	0.083
Normative Pressure -> Top manag. Sup.	0.112	0.342	**0.954**	0.112	0.364	0.879	0.342	0.358	0.440
Perceived Risk -> SIS Assimilation	0.126	0.127	0.386	0.126	0.274	0.689	0.127	0.274	0.733
Relative Advantage. -> SIS Assmili.	-0.013	0.137	0.842	-0.013	0.174	0.911	0.137	0.174	0.690
Top manag. Sup.-> SIS Assmili.	0.003	0.204	0.859	0.003	0.219	0.771	0.204	0.219	0.409

APPENDIX 8B: EFFECT SIZE ESTIMATES FOR ENDOGENOUS CONSTRUCTS

Endogenous : Assimilation					
	Original	Partial			
Excluded construct	R^2	R^2	F^2	Sig	Effect
Compatibility	0.349	0.284	0.100	*	Small
DC Energy Governance	0.349	0.326	0.035	*	Small
Green IT/IS Orientation	0.349	0.315	0.052	*	Small
Perceived Risk	0.349	0.332	0.026	*	Small
Relative Advantage.	0.349	0.347	0.003	n.e.	No effect
Top Management Support	0.349	0.345	0.006	n.e.	No effect
Endogenous : Value					
	Original	Partial			
Excluded construct	R^2	R^2	F^2	Sig	
Knowledge Stock	0.339	0.310	0.044	*	Small
SIS Assimilation	0.339	0.184	0.234	**	Moderate
Endogenous : DC Energy Governance					
	Original	Partial			
Excluded construct	R^2	R^2	F^2	Sig	
Coercive Pressure	0.137	0.129	0.009	n.e.	No effect
Energy Pressure.	0.137	0.130	0.008	n.e.	No effect
Environmental Preservation Pressure	0.137	0.137	0.000	n.e.	No effect
Normative Pressure	0.137	0.098	0.045	*	Small
Endogenous : Green IT orientation					
	Original	Partial			
Excluded construct	R^2	R^2	F^2	Sig	
Coercive Pressure	0.389	0.388	0.002	n.e.	No effect
Energy Pressure.	0.389	0.373	0.026	*	Small
Environmental Preservation Pressure	0.389	0.364	0.041	*	Small
Normative Pressure	0.389	0.268	0.198	**	Moderate
Endogenous : Top management support					
	Original	Partial			
Excluded construct	R^2	R^2	F^2	Sig	
Coercive Pressure	0.342	0.337	0.008	n.e.	No effect
Energy Pressure.	0.342	0.317	0.038	*	Small
Environmental Preservation Pressure	0.342	0.311	0.047	*	Small
Normative Pressure	0.342	0.306	0.055	*	Small

n.e.=No Effect

APPENDIX 9A: TOP MANAGEMENT SUPPORT (ALTERATIVE MODEL)

Is Units Data Centres [Single Tenant] and It Company Data Centres [Multi-Tenant]

	Single Tenant s=93 R2= 0.362			Multi-tenant :: s=112 R2= 0.355		
	Path	**T Stat**	**p value**	**Path**	**T Stat**	**p value**
Coercive Pressure -> DC Energy Gov.	-0.194	1.342	0.183	0.284	3.455	0.001
Coercive Pressure -> Green IT/IS orien.	-0.153	1.846	0.068	-0.035	0.539	0.591
Coercive Pressure -> Top manag. Sup.	0.093	0.865	0.389	0.021	0.301	0.763
Compatibility -> SIS Assmili.	0.370	3.446	**0.001**	0.212	2.423	0.016
DC Energy Gov. -> SIS Assmili.	-0.276	3.134	**0.002**	-0.192	1.826	0.069
Energy Pressure -> DC Energy Gov.	0.035	0.249	0.804	0.135	1.248	0.213
Energy Pressure -> Green IT/IS orient.	0.355	3.301	**0.001**	0.193	1.861	0.064
Energy Pressure -> Top manag. Sup.	0.165	1.173	0.244	0.333	3.305	0.001
Green IT/IS orien. -> SIS Assmili.	0.358	2.812	**0.006**	0.133	2.130	0.034
Nat. Pres. Pressure -> DC Energy Gov.	0.002	0.012	0.991	0.060	0.614	0.540
Nat. Pres. Pressure -> Green IT/IS orien.	0.290	2.708	**0.008**	0.037	0.447	0.656
Nat. Pres. Pressure -> Top manag. Sup.	0.326	1.986	**0.049**	0.053	0.776	0.439
Normative Pressure -> DC Energy Gove	0.375	2.734	**0.007**	0.058	0.684	0.495
Normative Pressure -> Green IT orien.	0.274	3.186	**0.002**	0.429	6.776	0.000
Normative Pressure -> Top manag. Sup.	0.094	0.923	0.358	0.334	5.335	0.000
P. Risk -> SIS Assmiliation	0.118	0.953	0.343	0.214	2.931	0.004
Relative Adva. -> SIS Assmili.	-0.033	0.343	0.733	0.143	2.368	0.019
Top manag. Sup.-> SIS Assmili.	0.005	0.051	0.959	0.177	1.972	0.050

APPENDIX 9B: DATA CENTRE ENERGY GOVERNANCE (ALTERATIVE MODEL)

Corporate Data Centres [Single-Tenant], And Managed And Co-Located Data Centres [Multi-Tenant] – Excluding External Factors)

	Co-located			**Corporate**			**Managed**		
	Path	T Stat		Path	T Stat		Path	T Stat	
Compatibility -> SIS Assimi.	-0.046	0.521	0.603	0.408	6.011	0.000	0.515	9.673	0.000
Energy Governance-> SIS Assimi.	0.044	0.506	0.614	0.333	3.208	0.002	0.188	1.82	0.073
Green IT orient -> SIS Assimi.	0.258	3.664	0.000	0.046	0.631	0.529	0.069	1.025	0.309
Knowledge Stock -> SIS Value	0.514	5.674	0.000	0.096	1.557	0.121	0.245	5.214	0.000
P. Risk -> SIS Assimi.	0.244	3.641	0.000	0.043	0.663	0.508	0.125	2.081	0.041
Relative Adva. -> SIS Assimi.	0.194	3.106	0.002	-0.076	1.031	0.304	0.124	2.037	0.045
SIS Assimi. -> SIS Value	0.158	1.355	0.177	0.492	11.85	0.000	0.541	9.453	0.000
Top mana. support -> SIS Assimi.	0.217	2.272	0.024	0.044	0.681	0.497	0.144	1.643	0.105

APPENDIX 9C: COUNTRY EFFECT

9c-1: The effect of Country difference on the Research Model through SmartPLS

	Path	T Statistics	P value	R	Sig of difference
Relative Adva. * Country -> SIS Assimilation	-0.055	0.778	0.437	0.357	0.909
Compatibility * Country -> SIS Assimilation	0.008	0.122	0.903	0.354	0.943
P. Risk * Country -> SIS Assimilation	0.044	0.431	0.667	0.356	0.920
Top manag. support * Country -> SIS Assimilation	0.043	0.361	0.718	0.356	0.920
Green IT/IS orient. * Country -> SIS Assimilation	-0.154	2.027	0.044	0.375	0.711
Energy Governance * Country -> SIS Assimilation	-0.075	1.145	0.254	0.358	0.898
Coercive Pressure * Country -> SIS Assimilation	0.046	0.873	0.384	0.356	0.920
Normative Pressure * Country -> SIS Assimilation	-0.061	1.046	0.297	0.384	0.617
Energy Pressure * Country -> SIS Assimilation	0.040	0.582	0.561	0.358	0.898
Nat. Pres. Pressure * Country -> SIS Assimilation	-0.071	0.921	0.358	0.360	0.875

9c-2: PLS estimates for the cross-country (Regional) through group-based sample

	AM (n=85), R^2=.393		AU (n=39), R^2=.514		EU (n=41), R^2=.612		RW (n=40), R^2=.356	
	Path	P value	Path	P value	Path	P value	Path	P value
Relative Adva. -> SIS Assimilation	0.00	0.99	0.21	0.24	0.00	0.99	0.38	0.34
Compatibility -> SIS Assimilation	0.29	**0.05**	-0.04	0.85	0.52	**0.01**	0.47	**0.04**
P. Risk -> SIS Assimilation	0.15	0.13	0.30	0.28	0.21	0.29	-0.21	0.49
Top man. support -> SIS Assimilation	0.05	0.71	-0.01	0.97	0.44	**0.04**	-0.29	0.09
Green IT orient. -> SIS Assimilation	0.33	**0.02**	0.70	**0.00**	-0.06	0.78	-0.19	0.49
DC Energy Govern. -> SIS Assimilation	-0.07	0.48	-0.21	0.15	-0.30	0.06	0.30	0.37
Normative Pressure -> SIS Assimilation	0.31	**0.02**	0.28	0.34	0.20	0.21	-0.07	0.82
Coercive Pressure -> SIS Assimilation	-0.07	0.51	0.01	0.98	0.24	0.15	-0.11	0.65
Normative Pressure -> DC Energy Govern.	0.32	**0.03**	0.11	0.52	0.23	0.18	0.24	0.34
Normative Pressure -> Green IT orient	0.41	**0.00**	0.62	**0.00**	0.57	**0.01**	0.40	0.12
Normative Pressure -> Top man. support	0.18	**0.02**	0.26	0.21	0.20	0.36	-0.08	0.82
Coercive Pressure -> DC Energy Govern.	0.19	0.11	0.13	0.42	-0.02	0.93	0.28	0.29
Coercive Pressure -> Green IT orient.	-0.07	0.41	-0.09	0.48	0.16	0.31	-0.14	0.48
Coercive Pressure -> Top man. support	0.08	0.18	0.21	0.30	-0.23	0.33	0.08	0.72
Energy Pressure -> DC Energy Govern.	-0.01	0.96	0.19	0.52	0.48	**0.04**	-0.33	0.44
Energy Pressure -> Green IT orient.	0.22	0.11	0.38	0.24	0.05	0.83	0.16	0.57
Energy Pressure -> Top man. support	0.39	**0.00**	0.44	0.17	-0.10	0.71	-0.29	0.27
Envir. Pre. Pressure -> DC Energy Govern.	0.05	0.77	0.32	0.27	-0.09	0.73	-0.13	0.56
Envir. Pre. Pressure -> Green IT orient.	0.29	**0.01**	-0.17	0.58	-0.07	0.78	0.27	0.19
Envir. Pre. Pressure -> Top man. support	0.34	**0.00**	-0.20	0.45	0.34	0.18	0.44	**0.02**

9c-3: Overview of The Significance of Differences between the cross-country (Regional) Groups Using Multi group Analysis

	AM vs. EU		EU vs. RW	
	|DIFF G1 - G2|	P-value	|DIFF G1 - G2|	P-value
Relative Adva. -> SIS Assimilation	0.004	0.992	0.385	0.376
Compatibility -> SIS Assimilation	0.235	0.508	0.049	0.87
P. Risk -> SIS Assimilation	0.054	0.865	0.418	0.238
Top man. support -> SIS Assimilation	0.388	0.286	0.727	**0.006**
Green IT orient. -> SIS Assimilation	0.395	0.317	0.123	0.726
DC Energy Govern. -> SIS Assimilation	0.232	0.387	0.608	0.096
Normative Pressure -> SIS Assimilation	0.109	0.712	0.266	0.41
Coercive Pressure -> SIS Assimilation	0.311	0.267	0.355	0.219
Normative Pressure -> DC Energy Govern.	0.096	0.76	0.013	0.964
Normative Pressure -> Green IT orient	0.162	0.625	0.166	0.607
Normative Pressure -> Top man. support	0.018	0.956	0.277	0.469
Coercive Pressure -> DC Energy Govern.	0.209	0.484	0.298	0.336
Coercive Pressure -> Green IT orient.	0.227	0.367	0.3	0.226
Coercive Pressure -> Top man. support	0.308	0.362	0.3	0.317
Energy Pressure -> DC Energy Govern.	0.488	0.227	0.806	0.09
Energy Pressure -> Green IT orient.	0.169	0.65	0.112	0.747
Energy Pressure -> Top man. support	0.493	0.25	0.183	0.622
Envir. Pre. Pressure -> DC Energy Govern.	0.147	0.755	0.037	0.916
Envir. Pre. Pressure -> Green IT orient.	0.353	0.35	0.331	0.275
Envir. Pre. Pressure -> Top man. support	0.007	0.987	0.105	0.729