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Information Technology & Sustainability: An Empirical Study of the Value of the Building Automation System

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
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Keywords: Green IT, Building Energy Conservation, Sustainable Value, Qualitative Analysis, Case Study, Environmental Sustainability

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DEDICATION

This dissertation is dedicated to my daughters Kenya Simmonds Desulme and Khana Simmonds Desulme, to my fiancé, Michael McGhie, and to the memory of my parents, Alda Merle McCaw-Simmonds and Lascelles George Simmonds.

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ABSTRACT

This study examines the environmental and economic effects of green information technology (IT). Green IT describes two sets of IT innovations: one set includes innovations that are implemented to reduce the environmental impact of IT services in organizations; and the other IT to reduce the environmental impact of other organizational processes. The two sets respond to the call for more environmentally friendly or “greener” organizational processes.

I developed and tested a preliminary model. The model applied the resource based view (RBV) of the firm (Wernerfelt 1984) the stakeholder theory (Freeman 1984) and included four constructs: (1) *BAS implementation*; *environmental value* conceived in a novel way as the conservation of electric energy in buildings; *economic value* -- from energy cost savings; and *BAS complements*. These four constructs formed three propositions: (1) *BAS implementation* is positively associated with *environmental value*; (2) *environmental value* is positively associated with *economic value;* and *BAS complements* moderate the relationship *BAS implementation* and *environmental value*.

The model was used to guide the investigation of three research questions:

1. What are the environmental and economic values of green IT?
2. How do green IT create the above values?
3. Are other dimensions of value created? If so, what are they?

The focal IT investigated was the building automation system – a system designed to conserve electric energy and decrease operational costs. The unit of analysis of the study was the facilities management team – the implementers of the system.

I collected data on a sample of six diverse cases of BAS implementations. The cases were diverse in terms of the BAS types, the building purposes, the building locations and the building occupancy and management. Two types of BAS were involved in the study, each with a different level of artificial intelligence: the more intelligent BAS self-reconfigured when changes in setpoints, for example, were necessary; the less intelligent BAS must be reconfigured by an engineer in similar circumstances.

There was also diversity in terms of the buildings in which the systems were implemented and the occupancy and management of the buildings. The buildings include: the corporate headquarters of a global telecommunications firm; university classrooms; a residence hall in a university; and three multi-tenanted office complexes. The building occupancy and management differ in that some buildings are owner-occupied and are managed in-house, while the others are leased and their management outsourced.

Data collection involved recorded semi-structured interviews of three sets of users in the organizations: building engineers; chief engineers; and property/facilities managers. The interviews were prearranged and were conducted onsite using an interview protocol. Each interview lasted approximately one hour and was conducted in one session. The data were transcribed and analyzed in Nvivo 10.

The findings showed support for the presence of the four constructs within the preliminary model as well as for the three propositions in the preliminary model. The data also revealed contextual details of the *BAS implementation* and *BAS complements* constructs. There were also new dimensions value including: unanticipated types of economic value (including savings from reduced labor demand; social value (comfort and safety for building occupants); and *strategic value* (knowledge used to position the organizations for greater efficiency and effectiveness). Overall, the value outcomes of the implementations can be summarized as short term social, environmental and economic value as well as strategic value – consistent with the concept of *sustainable value* defined by Hart et al. (1995).

Also, consistent with Zuboff's (1985) description of the duality of intelligent IT systems -- the ability to *informate* and *automate*, the *BAS implementation* construct was found to include two distinct sources of value: *equipment automation*; and *equipment* information. The unanticipated value dimensions and types, as well as the sources of value were used to refine the research model.

The study therefore a preliminary theoretical model – the *resource based view of the sustainable organization* (RBV-SO) -- as well as contextual implementation details that can be used to guide future investigations of the value created by intelligent green IT systems such as the BAS, as well as measurement items that can be used to inform quantitative studies of these systems. The study also adds to the practical body of knowledge concerning green IT implementations in general and implementations of the BAS in particular, concerning: details of the information value – for example, for measuring the environmental impact of the system and for substantiating claims in the application for green funds available to organizations; and details of some key complementary resources that enhance value creation within the context.

Two major limitations of this study are: (1) a single coder was used in the analysis process and therefore no inter-coder reliability was established for the results; and (2) user perceptions rather than actual quantities were used to validate the findings.

Some future research prospects include: use of these findings to conduct a quantitative study of an intelligent system extended with, for example, investigation of the impact of external forces such as government regulations, environmental issue salience, and market forces on the value created by green IT (such as the BAS); and investigation of the impact over time of the development of the strategic capabilities enabled by the BAS on creation of value.

CHAPTER 1: BACKGROUND & FOUNDATIONAL CONCEPTS

Introduction: Sustainable Development and the Organization

The concept of sustainability attracted global attention and became popular with the definition of the concept of sustainable development by the Brundtland Commission in 1987. The Commission defined sustainable development as "*development that meets the needs of current generations without compromising the ability of future generations to meet their own needs*" (Brundtland 1987). The main idea was to promote a development process that presented less threats to the planet and its inhabitants, in particular the people.

According to the Commission's report, sustainable development has three components. One of the three is *environmental sustainability*. Environmental sustainability is the potential to support the natural environment's ability to provide natural resources such as energy and water and to absorb the waste expelled. Environmental sustainability is concerned with the continuity of the planet and is, therefore, thought to be the foundation of the other two components (Starik et al. 1995).

Another component of sustainable development is *social sustainability* – the ability to ensure the wellbeing and continuity of people, with emphasis on the poor and underserved. Social sustainability is concerned with access to water, food, medicine, and other basic necessities. The final component is *economic sustainability*, which describes the ability of nations and societies to prosper (Goodland 1995). These three components are said to be interdependent. Consequently, threats to any one, present threats to the others.

In many instances, the threats to sustainability are posed by organizations. Organizations [industry] have been credited with "meeting essential human needs", but not always in a responsible manner (Brundtland 1987). Unfortunately, organization profits are often pursued at the expense of the wellbeing of the natural and social environments in which the organizations operate. This research focuses specifically on actions taken by organizations to reduce their threats to *environmental sustainability*.

Organizations and the Natural Environment

The natural environment has systems that act as ***sources*** and ***sinks*** for many organization processes. The natural environment is a source in that it provides renewable and non-renewable resources that are used as inputs to organization processes. The environment's renewable resources will regenerate if not consumed too quickly; however, the non-renewable resources can become diminished to the point of depletion with use. Examples of natural sources include: forests that can provide lumber; soil from which metals and fuel sources can be extracted; and rivers and seas from which water can be had.

These same natural resources also act as sinks. As sinks, they absorb the outputs of processes that are not used by organizations – organization waste. For example, the forests absorb greenhouse gases (GHG) which are created when organizations consume electric energy; and the soil, rivers and seas absorb solid waste that organizations discard.

When organizations consume renewable resources at rates above the generative capacities of the environmental sources, they deplete the environmental sources until the resources are exhausted; however, in some cases, substitutes are found. Depleted resources impact the ability of the systems of the natural environment to act as sources as well as their capacity to act as sinks.

Expulsion of waste beyond the absorptive capacities of the environmental sinks means that the waste will not be completely assimilated into the environment and will result in levels of toxicity that are destructive to the natural systems. Thus the soil, water and atmosphere become polluted. This result in overburdened and, eventually, impaired environmental systems. Overconsumption of natural resources and/or expulsion of waste are defined here as negative impacts on the natural environment.

Impairment of the natural environmental sinks and sources compromises the ability of future generations to meet their own needs, and, is therefore, as defined by the Brundtland Commission *unsustainable*. However, fortunately, many organizations are seeking to rebrand themselves as *sustainable* organizations. Sustainable organizations are those that include social and environmental concerns in their business operations and in their interactions with stakeholders (Van Marrewijk 2003b) (p107). In doing so, these organizations commit to a mode of operation that is more environmentally and socially responsible (Bansal 2005; Hart et al. 2003; Starik et al. 1995). This study focuses on the reduction of the negative environmental impact of organizations processes. I define such reduction as *the creation of environmental value*. Environmental value is created when organizations reduce or slow the consumption of natural resources and/or the output of their waste into the environment.

Environment Value and Green Information Technology (GIT)

Organizations have introduced a number of projects that create environmental value through the implementation of information technology (IT). These include the implementation of IT initiatives that have less negative environmental impact such as IT storage or the implementation of IT that control and monitor the impact of non-IT related processes. Initiatives such as these have come to be known as green IT. *Green IT* is defined in this research as that subset of IT resources that are aimed at reducing the negative environmental impact of organization processes and, in so doing, enable the organization to create environmental value.

One of the greatest threats that organizations indirectly pose to the natural environment is the consumption of electricity. This is so because the generation of electric energy negatively impacts the source capacity of the environment by depleting fossil fuel such as coal, oil, and natural gas – non-renewable natural resources from which electric energy is generated for most organizations. The generation of electricity also releases carbon dioxide that makes up the vast majority of GHG emissions. These gases are released during the combustion of fossil fuels that produce electricity. Excessive GHG emissions are known to be a cause of global warming – one of the major threats to the planet (Cline 1992; Soytas et al. 2007). Organizations' demand for electricity also impacts the sink capacity of the natural environment negatively. In this research I investigate how organizations create environmental value by implementing green IT to reduce their consumption of electric energy and, by virtue of doing so, reduce the threats to environmental sustainability that are associated with electric energy consumption.

Early Research: Green IT

The literature discusses two sets of green IT. The first comprises IT innovations that are implemented to reduce the negative environmental impact of IT (Alena et al. 2012; Kuo et al. 2010). These innovations replace older generations of IT resources while providing the same or greater data collection, analysis, storage, and other IT capabilities as the older resources. However, relative to the older resources, they reduce the IT impact on the environment and result in more environmentally-friendly IT processes. They may, for example, be more efficient and consume less energy, or they may be smaller or made from recyclable materials and therefore generate less toxic waste on disposal. Examples of these innovations include consolidated and virtualized servers.

The second set of green IT are IT innovations that are implemented to monitor and control the environmental impact of organization processes other than those that provide IT services. These IT resources increase the environmental efficiency of a range of processes across organizations, including manufacturing, logistics and facilities maintenance, in which they are used. An example is seen in the case study of the "*telematics-based*" IT system implemented by UPS. The software was used to analyze historical process data in order to identify opportunities for reengineering or improving the logistics process to minimize fuel consumption. The software enabled UPS to reduce its negative environmental impact by reducing delivery mileage, fuel consumption and vehicle replacement parts (Watson et al. 2010).

The second set of green IT provides organizations with "the ability to incessantly assess and reinvent themselves" (Kohli et al. 2008) and so become more sustainable. My research investigates an IT innovation from this second set.

Green IT literature is sparse. However, early research indicates that green IT enables the creation of environmental value, and that the creation of environmental value presents economic opportunities for organizations. For example, a case study of HAG – a Swedish furniture manufacturer – investigated a logistics software system that was used to optimize packaging and delivery of the organization's goods and monitor and reduce its consumption of energy. The system enabled the organization to create both environmental and economic value by reducing its fuel consumption (Høgevold 2011).

Other case studies also provide evidence of green IT value, in particular how these resources reduce the energy consumed by organizations. For example, there have been case studies of:

building automation systems conserving electric energy (Simmonds et al. 2013); and logistics software and other IT resources conserving transportation fuel (Watson et al. 2010b).

The empirical IT literature provides evidence of environmental value described by generic terms including: *environmental performance* (Meacham et al. 2013), which refers to negative environmental impact of organizations including the output of air emissions, effluent waste, solid wastes and hazardous and toxic materials (Ryoo et al. 2013).

Industry evidence also indicates that green IT enables the creation of environmental value. For example, Toyota manufactures cars that use IT to monitor and reduce fuel consumption for their customers. In doing so, the car manufacturer simultaneously creates environmental value and a greater market share – economic value (Toyota Motor Corporation 2012). Green IT therefore has the potential to enable two dimensions of organization value – environmental and economic.

The industry literature is interesting and provides useful insight into the potential of green IT to create environmental value. The academic literature is beginning to provide a background on the factors that influence green IT implementation (in particular, adoption stage factors), and how and what value is created. The literature also provides some insight into areas where further research on green IT is needed. For example, researchers have called for investigations: that apply known theories and methods to the problems related to environmental sustainability (Melville 2010); of the impact of IT resources on beliefs about the environment (Melville 2010); of the drivers of information systems (Melville 2010); and of the value of information systems as direct, mediating and moderating influences on environmental sustainability (Melville 2010; Watson et al. 2010).

Green IT and Building Operations

The United States Energy Information Agency (USEIA) recently announced that approximately 40 percent of total US energy consumption in the year 2014 was consumed in residential and commercial buildings (http://www.eia.gov/tools/faqs/faq.cfm?id=86&t=1). Corporate headquarters and other buildings that house many of the organization's services therefore represent a major source of energy consumption in organizations and provide a valuable source of knowledge for this stream of research.

The Building Automation System

Building lifecycle analyses have shown that electric energy represents the majority – 95% - of energy consumed in buildings operations (Kofoworola et al. 2009; Scheuer et al. 2003) and that it is possible to reduce building energy consumption by up to 40 per cent by introducing strategies including the implementation of energy management systems such as the building automation system (BAS) – see sample depicted in Figure 1-1.

The BAS is a computer-based control system that is used to centrally control and monitor digitally-controlled building appliances. The entire information system involves the following components: the BAS – used to centrally monitor and control the attached pieces of equipment that provide various building services, and facilitate integration of the various control systems for the attached equipment pieces; building engineers – who configure and reconfigure the system (for example, establish setpoints) and override existing configurations; building equipment – the pieces of operational equipment that are monitored and controlled by the BAS; digital controllers – logic control systems that provide the algorithms that check setpoints and other configurations set in the BAS and control the equipment accordingly; sensors that read and provide actual values of indoor conditions for comparison with the setpoints; and an IP network that connects the various control systems to their equipment and to the BMS server, and through which the Facilities Teams gain access to the systems and equipment. Figure 1-1 depicts the system components.

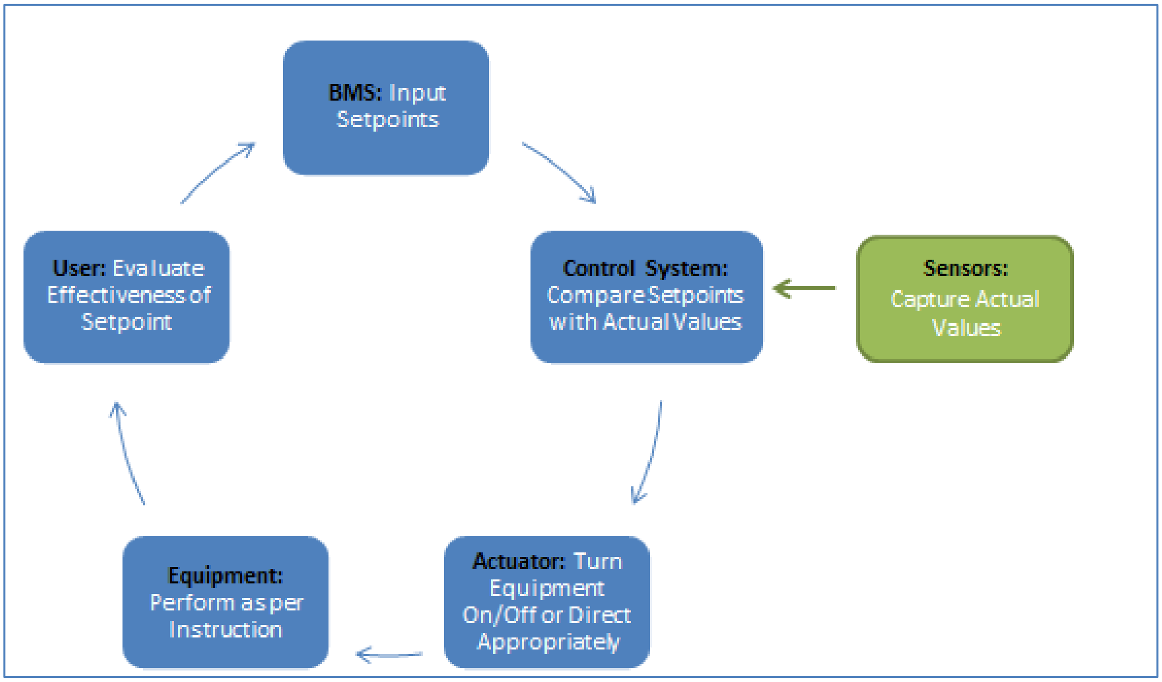

Figure 1-1: BAS Components

BAS implementation involves connecting to the digital controllers of building equipment such as HVAC, lighting, electrical, fire and security systems. The system is most commonly used within large buildings. Its core functions include automating the start-up and shut-down of connected building equipment to conserve the energy they use.

The major building equipment usually controlled by the BAS includes those associated with the building cooling and heating functions. These two functions typically represent at least 40 percent of a building's energy usage. When lighting is added, this consumption is said to approach 70 percent. BAS control is, therefore, critical for managing the energy consumption and demand especially in larger buildings. As such, its implementation provides an excellent opportunity to explore green IT implementation and value.

Figure 1-2: BAS Network Infrastructure. Source: [http://www.johnsoncontrols.com /](http://www.johnsoncontrols.com/)

A search of the Internet shows the availability of two types of BAS. Both systems are able to automate the startup and shutdown of building equipment; however, each type had a different level of intelligence which accounts for the system's ability to self-reconfigure, or not. The first BAS type, the more intelligent of the two, is able to self-reconfigure – to make changes to the control settings needed to manage the building equipment with little or no user intervention. This is necessary, for example, when there is a change in the weather pattern that affects the indoor climate. In such a case, these BAS "learn" the new patterns based on recent historical use and self-reconfigure to adapt to the changes.

The second BAS type is incapable of reconfiguring itself and thus requires constant user intervention for managing similar changes to control settings that are needed. These two types are referred to in this research as “user-reconfigured” and “BAS-reconfigured” respectively.

Despite the high carbon footprint of corporate buildings and the apparent energy conservation capabilities of the BAS, as far as is known, to date only one atheoretical business study has investigated these systems to understand how they enable organizations to create environmental value yet these systems provide a clear research opportunity. An investigation of the implementation of these systems can contribute to an understanding of the role of green IT in sustainable operations and environmental value creation, especially as it relates to the conservation of electric energy.

Research Questions

The current study is motivated by the need for more, and more in-depth, research in the area of green IT. There is also the need to understand, generally, how to create environmental value to address the imminent threats to the natural environment and, specifically, how electric energy can be conserved in buildings using BAS. Based on the above, the following research questions were proposed. The questions called for the development of a theoretical account that explained why, and how, green IT – specifically BAS – were used to create environmental value and to understand the other value outcomes that are created by these systems. Stated explicitly, the research questions are:

1. How do green IT /BAS implementation reduce negative environmental impact or, in other words, create environmental value?
2. Are other dimensions of value created? If so, what are they?

A number of theories that explain economic value creation could, potentially, be extended to guide the above research questions. Some of these include Wernerfelt's (1984) *resource-based view of the firm*; and the dynamic capabilities theory (Teece et al. 1997) (p516). It may be that the previous idea that the sole focus of organizations is to increase shareholder wealth (Friedman 1962) led to the singular focus on economic value in value theories. However, a relevant research model could, potentially, be developed by extending one of these theories to incorporate the creation of environmental value. The model would be used to guide a study that contributes to our theoretical knowledge on how green IT systems enable value creation.

The study investigates the use of the BAS and the outcomes of its use in an attempt to answer the above research questions. Guided by a preliminary model, the study focuses on the impact of the BAS on the organization's consumption of electric energy. To the best of my knowledge, this study is the first to present a theoretical investigation of these green IT systems. In the very next section I briefly describe how the rest of this dissertation is organized.

Organization of the Dissertation

Chapter 2 presents a review of the relevant literature. I provide a brief description of studies that have explored the factors that motivate implementation of green IT in organizations as well as the outcomes of these implementations. I also present a summary of a representative sample of the IT business value and building operations literatures – the IT business value literature because it sets a background for the concepts found in the green IT literature, and the building operations literature because it represents the context in which the study is conducted.

I extract variables from the significant relationships within the green IT literature, and abstract these to arrive at constructs that may be generalized across the studies. Using these constructs, I summarize the relationships that merge from the body of green IT literature. The chapter ends with a summary of the conflicts/gaps found in the literature.

Chapter 3 describes the theoretical framework that guides the investigation. Theories used in the exploration of IT (including green IT) value are presented. The value theory selected, the *resource-based view of the firm* (RBV), is extended to include *environmental value* – the new construct that represents the environmental benefits of green IT use as informed by the green IT literature – in addition to the economic value construct already present in the RBV. The chapter ends with a presentation of the preliminary research model that is used to guide the collection and analysis of the data used to explore the use of the green IT – *the resource-based view of the sustainable organization (RBV-SO).*

Chapter 4 presents the research methods. In this chapter I describe the method used to select organizations and participants and to collect data as well as the design and distribution of the research instrument. I also discuss the methodology used to analyze the data and validate the resulting model.

Chapter 5 presents the results of my research. In this chapter I discuss how the results support the preliminary model as well as refinements made to the model. I end by presenting the final model.

Chapter 6 discusses the implications of my research and describes how it adds to the extant literature. The chapter provides greater insight into how green IT implementations are carried out within companies within a context not yet discussed in the literature – green building operations. I also discuss the most significant contributions of this research – the development of a sustainable IT value research model based on the RBV – as well as the relevance of the findings.

CHAPTER 2: REVIEW OF PRIOR LITERATURE

Introduction

The major focus of this chapter is the discussion of studies that have explored the factors that motivate implementation of green IT in organizations as well as the outcomes of these implementations. I also present a representative sample of the IT business value and building operations literatures: the IT business value literature because it sets a background for the concepts found in the green IT literature, and the building operations literature because it represents the context in which the study is conducted.

There is much discussion within industry cases of the significant sustainability impact of green IT; however, the academic green IT literature continues to be sparse. Interestingly, the existing literature includes investigations conducted in several countries across the globe, including Jamaica, the United States (US), China, Korea, Norway and Australia. There have been investigations of a variety of different green IT including: *data centers* (Alena et al. 2012; Kuo et al. 2010); *virtualized and consolidated IT equipment* (Kuo et al. 2010; Molla et al. 2012); *green-modified ERP systems* (Meacham et al. 2013) and *logistics software* (Høgevold 2011; Watson et al. 2010b).

The earliest academic papers on green IT literature include a number of conceptual studies in which more experienced IT researchers developed agendas and issued calls for research at the intersection of IT and sustainability (Dedrick 2010; Melville 2010; Watson et al. 2010b). Following those calls, four streams of empirical green IT research developed, including: (1)

quantitative studies that explore the factors that influence green IT implementations; (2) quantitative studies that use different theories to examine green IT value creation; (3) case studies that reveal some level of detail of the entire implementation process from adoption to value creation; and (4) green IT decision modeling studies. These empirical studies focus on two sets of dependent variables: (1) green IT adoption; and (2) green IT value outcomes.

In addition to focusing on these empirical green IT studies, I also reference a small sample of representative, rather than exhaustive, studies that are germane to my research. These include IT business value studies and building lifecycle energy analyses. The business value studies are incorporated as it is thought that they could potentially be used to guide the review of, and provide insight into, the green IT literature. The building energy studies are incorporated because they focus on, and provide significant insight into some concerns of buildings operations – a part of the context of this study.

The rest of this chapter proceeds as follows. In the next section I present a review of the IT business value literature which sets a background against which the green IT value literature can be understood. I follow this with a review of the green IT literature in which I present: the major studies and their findings; insights gained from the studies; and an overall summary of the literature. I then present two building energy analyses. I end the chapter with a summary of the gaps and a rationale for this study.

IT Business Value Literature

IT business value studies investigate the relationship between IT resources and economic performance. Some studies have found positive associations between IT implementation and economic value. These studies show that IT resources, by themselves, do not create value. Rather, IT value is created when IT is combined with other key organization resources

(Brynjolfsson et al. 2000; Mishra et al. 2007b; Tippins et al. 2003), and capabilities (Bharadwaj 2000; Rai et al. 2010; Zhu 2004). Economic value is primarily created when IT: increases process efficiency (Amit et al. 2001; Barua et al. 1995; Hitt et al. 1996); reduces process costs (Mithas et al. 2011; Mukhopadhyay et al. 1995; Zhu 2004); facilitates the innovation of products and services (Amit et al. 2001; Porter et al. 1985); and differentiates products and services in the marketplace (Brynjolfsson et al. 2000; Rai et al. 2010).

Insights from IT Business Value Studies

A number of variables were investigated in the IT business value studies. These variables can be grouped into five categories. In this study, *IT* describes digital technology assets and their capabilities for capturing, processing, storing, displaying and communicating data and information. The literature shows examples of IT resources and related variables including: *IT investments* (Anthony Byrd et al. 2006; Mithas et al. 2011); *IT use for competitive advantage* (Kearns et al. 2003); and *IT intensity* (Zhu 2004).

The second set of variables is ***IT implementation antecedents***. These represent the factors that influence IT implementation. Some antecedents that have been found to be influential include*: information* and *strategic alignment* of the business and IT functions (Kearns et al. 2003); and *digital capabilities* and *knowledge* (Mishra et al. 2007b). Kettinger et al. (1994) also found that fundamental differences, prior to implementation, in *environmental*, *foundation*, and *strategy factors* between *strategic* and non-*strategic IT users* made a difference in the extent of *economic value* created.

The third set of variables is ***complementary organization resources***. These are key resources that are combined with the green IT. These resources serve to enhance the extent of the value created by the IT resource. Examples of such resources from the literature include *business strategy* (Anthony Byrd et al. 2006) and *after-sales services* (Amit et al. 2001).

The fourth set of variables is ***complementary organization capabilities***. These refer to non-IT [human] capabilities and expertise that, along with the IT use and like the complementary organization resources mentioned above, enhance the extent of the value created by the deployed IT resource. Examples from the literature include: *organizational learning* (Tippins et al. 2003); *e-commerce capability* (Zhu 2004); and *process alignment* (Rai et al. 2010).

The fifth set of variables is ***economic value***. This refers to the economic outcomes of the implemented system that benefit (or potentially benefit) the organization. Examples from the literature include: *business performance* (Anthony Byrd et al. 2006); organization revenues (Mithas et al. 2011); and *procurement process performance* (Mishra et al. 2007a)(Mishra et al. 2007a)(Mishra et al. 2007a)(Mishra et al. 2007a)(Mishra et al. 2007a).

Overall, business value studies present evidence that ***IT implementation antecedents*** result in differences in ***IT use***, which, in turn, caused variations in the ***economic outcome levels*** among organizations carrying out the same processes (Kearns et al. 2003; Kettinger et al. 1994; Mishra et al. 2007b). They also indicate that IT has capabilities that enable the creation of business value and that the value is enhanced when other key resources and capabilities are implemented along with the IT resources (Zhu 2004).

These insights from the IT business value studies provide a background against which green IT value studies can be viewed. Given that green IT is a subset of IT, I use these constructs as a guide in the abstraction of the plethora of variables that are investigated within the green IT literature and to summarize the relationships found therein.

Review of the Empirical Green IT Literature

The green IT literature includes only a few studies that investigate the implementation factors and outcomes of green IT. Both types of green IT mentioned before in Chapter 1 were investigated in the literature: those IT resources that reduce the environmental impact of providing IT service; and those IT resources that reduce the environmental impact of organization processes that are unrelated to IT service provision – see Table 1.

Four sets of green IT studies are reviewed. The first are decision modeling studies that present ***decision factors*** and develop ***methodologies*** that organizations can use to determine the green IT that are to be adopted. The second are quantitative studies that explore the ***antecedents*** of green IT at three implementation stages – ***adoption***, ***procurement*** and ***use*** stages. Quantitative studies that investigate the ***environmental*** and/or ***economic value*** outcomes of the ***use*** of green IT represent the third set of studies and the fourth are case studies that investigate and describe the ***entire implementation process*** revealing both ***antecedents*** and ***outcomes***. In the following sections I describe the five sets of studies starting with the conceptual studies.

Green IT Decision Modeling Research

Two decision modeling studies were reviewed: Bai et al. (2013); and Hertel et al. (2013). Both developed models for determining how organizations should invest in green IT. Bai et al. focuses on the use of sustainability decision factors in a seven-step methodology to determine the **optimal investment choice** for an organization choosing among green IT. Their methodology involves the *grey-based fuzzy TOPSIS* which ranks and orders GSIT alternatives based on their similarity to an ideal solution. According to the authors, an ideal solution is one that integrates decision factors from all three sustainability dimensions: (1) economic factors – *net present cost*, *flexibility*, *maintenance rates*; and *scheduled start*; (2) environmental factors – *energy usage*, *material toxicity* and *percentage of recycled material used*; and (3) social factors – *safety*, *aesthetics* and *number of new jobs enabled*.

Table 2-1: Prior Literature: Environmental Impact of IT Resources

Green IT	Sources	Impact of Green IT Resources Studied
Server consolidation	Alena et al. 2012 Kuo et al. 2010 Molla et al. 2012	These IT resources reduce the environmental impact that IT service provision has.
Desktop virtualization		
Server and storage virtualization and consolidation		
Green IT	Cai et al. 2013	These IT resources reduce the environmental impact that other organization processes (unrelated to IT service provision) have.
IT capability	Benitez-Amado 2012	
Green modified ERP	Meacham et al. 2013	
Logistics software	Høgevold 2011; Watson et al. 2010	
Building management system	Simmonds et al. 2013	
Collaboration /teleconferencing IT	Høgevold 2011; Kuo e al. 2010; Molla et al. 2012	
Green practices-IS alignment	Ryoo et al. 2013	

The authors use simulated data on data centers to validate their method. The results showed that sustainability – social, environmental and economic – factors can be integrated into making the selection decision for IT resources.

Hertel et al. focus on determining the size of an IT investment that reduces both exposure to fluctuating energy prices and energy demand in the long-term, thereby ensuring that coherence of both economic and environmental goals is established. Economic and environmental decision factors are used to determine the **optimal IT investment size** – the size that maximizes both *exposure to fluctuating energy prices* and *energy demand* in the long-term.

The authors use simulated data representative of a typical medium-sized company to validate the model. The results show that: (1) a larger project size is economically reasonable, as long as increased environmental and economic performance compensate for increasing investment costs, and the environmental value is consistent with the economic requirements of the company; (2) green IT implementation not only enhances organizational performance, but reduces dependence on fluctuating energy markets; and (3) while intensification is desirable for maximizing environmental value, guaranteeing the continued existence of organizations requires the establishment of coherence of both economic and environmental goals first.

Insights from the Decision Modeling Research

The major insights from the decision modeling studies are that organizations may use factors other than economic – for example, environmental – to determine the selection and size of an IT investment. However, they must first establish the economic and other sustainability goals, for example, the environmental, and seek to ensure a balance between their economic objectives and these other objectives.

Green IT Implementation Factors Research

The literature includes investigations of green IT implementation factors (Table 2) for various implementation process stages in various countries across the globe. Alena et al. (2012) conducted a survey of 61 small and medium-sized businesses in the Czech Republic to examine the extent to which environmental considerations affect green IT at three lifecycle phases: *procurement*; *use*; and *end-of-life*. Their results show that the most significant factors were: *eco-friendliness* of the IT resources as well as of the IT manufacturers and/or distributors at the procurement stage; *energy-efficiency* during use; and *material toxicity* at end of life.

Cai et al. (2013) administered a survey through postal mail to professionals in 82 Chinese organizations to explore the factors that influenced the implementation of green IT at the **adoption** stage. They explored factors including *public concerns*, *regulatory forces*, *cost reduction* and *differentiation*, but found significant results only for *cost reduction* and *differentiation* – both economic factors.

Molla et al. (2012) also explored the factors at the **adoption** stage. They conducted an online survey of 176 CIOs/IT managers from Australian organizations to determine the influence of eco-efficiency, eco-legitimacy, eco-effectiveness, and eco-responsiveness. All factors were found to be significant.

Kuo et al. (2013) conducted an online survey of senior and other IT professionals in 38 Australian and US organizations to determine the factors that influenced the **use** stage for improving the organizations' environmental sustainability performance. They explored several factors including *management influences, ongoing operational costs,* the *complexity of the implementation process*, the *availability of resources* and the *capability of the organization to adapt*, *limitations posed by software, hardware and infrastructure*, *complexity of green IT initiatives, bottom line consideration*, *normative legitimation pressures*, *coercive legitimation pressure*s, and *social responsibility pressures*. Three factors – *organizational adaptability*; the *influence of the legal affairs department*; and *employee-based social responsibility pressure* – were found to be significant.

Insights from the Implementation Factors Research

The factors so far found to be most influential may be summarized as ***expectations of*** both environmental impact reduction – especially to gain stakeholders' approval – and business value. With respect to stakeholder approval, the main stakeholders discussed are: internal stakeholders concern for the natural environment, such as employees – including top managers (Alena et al. 2012; Kuo et al. 2010) – and external stakeholders such as environmental regulators (Kuo et al. 2010; Molla et al. 2012).

One shortcoming of these studies is that the types of IT resources investigated to date have been limited to IT innovations, such as virtualized services and data centers, that are used in the provision of IT service (Alena et al. 2012; Kuo et al. 2010; Molla et al. 2012). Another is the failure to use theories. These studies have been exploratory, for the most part, except for the use of stakeholder theory by Cai et al. (2013).

Green IT Value Research

Green IT value research, like IT business value research, investigates the value outcomes of green IT implementations; however, two outcomes are explored – environmental and economic value. While some researchers focus on both these value outcomes, others focus on only one of the two. Overall, support was found for both. Meacham et al. (2013) conducted an online survey of 159 manufacturing managers to investigate how "*green-modified*" ERP systems[1] impact the environmental performance of organizations. They found evidence for a positive relationship between the modified IT systems and environmental value, as well as a positive relationship between the *information sharing* capability and the "*green-modified*" ERP systems. They found that *information sharing* indirectly impacts *environmental performance* through the "*green-modified*" ERP systems.

Ryoo et al. (2013) conducted a web-based survey of 77 South Korean manufacturing employees, each with responsibility for environmental management practices in his/her organization. The goal of the study was to apply the resource-based view (RBV) in an examination of how the IT function aligned with the green practices function influences first, the coordination of green practices with other business functions, and second, the environmental and economic firm performances. Their study examines two mediating *coordination capabilities*: *green practices-marketing*; and *green practices-manufacturing*. They found evidence for: a positive relationship between green practices-IT alignment and the coordination capabilities (green practices-marketing and green practices-manufacturing); a positive relationship between these capabilities and environmental value; and a positive relationship between environmental value and economic value.

Benitez-Amado et al. (2011) combined data on 63 organizations from three Spanish databases including: (1) Actualidad Economica; (2) Spanish Association for Standardisation and Certification database; and (3) Top Performers for Working in Spain. Their goal was to determine the impact of IT capability on business performance when environmental sustainability considerations were introduced into organization strategy. They applied the RBV, the natural RBV (Hart 1995) and dynamic capabilities theory (Teece et al. 1997) to investigate the impact of *IT capability*[2] on *proactive corporate environmental strategy*[3] - a dynamic capability, and of *proactive corporate environmental strategy* on the organization's *economic performance*. Their results show a positive relationship between *IT capability* and *proactive corporate environmental strategy*, and a positive relationship between *proactive corporate environmental strategy* and *economic value*. Their study omitted *environmental value* outcome.

Finally, Ko et al. (2011) applied the RBV and Schumpeter's innovation theory (Schumpeter 1942) to investigate 42 of the 500 organizations most IT innovative organizations in the United States using data collected from *Information Week*'s annual survey from 2001 to 2006. Their goal was to determine whether IT innovators[4] achieved competitive advantage after "*going green*". The "*matched sample comparison group*" methodology was used to compare innovators with non-innovating organizations. They examined the impact of *green IT innovation* on *profitability*. The results show that green IT innovators perform significantly better than the followers (non-innovating organizations) for all financial performance indicators. Their study also omitted *environmental value* outcome.

Insights from the Green IT Value Research

The major insights provided by the green IT value research are that: (1) green IT use enables organizations to create environmental value; (2) environmental value results in business value; and (3) as in IT business value research, green IT value creation is enhanced when key complementary organization resources and capabilities are deployed with the focal IT resources.

There are a few clear shortcomings within the research stream. One is that, despite its apparent importance, the area continues to fail to attract research and so there is very little knowledge. Another is that the investigations carried out have treated IT as a "black box". Most investigations fail to specify the type of IT resource that is being examined. One exception among those reviewed is Meacham's (2013) study of green-modified ERP systems.

And, just as these studies have failed to specify the IT resources being investigated, they have also failed to explicitly state the type of environmental value that the IT resources create. Instead, they have used generic terms such as: organization *environmental performance* (Meacham et al. 2013); and *environmental performance* (Ryoo et al. 2013).

Where application of theory is concerned, green IT value studies have applied existing theories and research models from the literature in their investigations. For example, *Schumpeter's innovation theory* (Ko et al. 2011) as well as the *resource-based view of the firm* and *dynamic capabilities theory* have been used to explain environmental and, in some cases, business value creation (Benitez-Amado et al. 2012; Ryoo et al. 2013) and reference has been made to the advanced model of corporate ecological responsiveness by Benitez-Amado (2011); Kuo et al. (2010); Molla et al. (2012); Cai et al. (2013); Ryoo et al. (2013); Ko et al. (2011). The literature on green IT antecedents has also applied stakeholder theory (Cai et al. 2013).

Case Research of Green IT Resources

Case studies on green IT corroborate the evidence of stakeholder influence on implementation and of value outcomes that were found in the quantitative studies. The greater value in case studies, however, is that they have provided deeper insight into IT use. Five case studies were reviewed. I start with Watson et al. (2010).

Watson et al. 2010

Watson et al. (2010) investigated the use of various IT resources including a dispatch planning system, handheld computers, sensors, and printed information labels. Overall, these IT resources were found to improve the environmental and economic performances of UPS' logistics processes and increase the safety and wellbeing of employees within the organization.

The findings support some of those within the quantitative studies such as *regulatory pressures* as a key antecedent and *energy conservation* as a key outcome. Additionally, the findings of this case study revealed greater insight into the use of these green IT, such as details related to their antecedents and outcomes. Other major antecedents include UPS' *IT innovation* and *sophistication*, and *employee awareness of the need for, and their commitment to, the conservation of the environmental*; and major outcomes also include *employee safety*, and *fuel and parts replacement cost reduction*.

Simmonds et al. 2013

A second green IT case study was conducted by Simmonds et al. (2013) who investigated the Digicel Group, a mobile telecommunications provider in Kingston, Jamaica. The study investigated the use of the BAS – a green IT initiative used to monitor and control the building equipment in the corporate headquarters of the organization.

Some implementation factors evident from the case include *management and employee support* for environmental sustainability and the *availability of appropriate green technology systems*. Similar to outcomes found in Watson et al. (above), the study found evidence of: *reduced energy consumption* and other operational costs; and increased *employee safety*. *Employee comfort* was another major outcome of BAS use.

Høgevold 2011

Høgevold (2011) conducted a case study of a Norwegian furniture manufacturing company, HAG. The author explored drivers of the firm's corporate environmental profile and initiatives; and the impacts of the initiatives along the value chain – internally, as well as upstream and downstream in its supply chain. The firm's sustainability initiatives included the implementation of green IT including *collaboration IT* and *logistics software*. Like the UPS case, the nature of the study provides insights into the process through which green IT innovation proceeds. As well, the details of the case corroborate the findings of the studies presented above.

Findings of key antecedents of adoption include *employee support* and *management support* (for "doing the right thing" – supporting environmental sustainability). Factors that drive continued use include *employees' environmental awareness*, and *customers' demand* for sustainability (knowledge of the products).

The study also gave insights as to some key capabilities used before, and developed after, with the use of the IT resources. A key capability that was used to determine the need for the system is *external consultants' expertise* (used to measure carbon footprint through the value chain). A key IT-enabled human capability that resulted from the use of the IT resource is *logistics optimization* (which led to reduced number of trips and doubled the number of products per trip).

The company realized both environmental and economic value outcomes. Environmental outcomes include: *reduced eco-impact* – from employee business travel; *reduced fuel consumption* – for product transportation; and *low carbon footprint products*. Economic value outcomes include: *reduced transportation costs*; *reduced employee travel costs*; *competitive company environmental profile* that leads to a competitive market position, *competitive product brand*; and *long-term company differentiation* for the firm and its products.

World Business Council on Sustainable Development Research

From industry, some case studies of outcomes of multiple green IT have been conducted and documented by the World Business Council on Sustainable Development (WBCSD). One example is the study of the IBM *Mobile Monitoring Technology* – a technology resource used to analyze the thermal profiles of operating data centers. The study reports that the system assisted IBM personnel in identifying opportunities for reducing energy demand at four of the company's data centers. Outcomes of use include reduction in energy usage by 7,553 megawatt-hours (MWh) per year (11%), and savings of US$619,000 per year (WBCSD 2008).

Insights from the Case Study Research

The case studies report the impact of specific green IT. All these resources fall into the second category of green IT identified – those used to monitor and control the environmental impacts of firm processes other than IT. Specifically, they are used to monitor and control firm transportation logistics (Høgevold 2011; Watson et al. 2010b) and building operations (Simmonds et al. 2013).

The case studies support the findings of the quantitative studies, except that they offer greater insights into the use of green IT. As do the quantitative studies, the case studies show that: (1) green IT use enables organizations to create environmental value; (2) environmental value results in business value; and (3) as in IT business value research, green IT value creation is enhanced when key complementary organization resources and capabilities are deployed with the focal IT resources. Some key implementation factors for which evidence is seen are: external stakeholders' pressures including from regulators and customers; internal stakeholders' pressures from management and employees; IT innovation and sophistication; and the availability of appropriate green technology systems. Some key value outcomes are: energy conservation – fuel and electric energy; and the associated reduced cost of energy.

In terms of shortcomings, again the major ones are similar to those within the quantitative studies: (1) few studies are carried out despite the apparent importance of environmental sustainability and the potential impact of green IT; and (2) little attempt has been made to incorporate existing theories or to develop new ones within this area of research despite the fact that industry apparently abounds with cases of green IT implementations. Unlike the quantitative studies, the case studies explicitly identified the types of IT resources used as well as the types of environmental value created.

Building Energy Lifecycle Research

Two cases of building energy lifecycle analyses (Kofoworola et al. 2009; Scheuer et al. 2003) were reviewed to gain an understanding of building operations with respect to energy demands. Both include lifecycle energy analyses in which different building phases are analyzed to understand the energy demand of each. Additionally, scenario analyses are done on the operations phase to understand the impact of key building appliances on the buildings' energy demand. In one case, the impact of energy demand on the environment was also examined (Scheuer et al. 2003).

Kofoworola et al. (2009) investigated an office building in Bangkok, Thailand. Their study entailed: (1) a life cycle energy analysis (LCEA) of the building in which they investigated the energy demand at the various stages of the building project including construction, operations and demolition; (2) an appliance analysis in which they investigated the energy demands of building appliances in the operation phase; and (3) a scenario analysis of energy saving measures in which they investigated practices that could complement the HVAC system – the appliance with the highest demand – to improve the energy demand of the building.

In the lifecycle analysis they found that energy consumption was highest during the operations phase (81.3%). The appliance analysis revealed that the HVAC system was the major energy consumer, demanding approximately 64 percent of the total energy consumed during the operations phase. The scenario analysis revealed that various strategies could be used to reduce the energy consumption of the HVAC system by between 40 and 50 percent. Some operational strategies include: periodic load shedding; and increasing indoor set-point temperatures by up to 2^{o}C. Some building design strategies include: reducing window-to-wall ratios; and glazing windows with low solar heat gain coefficient.

Scheuer et al. (2009) used computers to conduct a case study of the Sam Wyly Hall – a 7300m2, six-story building at the University of Michigan campus in Ann Arbor, Michigan. The goal of the study was to evaluate how key design parameters influence a building's environmental performance. Like Kowoforola et al. (2003), these authors conducted a lifecycle energy analysis of the building, reporting on the major factors that influenced energy demand at the various lifecycle stages. They also found that energy consumption was highest during the operations phase (97.7%) of primary energy sources (natural gas and coal). Their appliance analysis was less detailed but, as done, it revealed a high impact of HVAC and other electrical equipment (94.4%), and a significant impact for water heating (3.3%). The study found that eliminating skylights, a building design strategy, also significantly impacts energy consumption.

The Scheuer et al. study also differed in that the authors conducted an environmental impact analysis. They found that the dominant driver of negative building impact was emissions from fossil fuel consumption. The contribution to environmental destruction was estimated at 0.5 k-g of CFC-11 equivalent to **global warming**; approximately 7g CFC-11/year to **ozone depletion** potential;[5] and approximately 40 tons of PO4to **nitrification** equivalent.

Insights from the Building Lifecycle Analyses

The building cases show that the majority of building lifecycle energy is consumed in the operations phase, 81.3 percent in one case and 94.4 percent in the other. Of the energy consumed in this phase, the majority is utilized in providing heating, ventilation and air conditioning (HVAC) and lighting services. Electric energy represents the majority (95%) of energy consumed in buildings' operations and the environmental impacts from its consumption include emissions that result in global warming; ozone depletion and nitrification (Kofoworola et al. 2009). Periodic shutdowns and targeted building design strategies are shown to reduce energy consumption by between 40 percent and 50 percent.

This area of research highlights the extensive use of energy within building operations and especially by building appliances such as HVAC and lighting systems. These studies also show that these areas can enjoy significant energy consumption reduction if effective strategies are employed.

Summary of the Green IT Literature

Green IT research is sparse. The few existing studies can be categorized into four streams. Each stream provides some insight despite the paucity. From the *decision modeling* stream we learn that organizations are able to use sustainability factors – economic, environmental and social factors – to make decision regarding optimal IT investment size and alternative (among green IT). The *implementation factors* stream show that stakeholders' approval and business value are key influential factors. The *green IT value* stream shows us that both environmental and business value are outcomes of green IT and that other key resources and capabilities enhance the value created by green IT use. Finally, the *case studies* corroborate the major results of the quantitative studies while providing greater insights as to the type of value, implementation factors, resources and capabilities associated with different green IT.

Table 2-2: Prior Literature: Green IT Implementation Antecedents

Dependent Variable	Independent Variables	Source
Green IT Resources and Implementation Antecedents		
Green IT adoption	Cost reduction	Cai et al. 2013; Simmonds 2013
	Differentiation	Cai et al. 2013; Simmonds 2013
Green IT adoption	Eco-efficiency	Molla et al 2012
	Eco-effectiveness	Molla et al 2012
	Eco-responsiveness	Molla et al 2012
	Eco-legitimacy	Molla et al 2012
Green IT use	Legitimation pressures – legal department	Kuo et al 2010
	Social responsibility – employee influence	Kuo et al 2010; Hogevold 2012
	Organizational capability - adaptability	Kuo et al 2010
Green IT procurement	ES friendly characteristics of IT	Alena et al 2012
	ES friendliness of IT suppliers	Alena et al 2012
Green IT adoption	Top management support for ES	Høgevold 2012; Simmonds et al 2013; Watson et al 2010

Across the literature, a plethora of variables are investigated. On examination however, many of the variables fit into one of the same five major construct groups that exist in the IT business value literature. The five are: (1) green IT implementation factors – Table 2-2; (2) green

IT – Table 2-3; (3) complementary organization resources; (4) complementary capabilities; and (5) economic value. One set of constructs is novel, failing to fit into any of the above five categories. These are green IT value outcomes. However, unlike the usual economic value outcomes that benefit the organization, these new outcomes are benefits to the natural environment.

These variables have been abstracted to what is known within this study as ***environmental value*** – a construct that is, thus far, unique to green IT studies. Table 2.3 presents the latter four of the five sets of variables discussed above, as well as those related to environmental value.

Environmental value is defined here as outcomes of green IT use that benefit the natural environment. As such, it represents the organization's contribution to a second dimension of sustainable development. Examples of *environmental value* variables within the literature include: *reduced employee travel eco-impact; reduced product transportation fuel; low carbon footprint products* (Høgevold 2011); *reduced atmospheric emissions*; *reduced building energy* (Simmonds et al. 2013)*;* organization *environmental performance* (Meacham et al. 2013); (Ryoo et al. 2013); and *energy conservation* (Watson et al. 2010a).

Table 2-4 summarizes the relationships from Tables 2-2 and 2-3, using the six construct groups discussed.

Green IT Research Opportunities

Three sets of literature have been presented in this chapter: the green IT literature; representative (but not exhaustive) samples from the IT business value literature; and representative (but not exhaustive) samples from the building operations literature. The green IT literature is the main focus of the chapter; however, the business value literature was also reviewed for its potential to guide the interpretation of the green IT value literature, and the building operations literature for its potential to create an understanding of the context in which this study is proposed.

Table 2-3: Prior Literature: Outcomes of Green IT Use

Outcomes/ Dependent Variables	Independent, Mediating and Moderating Variables	Literature Sources
	Green IT Resources and Value Outcomes	
Environmental performance	**IT Capability:** • **Information sharing** (IV) • **IT Resource**: • **Green-modified ERP system** (Mediator)	Meacham 2013;
Environmental performance	**Capability (to use IT resources):** • **Green practices-IS alignment** (IV)	Ryoo et al 2013
Economic performance	**Capability (to use IT resources):** • **Green practices-IS alignment** **Value Outcome:** • **Environmental performance** (Mediator)	Ryoo et al. 2013 Ryoo et al. 2013
ES improvement	**IT Resources:** • **Server and storage virtualization** (IV) • **Desktop virtualization** (IV) • **Server consolidation** (IV)	Alena et al 2012
Reduced product carbon footprint Reduced eco-impact - employee travel Overall ES impact	**IT Resources:** • **Logistics software** (IV) • **Videoconferencing** (IV) **Capabilities**: • **Consultants' expertise** (Mediator) • **Logistics optimization** (Mediator)	Høgevold 2011
Energy conservation	**IT resources:** **Building management system**	Simmonds et al. 2013
Energy conservation	**IT resources:** • **Building management system**	Simmonds et al. 2013
	IT Resources: • **Logistics software**	Watson et al. 2010
Firm Economic performance	**Capability (to use IT resources):** • **Proactive corporate environmental strategy** (IV)	Benitez-Amado 2011
Economic performance - Profit ratios and cost ratios	**IT Resources:** • **unnamed IT** (IV) • **Company innovation** (Moderator)	Ko et al. 2011
Economic Benefits 1. Reduced product transportation costs 2. Reduced employee travel costs 3. Competitive product brand 4. Competitive environmental profile 5. Competitive market position 6. Long-term differentiation	**IT Resources:** • **Logistics software** • **Video-conferencing** **Mediator**: Environmental value outcomes: (1) Reduced eco-impact of employee travel; (2) Reduced fuel consumption; (3) Reduced carbon footprint of products **Mediator**: Environmental profile	Høgevold 2011

The IT value literature provides a parsimonious set of generalizable constructs that are useful in categorizing the many, seemingly, unrelated variables that were investigated in the green IT literature. This set of constructs, used to categorize the variables from the green IT literature, made it easy to summarize the findings of the green IT studies reviewed, to isolate the existence of the new construct – *environmental value* – that appears in the literature, and to see where gaps exist within the literature.

Table 2-4: Prior Literature: Relationships between Constructs (Abstracted Variables)

Relationship	Source
DV: Green IT **IV**: IT implementation antecedents	Molla et al. 2012; Cai et al. 2013; Simmonds et al. 2013; Watson et al. 2010; Kuo et al. 2010; Alena et al. 2012
IV: Green IT **DV**: Green capability	Ryoo et al 2013; Benitez-Amado 2011
DV: Environmental value **IV**: Green capability	Ryoo et al 2013
DV: Economic value **IV**: Environmental value	Høgevold 2011; Ryoo et al. 2013
DV: Environmental value **IV**: Green IT	Høgevold 2011; Alena et al. 2012; Meacham 2013
DV: Environmental value **IV**: Green IT **Moderator**: Complementary Green capability	Høgevold 2011; Alena et al. 2012; Scheuer et al. 2003
DV: Environmental value **IV**: Green IT **Moderator**: Complementary resources	Høgevold 2011; Alena et al. 2012; Scheuer et al. 2003
DV: Economic value **IV**: Green IT	Ko et al. 2011
DV: Economic value **IV**: Green IT **Moderator**: Green capability	Ko et al. 2011
DV: Economic value **IV**: Green capability	Benitez-Amado 2011

Figure 2-4 captures the variables investigated and found significant in the literature. The unique relationships among them are noted as hypotheses and presented as such in Figure 1.

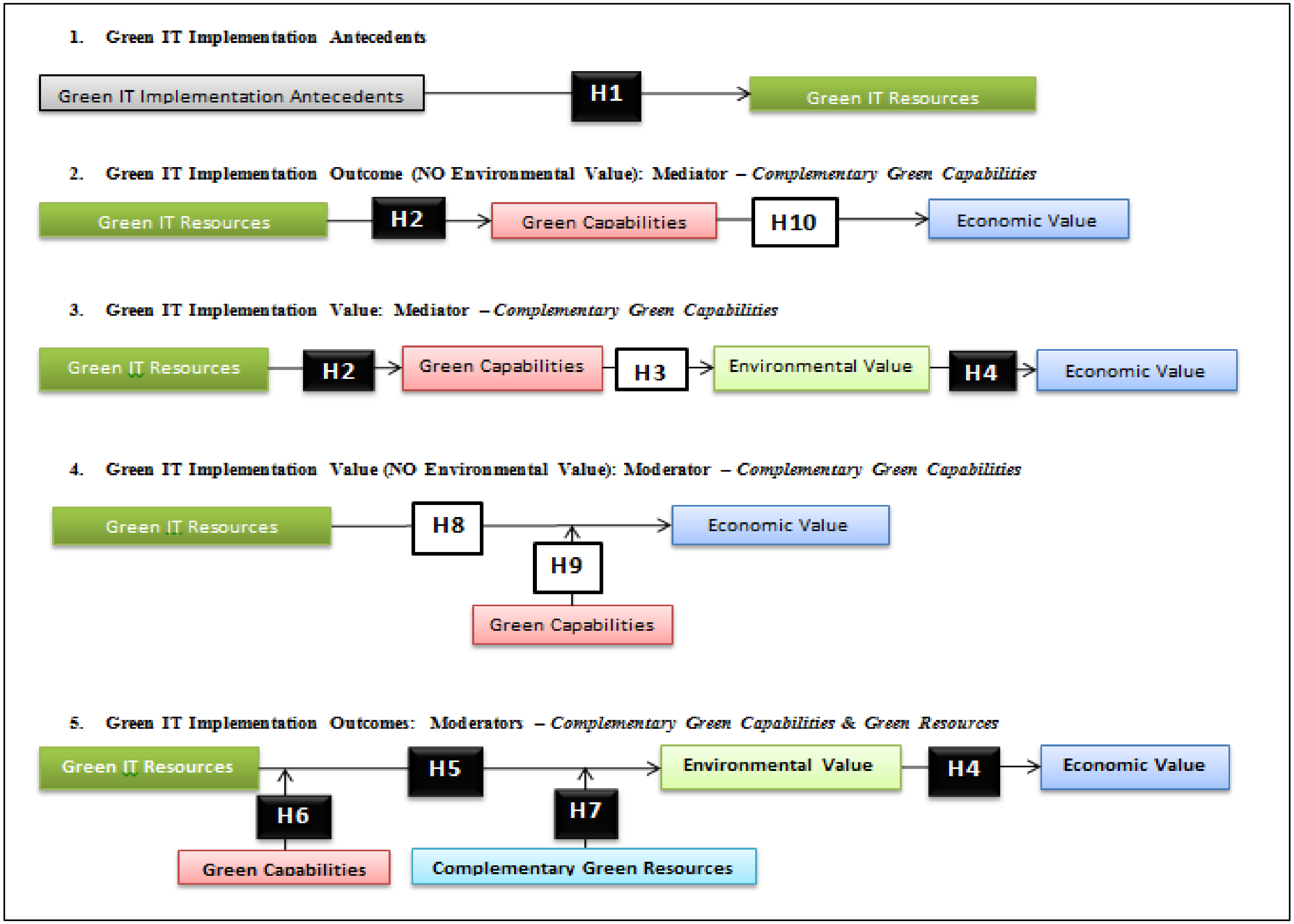

Figure 2-1: Green IT Implementation Models - Significant Relationships

Green IT are interesting – they appear to have the potential to positively affect not just the economic performance of organizations, but also their environmental performance. Nevertheless, environmental value as an outcome of green IT has been investigated only in two quantitative studies (Meacham et al. 2013; Ryoo et al. 2013).

The quantitative literature also generally fails to disclose both the specific green IT being investigated, except in one study (Meacham et al. 2013), and the specific environmental impact of the IT resources. With respect to the environmental value outcomes, the authors use generic terms such as "*environmental performance*" to indicate these.

The case studies are clearer on the green IT investigated as well as the environmental impact they have. Specifically, they focus on IT resources used in transportation logistics (Høgevold 2011; Watson et al. 2010a) and in building management (Simmonds et al. 2013) and specify that these resources had an impact on the organization's energy demand – fuel and electric energy. The case studies are also fairly detailed in terms of the complementary resources and capabilities that are deployed before and with the IT resources. However, only three case studies have been conducted, and all three are atheoretical.

Overall, theories were included in very few of the studies. Those studies that did apply theory, cited the dynamic capabilities theory (Benitez-Amado et al. 2012), Schumpeter's innovation theory and the resource based view of the firm (Benitez-Amado et al. 2012; Ko et al. 2011; Ryoo et al. 2013), and stakeholder theory (Cai et al. 2013). The most dominant was the RBV which was cited thrice. The others were each used only once. The theory based studies have been quantitative in nature. And, possibly because of the lack of measures specific to green IT implementation, these have failed to focus on IT implementation, even when the RBV has been applied.

Two case studies have provided detailed descriptions of the use of logistics software (green IT) that could potentially open the way for studies of the same green IT that apply theory; however, no such studies have followed. One atheoretical study focused on the use of building automation systems and showed their potential to enable significant environmental value impact. However, the description was not detailed enough to provide insights into how to measure the variables relating to how the systems are used.

Overall, the research opportunities may be summarized as: (1) the need for more research; (2) the need for more case study research to increase awareness of the variety of green IT used in organizations and their impact, and also to assist in the development of new theories and provide measures for testing existing theories; (3) more value research that specify the types of green IT being investigated and the value created; and (4) green IT value research that focuses explicitly on environmental value – presumably the main thrust of green IT implementations.

The current research will contribute to the reduction of all these gaps. For example, the current study will seek to explore both environmental and economic impact of the BAS. The study will start with a preliminary model that extends an appropriate value theory to incorporate the constraints imposed by the natural environment – one of the most critical stakeholders of the organization. The extension will incorporate the new construct - *environmental value* – found in the green IT value literature.

In the next chapter, existing value theories are presented. These are reviewed with the goal of developing the preliminary model that will guide the investigation of BAS value.

END NOTES

1. ERP systems modified to monitor environmental initiatives and outcomes.
2. The ability of the organization to implement IT resources to improve its business processes.
3. The ability of the organization to voluntarily implement environmental management practices to prevent negative environmental impacts in advance of environmental regulations and social trends.
4. Green organizations that either implement IT innovations first, or that implement IT to create new products.
5. The Ozone Depletion Potential (ODP) is defined as the ozone depletion produced by a unit of the gas converted into ozone depletion values produced by the reference substance trichlorofluoromethane (CCl_3F = CFC-11). It is the meter which is used to assess the importance of the effect produced by the various gases.

CHAPTER 3: THEORETICAL BASES

Introduction

The green IT literature is investigated using a number of theories including: the RBV of the firm (Wernerfelt 1984); the dynamic capabilities theory (Teece at al 1997); the stakeholder theory (Freeman 1994; Freeman 1999); and the NRBV (Hart 1995). The first two of these – RBV and dynamic capabilities – are also used pervasively throughout the traditional IT business value literature.

Review of Value Theories

I present each of these value creation perspectives in this chapter. For each, I describe the main theoretical approach regarding the creation of value including: the sources of value – the main independent variables; and the value outcome – the main dependent variables. I then show how each of these, as well as the literature findings, help to develop a preliminary model that is used to guide this research. Table 3.1 lists the theories that are reviewed.

The main independent variable in this theory is the focal resource with properties that create competitive advantage. These properties include: the ability to create value (mentioned above) as well as being "*rare, imperfectly imitable, and not substitutable*" (Barney 1991). The four, together, enable organizations to create and sustain a competitive advantage in the market. The main dependent variable of interest is the competitive advantage created by the focal resource. However, many studies that apply the RBV tend to focus on the value creation property of organization resources – their ability to impact the economic performance of the organization (Bharadwaj 2000; Mishra et al. 2007a; Zhu 2004).

Table 3-1: Value Creation Theories Used in IS Research

Value Creation Theories Used in Green IT (GIT) and IT Business Value (BV) Studies		
Theory/Research Model	**Value Source**	**IT Value Studies in which Applied**
Resource based view of the firm (RBV)	Firm resource	GIT: Ryoo et al. 2013; Benitez-Amado 2011; Ko et al. 2011 BV: Amit et al. 2001; Mithas et al. 2012 Tippins et al. 2003; Kearns et al. 2003; Mishra et al. 2007; Zhu 2004; Bharadwaj 2000
Dynamic Capabilities Theory	Human capabilities	GIT: Benitez-Amado 2011 BV: Kearns et al. 2003; Amit et al. 2001
The natural resource based view of the firm (NRBV)	Ecological response	GIT: Benitez-Amado 2011
Stakeholder Theory	Stakeholder feedback	GIT: Cai et al. 2013

The Resource Based View of the Firm

Wernerfelt's (1984) *resource-based view (RBV) of the firm* proposes that firms can use resources with certain properties to produce competitive advantage. One of these "certain properties" is the ability **of the resource** to enable the firm to gain economic value by either reducing economic costs or increasing firm revenue. The RBV guides the analysis of firm resources, examining how they impact the creation of firm products and/or services. According to the theory, resources enable the firm's products and/or services to be competitive in the firm's industry, thus creating profit for the firm and enabling it (the firm) to have a competitive advantage in the market.

The main independent variable in this theory is the focal resource with properties that create competitive advantage. These properties include: the ability to create value (mentioned above) as well as being "*rare, imperfectly imitable, and not substitutable*" (Barney 1991). The four together allow the firm to create and sustain a competitive advantage in the market. The main dependent variable of interest is the competitive advantage created by the focal resource.

However, many studies that apply the RBV tend to focus on the value creation property of firm resources – their ability to impact the economic performance of the firm (Bharadwaj 2000; Mishra et al. 2007a; Zhu 2004).

Since the RBV was proposed, Teece has elaborated on the value creation properties of firm resources by proposing that firm resources by themselves do not create value. Rather, there is potential for creating even greater value with a focal resource when it is combined with other key organizational resources and capabilities, (Teece 1986; Zhu 2004). Therefore, the RBV can be applied to this study – as it is to other IT business value studies – to explain how the BAS, as the focal firm resource in the study, combines with other firm resources and capabilities to increase firm value.

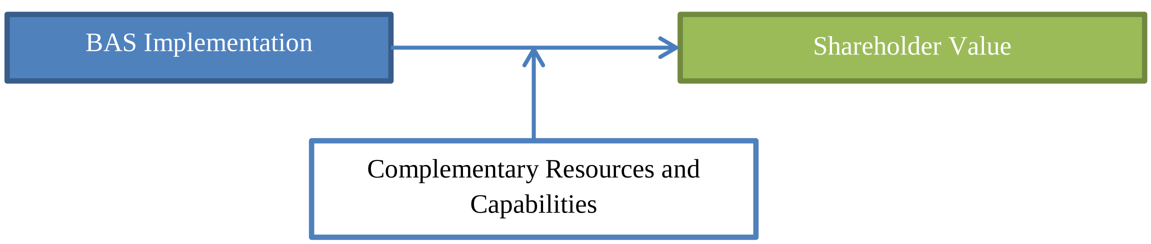

Figure 3-1: Theoretical Model Based on the RBV

Dynamic Capabilities Theory

The dynamic capabilities theory builds upon the RBV of the firm. This theory also focuses on sustained competitive advantage as the main dependent variable. Like the RBV, dynamic capabilities theory also identifies resources as sources of value. However, the dynamic capabilities theory differs in that it identifies, as being more critical, the capability to reconfigure the resource mix so as to create and sustain (and thus avoid erosion of) the firm's competitive advantage (Eisenhardt et al. 2000; Teece 2007; Teece et al. 1997).

The term *dynamic capabilities* describes three sets of top management skills: the ability to first spot opportunities to earn economic profits for a business enterprise; the ability to routinize the use of firm resources to capitalize on those opportunities; and finally, the ability to stay agile so as to continuously reconfigure and recombine firm resources to continuously generate economic

value over time.

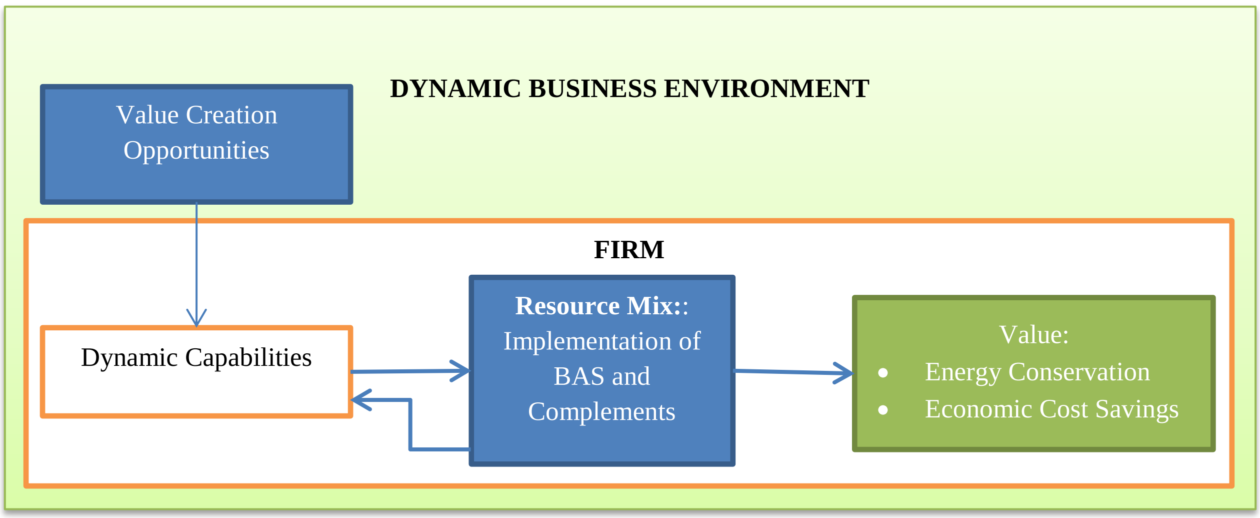

Figure 3-2: Theoretical Model based on the Dynamic Capabilities Theory

According to Teece (Teece 2007), the use of dynamic capabilities and the use of resources differ in that, "*if an enterprise possesses resources/competences but lacks dynamic capabilities, it has a chance to make a competitive return (and possibly even a supra-competitive return) for a short period; but it cannot sustain supra-competitive returns for the long term except due to chance*" (p1344). Therefore, the BAS as a firm resource would need to be deployed for creating competitive value using dynamic capabilities for its effectiveness in creating sustained competitive advantage for the firm.

The dynamic capabilities theory may be used to explain how managers, spotting the economic opportunities associated with energy conservation, may seize such an opportunity by implementing green resources such as the BAS, and later recombine and reconfigure those resources to increasingly improve the firm value and thus its competitive advantage in the market. However, the dynamic capabilities theory would be applied in a longitudinal, rather than cross-sectional.

The Natural Resource Base View of the Firm (NRBV)

A second theory that is based on the RBV is the *natural resource based view (NRBV) of the firm* (Hart 1995). The NRBV deserves mention as it appears to be relevant to this study in that it emphasizes the constraints and challenges posed by the natural (biophysical) environment.

In his seminal article introducing the *NRBV*, Hart argues that these constraints and challenges will be among the most important drivers of new resource and capability development for firms. According to the author, these constraints – the growing magnitude of ecological problems – challenge the power of existing theory to explain the important emerging sources of competitive advantage opening the way for new theories such as the NRBV.

The NRBV posits three key resources that are critical to the development of three strategic capabilities that drive strategic outcomes and produce competitive advantage for the firm. The three are called *continuous improvement*; *stakeholder integration* and *shared vision*. *Continuous improvement* is described as a resource that is said to be critical to the development of the strategic capability, *pollution prevention* – which (strategic capability) is necessitated by the need for minimization of emissions, effluents, and waste. The outcome of this capability is *lowered costs.*

A second resource described in the theory, *stakeholder integration*, is said to be critical for *product stewardship* – a strategic capability necessitated by the need for minimization of product lifecycle costs. The theory posits that the outcome of this capability is improved market position or *competitor preempting*.

The final resource described in the theory, *shared vision*, is said to be critical for developing the strategic capability *sustainable development* which is necessitated by the need for minimization of the environmental burden of firm growth and development. The theory posits that the outcome of this capability is *future positioning*.

A distinct advantage of this theory is that it already incorporates value for the natural environment and, therefore, has no need for extension where the dependent variable is concerned. However, it may be argued that focal resources proposed in the NRBV are not resources. Also, the resource of interest – the BAS – should somehow be incorporated in the theory as an independent variable in order for the theory to be applicable.

Stakeholder Theory

The stakeholder perspective, essentially, presents a senior management perspective that posits that "*if a group of individuals can affect the firm (or be affected by it, and reciprocate) then managers should worry about that group in the sense that they need an explicit strategy for dealing with the stakeholder*" (Freeman 2004). Freeman defined stakeholders as "those groups who can affect and/or be affected by the achievement of an organization's purpose" (Freeman, 1984 p. 49).

The stakeholder theory posits that variations in corporate performance may be explained by the differences in strategies designed to satisfy multiple stakeholders (Harrison and Freeman, 1999; Henriques and Sadorsky, 1999). The main independent variable of interest here is stakeholder value and the dependent variable, stakeholder interest. A number of other researchers have elaborated on stakeholder theory since Freeman's original proposal of the theory. For example, Clarkson proposed that all stakeholders are valuable and so the interests of no set of stakeholders are deemed more important than those of another set (Clarkson, 1995).

Whereas traditional firm theories tended to focus on value for economic stakeholder, more recently, firm stakeholders with an interest in the sustainability of the natural environment appear to have become increasing influential (Elkington 1998). As a result, environmental, in addition to

Figure 3-3: Theoretical Model Based on Stakeholder Theory

economic, interests are increasingly being incorporated into firm activities.

The usefulness of stakeholder theory in this research is its emphasis on the importance of different stakeholder groups. Because this research focuses on green IT and its potential to create sustainable value, it may be used to extend an appropriate value creation theory that focuses on the use of firm resources to create value. In this way, the incorporation of environmental value as an important outcome can be explained within such a theory.

Summary of the Theoretical Review

Various theories have been discussed in this section. Each has the potential to provide insight into how economic value may be created through the use of the BAS. The RBV proposes that a particular strategic resource, complemented by other resources and capabilities, has the potential to create economic value for the firm. The implementation of the BAS may thus be analyzed using this theory in such a way that it (the BAS) is the focal resource and other resources and capabilities are explored – Figure 3-2.

The dynamic capabilities theory proposes dynamic capabilities as the key source of economic value. These capabilities are used to sense and seize opportunities through which the firm may create economic value. As concerns the use of firm resources, these capabilities are used to determine the relevant mix of resources to be used to address the value opportunities and continuously create and protect the competitive advantage gained by the firm in a dynamic business environment. Again, the BAS may be explored using this theory in such a way that the analysis emphasizes the BAS as the focal resource and both WHAT (if any) dynamic capabilities are employed in BAS implementation, as well as HOW these capabilities are implemented - Figure 3-3.

Stakeholder theory differs from the above in that it introduces the concept of multiple and diverse stakeholders. Through its focus on these groups, the theory expands the view of value to incorporate different forms of value that can, potentially, appeal to a broad base of firm stakeholders (Elkington 1998). As such, it provides an explanation for the incorporation of other types of firm value, in this case for environmental value as an outcome of the BAS – Figure 4.

Preliminary Research Model

The primary goal of this research is to develop a model of green IT use and value creation based on an interpretive analysis of data collected from firms engaged in the use of BAS. Through the analysis of qualitative data, I seek to understand what resources and capabilities firms use to create value and what value is created. I also seek to understand how value is created. To collect the research data, I start with a preliminary model developed from a review of the green IT literature and existing theories.

There is little green IT research. Additionally, despite the importance of its implementation in reducing energy consumption in buildings, the BAS – the focal green IT resource – has not, before now, received any attention in theoretical business studies. Nevertheless, prior research provides some guidance for this research. Figure 2-1 (Chapter 2) shows five models that emerge from the literature based on evidence found in both quanitive theory-based and atheoretical (but detailed) case studies. Model 1 is concerned with green IT implementation antecedents which is outside of the scope of this study. Model 3 (which subsumes Model 2) predicts that green IT develops capabilities, which in turn produce firm value. Model 5 (which subsumes Model 4) predicts that, complemented by key resources and capabilities, green IT resources produce value. Both Models 3 and 5 indicate that economic and environmental value are green IT resource use outcomes and that economic value is preceded in the value creation chain by environmental value.

The concepts and relationships within the various models are supported by the major value theories presented in this chapter. The RBV predicts the value creation potential of the implementation of the BAS – a firm resource, along with other key firm resources and capabilities. The stakeholder theory predicts the creation of value for stakeholders other than shareholders. The dynamic capabilities ties the two sets of value models together – one set predicts the development of capabilities that then create firm value, and the other set predicts the use of capabilities for enhancing firm value1. The NRBV, like the stakeholder theory, predicts stakeholder integration and the creation of stakeholder value, in particular environmental value. It also predicts the creation of economic value through environmental value.

This preliminary model – Figure 3-4 – is simple. As such, it leaves room for exploration of the relationships and constructs predicted by the literature findings and theories discussed above. The model explains firm value as created by implementing a focal firm resource – in this case the BAS – as well as other key firm resources and capabilities. However, unlike the dynamic capabilities theory, the model does not specify whether the key capabilities are dynamic. Instead, it leaves room for specificity to arise based on the interpretation of the data. Finally, it incorporates the creation of environmental value – a key construct within the green IT literature and also within this investigation.

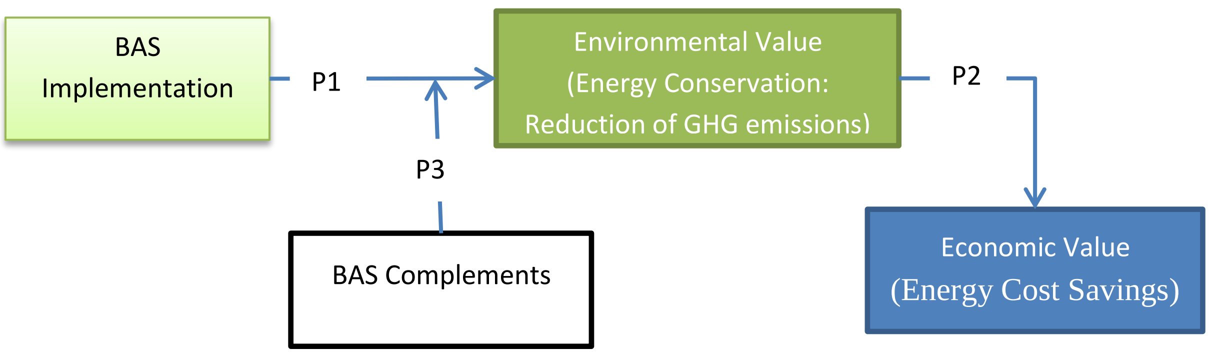

Figure 3-4: Model: The Resource Based View of the Sustainable Organization

CHAPTER 4: RESEARCH METHODS

Introduction

The purpose of this research was to test a model that could be applied to the investigation of the environmental and economic value creation capabilities of the building automation system (BAS), particularly as it relates to the conservation of electric energy.

In Chapter 3 I developed a preliminary model – *the resource based view of the sustainable organization (RBV-SO)* – by using the stakeholder theory to extend the RBV. This model was designed to facilitate the investigation of both value dimensions as opposed to just economic value as is possible when the RBV is applied. The model includes four constructs and three propositions and is re-presented here for ease of reference and clarity. The investigation was conducted to support and refine this model.

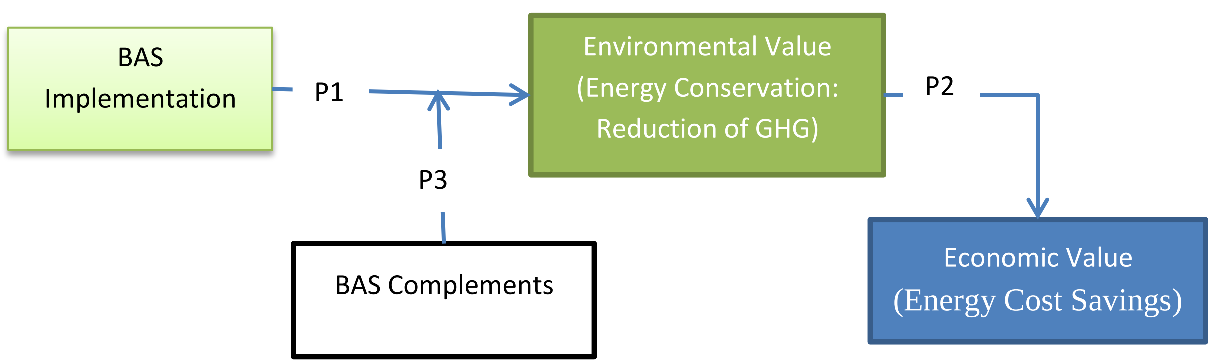

Figure 4-1: Model: The Resource Based View of the Sustainable Organization

I employed the collective case study methodology to conduct the investigation. This methodology involves the simultaneous investigation of a collection of cases to understand the particular phenomenon. The collective case study methodology essentially replicates the study across multiple cases, thereby facilitating a better understanding as well as a more robust set of data for theory development (Stake (2000).

An interview protocol – please see Appendix 8 – was designed to capture the constructs and relationships proposed in the preliminary model. The interview questions were drawn from the theoretical model proposed for the investigation, and refined through a pilot in one organization. The interview purposely focused on implementation experiences related to how the system creates environmental and economic value. The unit of analysis of the study was the facility maintenance team. Interviews were to be conducted with members of the team that interacted with the BAS at the various stages of its implementation, from its use when it became functional to its incorporation when its benefits had been reaped.

Data Collection

Data were collected using recorded semi-structured interviews with six facility maintenance teams each having implemented a building automation system (BAS). Two of these teams were identified from personal contacts of other members of USF's Department of Information Systems and the other four through my own personal contacts. These contacts included the facilities managers of some teams and the managers of the facility managers in others. The contacts were told that the goal of the study was to understand how the BAS conserves electric energy and associated energy costs. They were also offered a summary of the results. Based on their interest in the project, they agreed to secure participation of, and interview appointments with, their facility maintenance team members.

In Chapter 1 (Green IT and Building Operations), I described the two types of BAS that were found to be available – the "BAS-reconfigured" and the "user-reconfigured." In the data collection process, a concerted effort was made to ensure that both types were equally represented in the implementation cases selected. As such, three teams were selected with BAS-reconfigured systems and three with user-reconfigured BAS. Within the cases, the *Trane Tracer Summit* represents the BAS-reconfigured systems and the *Johnson Control Metasys* represents the user-configurable BAS.

The locations of the teams selected, and thus the buildings in which the BAS are implemented, were also diverse. The resulting sample includes one team located in Kingston, Jamaica and the other five located in three cities in Central Florida: three in Tampa; one in St. Petersburg; and another in Orlando.

The sample consisted of teams operating in environments as presented in Table 4-1.

Table 4-1: Case Details: Types and Locations of Case Buildings

Case/ Building Purpose	BAS-Type	Location	Occupancy / Management
Case1: Corporate Headquarters	User-reconfigured	Downtown Kingston, Jamaica	Owner-Occupied and Managed
Case2: Multi-Tenanted Office Complex	BAS- reconfigured	Downtown Orlando	Leased; Outsourced Management
Case3: Multi-Tenanted Office Complex	BAS- reconfigured	Downtown Tampa	Leased; Outsourced Management
Case4: University Housing	User- reconfigured	North-East Tampa	Owner-Occupied and Managed
Case5: Multi-Tenanted Office Complex	User- reconfigured	South-West Tampa	Leased; Outsourced Management
Case6: University Classrooms	BAS- reconfigured	St. Petersburg	Owner-Occupied and Managed

In addition to the differences in maintenance teams in terms of the BAS types implemented and the building locations, though not by design, the cases also reflected differences in terms of the purposes and the occupants of the buildings in which the BAS were implemented. Three of the cases were within commercial office complexes and the facility management outsourced to teams within organizations that managed properties. The fourth was in the residence hall of a university, and managed by an in-house facility management team. The fifth was in classrooms of another university, again managed by an in-house facility management team. The sixth was in the corporate headquarters of a mobile telecommunications company also managed by an in-house facility management team.

The cases were developed through interviews carried out with three types of personnel within each maintenance organization – a manager, a supervisor and a building engineer. The building engineers used the BAS daily and were responsible for reconfiguring the BAS or over-riding BAS configurations when necessary. They ensured that the building equipment was operating according to specifications set by the supervisors and therefore that the BAS was configured to ensure these same targets. The supervisors have oversight of the building engineers. The property managers/facility managers are in charge of the maintenance teams.

In all six cases selected, respondents included building engineers and property/facility managers. In four cases, chief engineers were supervisor and in the other two cases, the building project manager and the (resident) architect were selected at this level. These selections were intended to capture the experiences of personnel with different views of the system.

All respondents had an appropriate knowledge-base with respect to the system implementations and agreed to dedicate sufficient time to answer the questions. The data collection process thus resulted in the selection of a sample of teams composed of personnel as presented in Table 4-2.

Table 4-2: Case Details: Respondent Types in Facility Management Teams

Case	User & User Level		
	Engineers	**Supervisors**	**Managers**
Case1: Downtown Kingston	Building Engineer	Project Manager	Facilities Manager
Case2: Downtown Orlando	Building Engineer	Chief Engineer	Property Manger
Case3: Downtown Tampa	Building Engineer	Chief Engineer	Property Manger
Case4: North-East Tampa	Building Engineer	Architect;	Associate Director
Case5: South-West Tampa	Building Engineer	Chief Engineer	Property Manger
Case6: St. Petersburg	Building Engineer	Chief Engineer	Facilities Manager

In all cases, access to the selected teams was gained through appointments set up by the personal contacts used to find and select the organizations. All interviews were, therefore, pre-arranged, and agreement on the part of each team members to participate was secured ahead of the appointment with each team member. In spite of the prearrangements, the participants were, at the time of the interview, reminded of the goals of the study, asked to agree yet again, and reminded of their rights to withdraw at any time during the process.

Interviews were carried out on-site in all cases except for one session in which a property manager was interviewed by telephone. The interview protocol (Appendix 8) was followed in each session to ensure a level of consistency across the data sets; therefore, the same questions were administered to each respondent. Although the interview protocol was used, respondents were allowed to elaborate on their experiences with the BAS so that other constructs could be captured. As such, unplanned probes were also used during the interviews – each conversation was allowed to follow the paths set by the interviewee. The interviews generally lasted approximately 1 hour and, based on the time constraints expressed by the respondents, each was confined to one occasion. All interviews were recorded and the audio files transcribed and imported into the NVivo 10 qualitative package for analysis.

Data Analysis

Across-case analysis was conducted. Data analysis commenced with setting up file folders to house the data and then coding the interview documents. File folders were set up in NVivo 10 to house the interview documents for each case. Therefore, interviews were included for all respondents associated with a particular case. Six folders were created. Additionally, each interview was established as a node in order to attribute to it values that were useful for query classification purposes. See Figure 4-2 for an example of the classification of the interview of the Chief Engineer in Downtown Tampa.

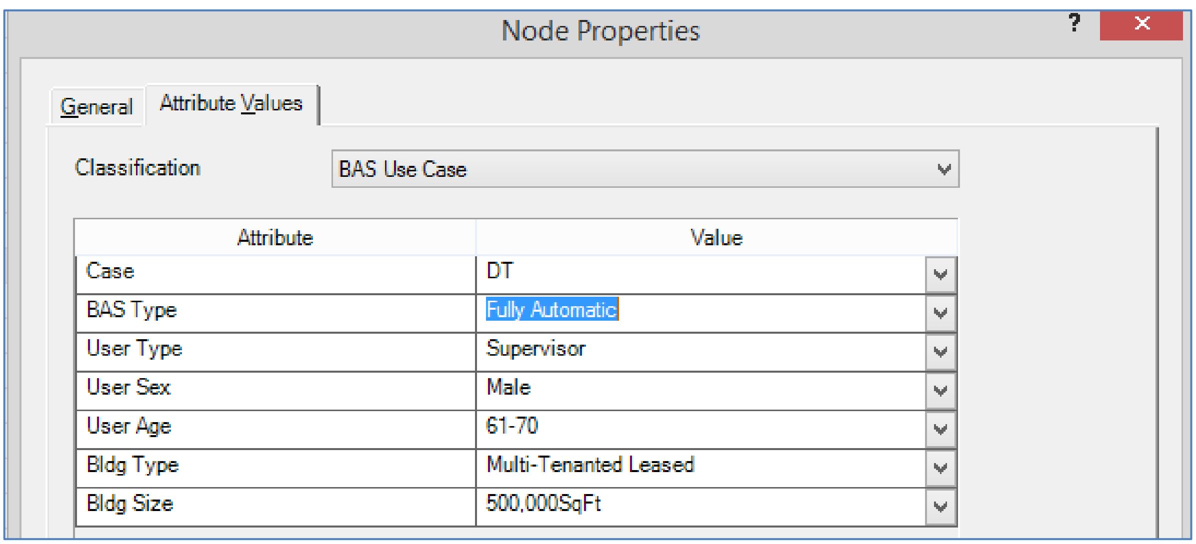

Figure 4-2: User Interview Classification by Attributes

For coding the interviews, nodes were established. In Nvivo 10, nodes represent containers for housing the statements from the data that are perceived to be associated with the constructs and relationships being sought. In this case, the initial nodes established were for the purpose of housing the statements related to the four constructs and three relationships from the preliminary model. In accordance with the model, four construct nodes and three relationship nodes were established initially.

To contain statements related to the preliminary model constructs, four nodes were established: ***BAS implementation***; ***BAS complements***; ***environmental value***; and ***economic value***. These were to house statements as follows: the *BAS implementation* node was to house statements related to the capabilities of the system that are available to the maintenance teams based on the deployment of the system; the *BAS complements* node was to house statements related to key resources and capabilities within the context that enhanced whatever value is enabled by *BAS implementation*; the *environmental value* node was to house statements related to the energy conservation enabled by *BAS implementation*; and the *economic value* node was to house statements related to energy cost reduction enabled by *BAS implementation*.

To contain statements related to the preliminary model relationships, nodes were established for each of the three propositions: (1) *BAS implementation* is positively associated with *environmental value*; (2) *environmental value* is positively associated with *economic value*; and (3) *BAS complements* positively enhance the relationship between *BAS implementation* and *environmental value*.

Once nodes were established to house the statements, each document was read thoroughly and the statements coded – assigned to the established nodes. The coding process entailed searching the data for statements related to relevant constructs and relationships and, on finding them, assigning them to established nodes.

Statements from **ALL** interviews across the six cases were assigned to the established nodes and sub-nodes during the coding process. Therefore, statements interpreted as the constructs and relationships within the preliminary model were assigned to the established nodes. For example, from the data, the following statement made by the Chief Engineer in St. Petersburg was assigned to the node that contained statements that were interpreted as ***environmental value***: "*You can assume that you're saving energy whenever you shut the chiller plant down for any period of time or even run one rather than running two you know run one up to a certain percentage rather than running the second one sometimes you save energy there too*." These assignments were used to develop support for the preliminary model.

The process also entailed two activities that resulted in the refinement of the preliminary model. One of these was the creation of new nodes to contain statements that emerged from the data and that were interpreted as new concepts that represented dimensions of value not existent within the preliminary model. An example is the following statement, made by the Building Engineer in Downtown Orlando: "*There's an analog signal that opens the gate and another that closes it. This is mainly for safety. It's a private garage and you don't want people loitering.*" While this statement did not refer to environmental or economic value, it was obvious that it referred to a benefit derived from the system implementation, and was, thus, important. The node created for such a statement was *tenant safety and comfort* – a value dimension that represents how the system ensures comfort and safety for the building occupants. The construct was used to refine the model so that *BAS value* rather than *environmental value* was the outcome of BAS implementation, and *tenant safety and comfort* and *environmental value* were subcategories or lower level constructs representing dimensions of value.

The second model refinement activity was the establishment of sub-nodes for concepts that were found and perceived as details of higher level constructs. These concepts were to capture subcategories of established constructs. For example, as the process ensued, it was recognized that BAS implementation involved two dimensions: BAS automation – which refers to the capability of the system to shut down the building equipment; and *BAS information* – which represents the capability of the system to report details of the equipment activities including shutdowns and level of engagement. When no new codes or sub-nodes were added, the coding was assessed to be final – theoretical saturation was deemed to have been reached.

The sub-categories were refined so that, while they captured a high level of detail, parsimony of the final model was also considered. The process resulted in a model that included the original constructs and relationships as well as other dimensions of value that were not anticipated. As well, the final model included details which captured dimensions of the implementation construct, the value constructs, the complementary resources constructs and the relationships among these dimensions, all of which were unknown at the start of the investigation. The final model is presented in the results in Chapter 5.

CHAPTER 5: RESULTS OF ANALYSIS

Introduction

In this research I conducted a cross-case analysis of six cases of facility management teams that had implemented building automation systems (BAS). The research investigated the value creation capabilities of BAS implementations using a preliminary model. The model was developed by using the stakeholder theory to extend the RBV. The model proposes that *BAS implementation* enables *environmental value* which in turn enables economic *value*. Key complementary resources and capabilities – *BAS complements* – are proposed to enhance the association between that *BAS implementation* and *environmental value*.

The goal of this research was to test and, if necessary, refine the preliminary model. Three types of users within facility maintenance teams were interviewed to gather their experiences of the BAS implementation and the value it creates within the context of their facilities. The data were analyzed using Nvivo 10. The analysis proceeded with a search for evidence of the constructs within this model first and then evidence of the relationships among them. New constructs and details of existing constructs were also acknowledged as they were discovered in the data. These were used to refine the original model. The results are presented in this chapter.

The chapter is organized as follows. In the next section I discuss the findings related to the three propositions from the preliminary model. Within the discussion, I present samples of statements for the constructs and relationships within the model taken from each case. I follow with a discussion of new constructs and details of constructs that were found in the data but not anticipated in the preliminary model. These are used to refine the preliminary model. Again, within the discussion, I present samples of statements for the constructs and relationships within the model taken from each case. I then present the final model – refined with the details found within the data for the original constructs and revised to include the new constructs found and the relationships that are found to exist among the details of these new, and the original, constructs. The chapter ends with a discussion of some differences found in the constructs across the cases.

Preliminary Model Support: Constructs and Proposition

Overall, the data show support for the model across all the six cases (case details are shown in Table 4-1). For clarity of the discussion, the preliminary research developed from the literature is again shown in Figure 5-1.

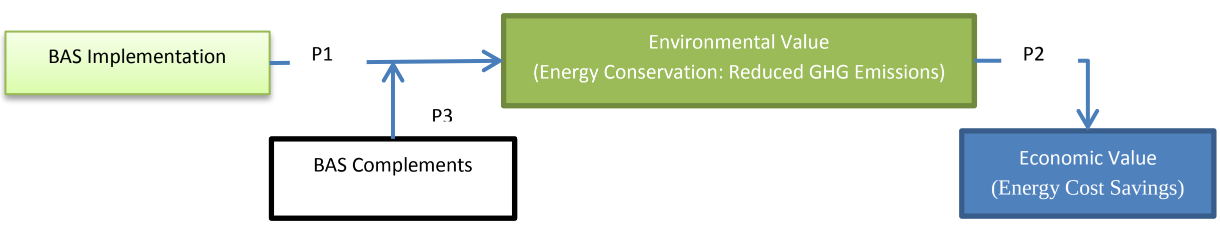

Figure 5-1: Model: The Resource Based View of the Sustainable Organization

Preliminary Model Support: Constructs

The model includes: four constructs – (1) *BAS implementation*, (2) *environmental value*, (3) *economic value* and (4) *BAS complements*. In the next four sub-sections, statements from the data that are interpreted as evidence of each construct are presented.

Support for BAS Implementation

The data included references to the ability of the system to control and inform on building equipment. These statements show that the BAS facilitates periodic shutdowns of the building equipment and also provides information on the equipment as well as the shutdowns. These references are interpreted as references to the *BAS implementation* construct. The following are statements from the six cases that were interpreted as evidence of the construct:

> **Case1:** *One thing we have done in terms of the system is to change the operation times for daytime, nights and holidays. So we have established setpoints from 6 to 6. Once it reaches 6 pm, it changes to a different setpoint. From 6:00 pm to 6:00 am the building is almost empty. So those are program changes. The setpoints are programmed; because we wanted a system that we didn't have to be pressing buttons all the while -- we want those changes to be automatic* (Building Engineer, Downtown Kingston).

> **Case2:** *I know the Chief Engineer can dial in remotely; so even when he's gone, he has access to the system* (Property Manager, Downtown Orlando).

> **Case3:** *It will learn that within three or four days. Three to four days, it will learn, it is constantly learning. So it learns, "okay we're going into the fall season and I don't need to start up at 3 o'clock. I can start up at 4 o'clock or 4:30." The computer's constantly analyzing the usage* (Property Manager, Downtown Tampa).

> **Case4:** *It is that kind of system that displays messages in the left hand corner consistently to draw my attention to anything that is seriously wrong … I can look at the individual rooms on the control system and tell what the heat and cold decks are doing, what the discharge temperature is, the setpoint in the room, the actual temperature in the room* (Building Engineer, NE Tampa).

> **Case5:** *We get alarms for high temperature – either in the space or at the unit. We get an alarm for the opposite – If the air is too cold* (Building Engineer, SW Tampa).

> **Case6:** *I do a lot with reports. I look at them when I'm doing an energy comparative analysis. Anytime there is an indoor air quality issue I look at the reports … Anytime there is a problem with energy being too high in a certain area then I will go ahead and get the report … Anytime that there is a complaint where it's too hot… or someone says for example that the humidity is high, that it's too cold for whatever reason then we go through and take a look at the report* (Facilities Manager, St. Petersburg).

Support for Environmental Value

Environmental value is the key construct of interest in the study. The data includes references to electric energy conservation which is known to represent (1) conservation of scarce natural resources and (2) the reduced global warming effect resulting from reduced electric energy consumption. These references are interpreted as evidence of the *environmental value* construct. While these statements are interpreted as evidence of *environmental value*, only is one case – *Case1* – was the natural environment actually mentioned as a focus of the system. The following are statements from the six cases related to *energy conservation* that were interpreted as evidence of *environmental value*:

Case1: *A benefit of the BAS is that the environment is protected as the building uses less energy to run* (Project Manager, Downtown Kingston).

It allows us to integrate the wind and solar power efficiently. My report shows the savings we make on CO_2 emissions by producing solar power. So we know that ozone depletion and other environmental hazards have been reduced (Building Engineer, Downtown Kingston).

Case2: *Well, as opposed to the way it was before, yes. Because we had the gate closed, and those are iron gates. I would probably guess that the gates weigh maybe 450 pounds. So you have the energy used raising and lowering that gate every time a car comes in here. The relay activates the gate arms. The benefit is less energy - activating the gate as each car gets to it, as opposed to once for many cars* (Building Engineer, Downtown Orlando).

Case3: *Taking two points off the speed drive and taking it from 60 to 58 hertz actually can save you eight to10 percent. Then if you take it another five hertz down and you're only reducing the output of the motor by six or eight percent can save you 40 percent of electricity* (Chief Engineer, Downtown Tampa).

Case4: *The BAS allows you to set a range and no matter what they do it will not get any colder in there because it shuts the unit down. So it has got to be saving us energy* (Associate Director, NE Tampa).

Case5: *If there is no efficiency, then it takes more energy to run it. More energy means more money. The whole purpose of the system is to give me the information to keep the units running at peak efficiency and in doing so reduce maintenance costs and energy consumption* (Building Engineer, SW Tampa).

Case6: *We are shut down basically six hours at night for five nights a week and then we're shut down probably over half the weekend. So we're saving 50, 60 hours a week easy because those things aren't cheap to run* (Facilities Manager, St. Petersburg).

Support for Economic Value

Economic value is the second value dimension represented in model. The data included references to cost savings realized from the conservation of electric energy which are interpreted as evidence of the *economic value* construct. The following are statements from the six cases that were interpreted as evidence of energy cost savings – representative of *economic value*:

Case1: *It provides the ability to save money by reducing energy consumption by various methods* (Project Manager, Downtown Kingston).

Case2: *We've basically cut our bill in half over the last ten years… even with all the increases, which is pretty dramatic* (Chief Engineer, Downtown Orlando).

Case3: *We've basically cut our bill in half over the last ten years even with all the increases -- which is pretty dramatic. You're not running you're equipment any harder than you need to.* (Chief Engineer, Downtown Tampa).

Case4: I *would say we are saving money because, like I said, the students no longer have control. When we have freshmen in the buildings sometimes you'll see that they crank the air* (Associate Director, NE Tampa).

Case5: *If there is no efficiency, then it takes more energy to run it. More energy means more money. The whole purpose of the system is to give me the information to keep the units running at peak efficiency and in doing so reduce maintenance costs and energy consumption* (Building Engineer, SW Tampa).

Case6: *We are shut down basically six hours at night for five nights a week and then we're shut down probably over half the weekend. So we're saving 50, 60 hours a week easy because those things aren't cheap to run* (Facilities Manager, St. Petersburg).

Support for BAS Complements

The fourth construct within the preliminary model is *BAS complements*. The data included references to complementary resources that enhance the value created by the BAS. These references are interpreted as evidence of the *BAS complements* construct. The following are statements taken from the six cases that were interpreted as evidence of the construct:

Case1: *There are **sensors** everywhere that can be used to accept inputs and control each space. Each set of users gets to control the temperature in their space. So you get a customized central air* (Facilities Manager, Downtown Kingston).

Case2: *We have all the drives in the building. And these are **variable frequency drives**. And what is unique about this building is that it's an older building and all the equipment is kind of dated. But just about everything is on variable frequency drives from the make-up air which brings fresh air into the building to every air handler in the building … The equipment is very important. The BAS can only do so much – it controls only what equipment can be controlled. It is a combination of the equipment and the BAS that gives optimal energy conservation* (Building Engineer, Downtown Orlando).

Case3: ***Trane*** [BAS vendor] ***offers classes*** *that we go to periodically. They have one just for the EMS system, and then they have for others for things related to the chiller plant, the chillers, air handlers* (Building Engineer, Downtown Tampa).

Case4: *I think it is interesting for me to know* [based on data from the BAS] *that **certain sides of the building** have a greater demand for energy* (Architect, NE Tampa).

Case5: *Our current system usually shows question marks where information is missing. It means that the system doesn't know. For example, **a tenant cut a cable to one of the sensors and my computer showed a question mark**. I then had to go track down that device. When I found it, it wasn't reporting so I had to trace it back to the connection* (Building Engineer, SW Tampa).

Case6: *I have **humidity sensors** in common areas: first floor; second floor. And they take the humidity reading. Each air handler has its own humidity sensor* (Building Engineer, St. Petersburg).

Preliminary Model Support: Propositions

The preliminary research model also includes three propositions: *P1 – BAS implementation* is positively associated with *environmental value*; *P2 – environmental value* is positively associated with *economic value*; and *P3 – BAS complements* moderate the relationship between *BAS implementation* and *environmental value*. In the next three sub-sections, statements from the data that are interpreted as evidence of each construct are presented. The following tables show where there were statements made in support of each proposition. Table 5-1 – shows by respondent type, and Table 5-2, by case.

Table 5-1: Statements In Support of Propositions - By Respondent Type

Proposition	Building Engineer	Chief Engineer	Facilities/Property Manager
P1: Equipment Automation and Energy Conservation	✓	✓	✓
P2: Environmental Energy and Economic Energy	✓	✓	✓
P3: BAS Complements Moderates P1	✓	✓	✓
Refinement: Equipment Automation and Tenant Safety & Comfort	✓	✓	✓
Refinement: Equipment Automation and Facility Preservation	✓	✓	✓
Refinement: Equipment Automation and Labor Content	✓	✓	✓
Refinement: Equipment Information and Labor Content	✓	✓	✓
Refinement: Equipment Information and User Learning	✓	✓	✓
Refinement: Equipment Information and Customized Energy Billing	✓	✓	✓
Refinement: Equipment Automation and Green Fund Qualification	X	✓	✓

Support for P1

Evidence of P1 -- *environmental value* (energy conservation) is positively associated with *BAS implementation* -- was found in the data in all cases. The following statements were interpreted as evidence of this proposition:

Case1: *If you look at the amount of CO_2 emissions, then having a more efficient system, what that will do is to reduce the amount of CO_2 emissions; overall, not just within Digicel. If you're using less energy from the Grid, which is JPS {Jamaica Light and Power Company] it means that you're potentially reducing the amount of CO_2 consumption* (Building Engineer, Downtown Kingston).

It really minimizes our footprint in terms of the amount of energy that we use. For example, we have sensors that automatically sense when we're not in the building or when we're not in a specific part of the building and that is really controlled by the BMS. That helps with energy (Building Engineer, Downtown Kingston).

Case2: *It's the shutdown in off-periods that provides the major energy savings* (Building Engineer, Downtown Orlando).

Case3: ***Trane*** *Without the air handlers running at 100% you're saving half the energy that you're burning really with it running at only 55%; so the motors are more efficient and you save a lot of electricity that way* (Building Engineer, Downtown Tampa).

Case4: *The BAS allows you to set a range and no matter what they do it will not get any colder in there because it shuts the unit down. So it has got to be saving us energy* (Associate Director, NE Tampa).

Case5: *The chiller demand will go down 12-20 percent just by shutting those pumps off because they are not blowing air cross way between the water* (Chief Engineer, SW Tampa).

Case6: *I can set the air - what time it comes off and on. Today it runs 6:30am to 10pm and the same on Monday Tuesday, Wednesday, Thursday, Friday. Saturday it runs 11 to 5 and Sunday it doesn't run at all. I can tell how much energy we are saving by how many hours we cut off* (Building Engineer, St. Petersburg).

Table 5-2 : Statements In Support of Propositions - By Respondent Type

Proposition	Case1	Case2	Case3	Case4	Case5	Case6
P1: Equipment Automation and Energy Conservation	✓	✓	✓	✓	✓	✓
P2: Environmental Energy and Economic Energy	✓	✓	✓	✓	✓	✓
P3: BAS Complements Moderates P1	✓	✓	✓	✓	✓	✓
Refinement: Equipment Automation and Tenant Safety & Comfort	✓	✓	✓	✓	✓	✓
Refinement: Equipment Automation and Facility Preservation	✓	✓	✓	✓	✓	✓
Refinement: Equipment Automation and Labor Content	✓	x	✓	x	✓	✓
Refinement: Equipment Information and Labor Content	✓	✓	✓	✓	✓	✓
Refinement: Equipment Information and User Learning	✓	✓	✓	✓	✓	✓
Refinement: Equipment Information and Customized Energy Billing	x	✓	✓	x	✓	x
Refinement: Equipment Automation and Green Fund Qualification	x	✓	✓	✓	✓	x

Support for P2

Evidence of P2: cost reduction – *economic value* - realized from reduced electric energy consumption – *environmental value* -- was found in the data in all cases. The following statements were interpreted as evidence of this proposition:

> **Case1:** *So it's trying to do 2 things. The total output of what it's trying to do is use the least energy to move you* [with elevators] *as efficiently as possible. That's the 2 outputs that it has: least energy; most efficiency – meaning: shortest wait times for travelers; least cost; greatest comfort* (Facilities Manager, Downtown Kingston).

> **Case2:** *If we basically flip the switch and turn the system on 100%, then every 15 minutes the utility company is pulsing my meter to check how much energy drive I have and I get charged a peak load every month based on that. So if I don't sequence my start time, it could cost me 15 or 20 thousand dollars a month. Looking at our electricity bill, when I first got here it was $160-190,000 a month. Now we're down between 60 and 80,000* (Building Engineer, Downtown Orlando).

> **Case3:** *We've basically cut our bill in half over the last ten years even with all the TECO increases – which is pretty dramatic. You're not running you're equipment any harder than you need to. Taking two points off the speed drive and taking it from 60 to 58 hertz actually can save you 8-10%. Then if you take it another 5 hertz down and you're only reducing the output of the motor by like 6 or 8% can save you 40% of electricity* (Building Engineer, Downtown Tampa).

> **Case4:** *I save the money from the difference between the automated optimal start at 6:30 a.m. and my scheduled start at 5:00 a.m. Similarly, if I tell the system to maintain the floor to 73 degrees up to 7: 00 p.m., it may calculate that at 5:50 p.m. it can start to shut down and still have that 73 degrees at 7:00 p.m. This is different from me telling it too shut down at 7pm. There's definitely savings* (Building Engineer, NE Tampa).

> **Case5:** *Energy savings is a benefit. It does the basics – it turns on and off. It gives some energy savings – it closes off the air for some hour* (Property Manager, SW Tampa).

> **Case6:** *We are shut down basically six hours at night for five nights a week and then we're shut down probably over half the weekend. So we're saving 50, 60 hours a week easy because those things aren't cheap to run* (Facilities Manager, St. Petersburg).

Support for P3

Evidence of P3 -- the association between *BAS implementation* and *environmental value* is moderated by *BAS complements* – was found in the data in all cases. The following statements were interpreted as evidence of this proposition:

Case1: *To mitigate that electricity cost, what we have done is to use purely solar energy in one chiller. So, rather than having three fuel-based chillers, we have only two. The system is designed such that the solar-based chiller must be at capacity before the others kick in. Bear in mind that 1 chiller cannot run the building; but it must be at capacity before the fuel-based chillers come in. In that way we minimize the amount of fuel that we use in cooling* (Facilities Manager, Downtown Kingst*on*).

Case2: *There was no communication so it didn't know what to do. So the floors were hot. The system did what it was supposed to do. There was no communication so it did nothing. Not being told what to do, it should do nothing* (Building Engineer, Downtown Orlando).

Case3: *We installed DFD drives to actually slow down the air handlers. The motors used about, on average, even during the hottest part of the summer 20-30% less electricity than they did when they were standalone* (Chief Engineer, Downtown Tampa).

Case4: *One of the* [energy] *solutions we have is window solutions where you cut down on the overall gain, or shades. Because they're much less expensive to install, we also use a lot of vertical blinds* (Building Engineer, NE Tampa).

Case5: *Now we have air handlers with variable speed drives that work on demand. That makes a difference. The equipment is very important. The BAS can only do so much – it controls only what equipment can be controlled. It is a combination of the equipment and the BAS that gives optimal energy conservation* (Building Engineer, SW Tampa).

Case6: *Well the vendor actually comes in and has actually done an analysis of the equipment to see where things were and gave a report as to how we could save some money. They do try to help in that area of energy saving* (Building Engineer, St. Petersburg).

Preliminary Model Refinement

The preliminary model was refined in two ways: (1) statements that were captured as evidence of the *BAS implementation* and *BAS complements* constructs were grouped into themes that represent details of each construct; and (2) statements that were interpreted as unanticipated value dimensions, and therefore excluded from the preliminary model, were captured. These were included to refine the model in relation to the benefits of the BAS implementation.

Preliminary Model Refinement: Details of Existing Constructs

Distinct themes within the sets of statements that were used as evidence of the *BAS implementation* and *BAS complements* constructs were found during data analysis. The statements related to each were therefore grouped and the themes were interpreted as dimensions, in some cases, and types in others of the constructs. For example, statements from respondents about the implementations were grouped into two sets which were interpreted as two dimensions of *BAS implementation*: *equipment automation*; and *equipment information*. These details are presented next.

Preliminary Model Refinement: Details of BAS Implementation

BAS implementation included statements about how the deployed system controled and monitored the building equipment. These two functions were distinct within the data and therefore grouped within the subcategories: *equipment automation*; and *equipment information*. The refined construct is presented in Figure 5-2. Details of the subcategories of *equipment automation* and *equipment information* are presented next.

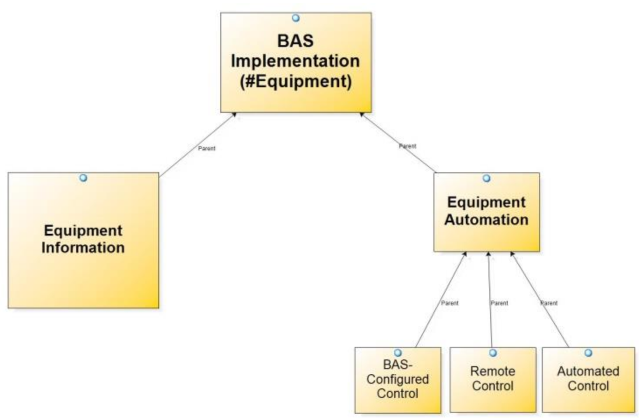

Figure 5-2: Results: Refined BAS Implementation Construct

Details of BAS Implementation: Equipment Information

Equipment automation included statements made about capabilities of the system that were implemented to control the building equipment. Statements that were captured within this *BAS implementation* subcategory were further grouped into three subcategories: *automated control*; *remote control*; and *BAS-configured control*.

Automated control included statements made about how the BAS were configured (initially and sometimes reconfigured after) by implementation experts on deployment (maintenance engineers and sometimes vendor contractors). These configurations caused the systems to automatically start and stop the building equipment. For example, *automated control* was implemented to establish the temperature, humidity and carbon dioxide levels that were to be maintained by HVAC systems. The following statements from the six cases were interpreted as evidence of this construct:

> **Case1:** *One thing we have done in terms of the system is to change the operation times for daytime, nights and holidays. So we have established setpoints from 6 to 6. Once it reaches 6 pm, it changes to a different setpoint. From 6:00 pm to 6:00 am the building is almost empty. So those are program changes. The setpoints are programmed; because we wanted a system that we didn't have to be pressing buttons all the while -- we want those changes to be automatic* (Building Engineer, Downtown Kingst*on*).

> **Case2:** *The water pump is tied to the Trane system. It sends signals to the Summit and can be shut down by it. There is a water sensor on every floor. If the water sensor gets wet, the Trane shuts down the pump* (Building Engineer, Downtown Orlando).

> **Case3:** *The programming from the EMS system controls how fast or how slow it ramps up the pump depending on what the demand is … Originally we ran two 850 ton chillers about six months a year. Now we're running one 750-ton chiller all year. It's from all the programming, setting the temperatures correctly and having the system constantly watch everything and not over cool* (Building Engineer, Downtown Tampa).

> **Case4:** *The students no longer have control. When we have freshmen in the buildings sometimes you'll see that they crank the air. Here in Florida it is hot when they get here in August to September and they want it cold; so they'll just crank it down and it's running and running trying to keep the place cold. The BAS allows you to set a range and no matter what they do it will not get any colder in there because it shuts the unit down when the unit reaches a certain temperature* (Associate Director, NE Tampa).

> **Case5:** *So, essentially, the way it operates is that it tries to maintain the temperature at each end of the floor… If we have a setpoint that says 73 degrees, the system will seek to maintain that. It will turn on or off the air handler and slows down or increases the speed of air handler based on our needs* (Building Engineer, SW Tampa).

> **Case6:** *We are shut down basically six hours at night for five nights a week and then we're shut down probably over half the weekend. So we're saving 50, 60 hours a week easy … We shut our chillers down at midnight and, unless we run our pumps, our water source heat pump is only*

circulating the cool water. It's not actually chilling the water down anymore. So when the chiller pans down, we run pumps; but the chillers themselves aren't running. So we shut them down at night and they don't start back until 5:00 a.m.; so there's a nice period there where the chillers don't run (Building Engineer, St. Petersburg).

Remote control included statements made about overrides (by BAS engineers) of existing configurations over an IP network using mobile devices such as cell phones and laptops. Only in five of the six cases were there references that were interpreted as evidence of this construct – *Case4* (Downtown Tampa) made no references to this implementation dimension. The following are statements from the five cases:

Case1: *If a system shuts down, they don't have to drive here to come and check it out. So if they call and say, "I'm here and there is no light on the floor", they can go on their machine and turn on the light ... There are also benefits for us as Facilities – we can respond to requests without major interruptions to whatever we were doing; we don't have to come in on Saturdays – can stay at home and make whatever changes* (Building Engineer, Downtown Kingston).

Case2: *I know the Chief Engineer can dial in remotely; so even when he's gone, he has access to the system* (Property Manager, Downtown Orlando).

Case3: *We have the ability to log in from a remote site to turn on after-hours air or verify it. In the morning we could look at it from our house if we wanted to. It has that capability. This one is especially nice, because we can dial in from our phones, homes, wherever* (Building Engineer, Downtown Tampa).

Case5: *With the BAS you can actually remote access the system* (Property Manager, SW Tampa).

Case6: *I have a laptop at home I have access through the Internet. I can remotely reset most things, except what is a manual reset. 95 per cent can be done remotely. I can reset pumps, chillers; but I couldn't reset the cooling power* (Building Engineer, St. Petersburg).

BAS-configured control included statements made about how the BAS made configuration changes completely independent of human involvement. These references occurred only in those cases where the auto-reconfigurable BAS that "learnt" – the *Trane Tracer Summit* – were implemented. The data indicated that, on occasion, BAS learning was deemed to be incorrect and the system therefore lost efficiency and ran counter-productive to the creation of value:

Sometimes it can get tricked. For example let's say in the middle of the day it is blazing hot and then the rain comes down and the temperature falls and the humidity goes crazy. The cooling was *really efficient before and then it just suddenly gets cold. The system is off – it then has to relearn. It really is the most intelligent program though* (Building Engineer, Downtown Orlando).

In such cases, an operator may have placed overrides on the system settings:

For a particular zone, if the lights are detected to be off for a particular set of time then it shuts everything down. And then obviously you always have the capability of doing an override if needed (Facilities Manager, St. Petersburg).

However, the data also indicated that, in some cases, such users must have the requisite permissions within the implementation:

Some people are not allowed it depends on how much knowledge they have. If I have a technician who is not that knowledgeable or I'm trying to train him I'm not going to give full control access to the system (Facilities Manager, St. Petersburg).

The following statements from the three cases that implemented the *Trane Tracer Summit* were interpreted as evidence of this construct:

Case2: *The program allows your setpoints to be changed. Ours are typically from 52 to 75 degrees. Let's say you want 52 degrees for the 16th floor. But in the morning, do you really need 52 degrees for the 16th floor? So what this does is that it moves the setpoint for you. This morning the setpoint was at 62degrees. This is good because we have a lot of variables throughout the day. Like I said, if it rains it picks up on that and raises the setpoint so it stops freezing the people on the 16th floor based on the thermostat settings. Let's say everything is set at 75 and outside is 95 and it rains and cools down, we don't need 52 degrees supply temperature because we're no longer trying to move the temperature against a 95 outside temperature. That decreases the load on the chiller, and decreases the amount of energy used* (Building Engineer, Downtown Orlando).

Case3: *It will learn that within three or four days. Three to four days, it will learn, it is constantly learning. So it learns, "okay we're going into the fall season and I don't need to start up at 3 o'clock. I can start up at 4 o'clock or 4:30." The computer's constantly analyzing the usage* (Property Manager, Downtown Tampa).

Case6: *It has these features now that is called optimal start and optimal stop. This means that it tries to learn the occupancy of your building and instead of turning on a chiller at 3:00 a.m. to try and cool it down for your first occupants at 8:00 a.m, it says, "you know what, it only needs to turn on two hours before so I'm going to turn it on two hours before". The system does it by checking what the temperature creep is. But the lighting control system does something very similar. It says these occupancy centers were turned on at this time and they were turned off at this time and so it tries to learn that* (Facilities Manager, St. Petersburg).

Details of BAS Implementation: Equipment Information

Equipment information included statements made about the capabilities of the system implemented to inform on the building equipment. These statements were grouped into three subcategories: *status views; status alerts*; and *usage trends*. The three were interpreted as **types** rather than **dimensions** of information and are therefore not captured in the figure presenting the detailed *BAS implementation* construct. They are, nevertheless, distinguished and presented here.

Status views included statements made about on-screen user interfaces that present users with views of building equipment by floor or by office space in detail (as required by user). The category also included statements that refer to views of the desired system configurations and actual readings associated with the equipment, for example views of temperature and humidity setpoints and actual temperature and humidity within the areas being conditioned. The following statements from the six cases were interpreted as evidence of this construct type:

> **Case1:** *One of the key things is room temperature: rather than trying to adjust when someone calls to say it's too warm where they are. Mark can look at the BAS, know that the temperature on the floor is where we want it to be so he immediately know it's personal; not the environment. So the reference is more specific and more direct* (Facility Manager, Downtown Kingston).

> **Case2:** *I can look at the individual sensor readings and see what they are. Now if they're not at setpoint it may say there's an issue with the air handler or one of several things that may be wrong. Looking at the system I can say what's wrong if it's isolated. There are pretty good graphics on the system so I can see the equipment, the sensors* (Building Engineer, Downtown Orlando).

> **Case3:** *It's a lot easier to observe what's going on than before. Everything used to have a status, but now you can see what they're running at, what the frequency is, how loaded or unloaded it is. Basically, it's on and off before and now it's more user friendly to where you can actually pin it in to where it's not so inefficient* (Building Engineer, Downtown Tampa).

> **Case4:** *It is that kind of system that displays messages in the left hand corner consistently to draw my attention to anything that is seriously wrong … I can look at the individual rooms on the control system and tell what the heat and cold decks are doing, what the discharge temperature is, the setpoint in the room, the actual temperature in the room* (Building Engineer, NE Tampa).

> **Case5:** *Each condenser, each air handler and each outdoor fresh air unit is represented on the system. And then I can pull each up and look at each device* (Building Engineer, SW Tampa).

Case6: *It's a fantastic trouble shooting tool. I can take you around this building. We have: a VAV here; chiller behind the building; air handler down the hallway; sensors and temperatures everywhere. It is an unbelievable tool – I'm able to get a good snap shot all at once time* (Facility Manager, St. Petersburg).

Status views appear to be the most frequently used information.

Status alerts included statements made about equipment status that were relayed to users' cellular phones. They represented critical equipment status information that alerted users that some critical settings had gone beyond their upper or lower parameters. The alerts were configured to be automatically sent based on the users' (or their managers') perception of the importance of the information they relay. Only in five of the six cases were there references that were interpreted as evidence of this construct – Case1 (Downtown Kingston) had no references to this implementation dimension. The following are statements from the five cases:

Case2: The tenants use different computer software – nothing to do with the Trane. When they complain, Trane sends an email to my phone (Chief Engineer, Downtown Orlando).

Case3: *If other components on the chillers fail, or get out of the set parameters, it will send you an alarm to tell you that there's something wrong* (Chief Engineer, Downtown Tampa).

Case4: *I get the alarms about the air handlers on my cell phone – so if we have a temperature issue I can retrieve those from my cell phones* (Building Engineer, NE Tampa).

Case5: *We get alarms for high temperature – either in the space or at the unit. We get an alarm for the opposite – If the air is too cold* (Building Engineer, SW Tampa).

Case6: *We have the data center here on this campus so I have an alarm for when that generator goes ahead and turns on because when that generator turns on I know I don't have normal power to my UPSs which feed the data center ... The alarms that I get are only for the areas that I need to be aware of which are highly sensitive areas* (Facilities Manager, St. Petersburg).

Historical trends included statements made about historical data on energy and/or equipment usage. *Historical trend* data includes, for example, reports of a piece of equipment over a set period that contained, for example, details of the start and stop times, the kilowatt hours of energy used and the temperatures or other readings associated with the equipment being monitored during the period. *Historical trends* were frequently analyzed by engineers to address operational issues or by managers for decision making and other strategic uses. Only in four of the six cases were there references that were interpreted as evidence of this construct – *Case5* (SE Tampa) and *Case6* (St. Petersburg) contained no references to this implementation dimension. The following are statements from the five cases:

> **Case1:** *We have the information to make decisions and we can be more specific – decisions are based on knowledge of the local area in the AC case. And we can do that now. If you take into consideration the elevators, you're monitoring the elevators. You say, "Okay, fine, I've used this amount of energy for the month" -- based on the traffic* (Building Engineer, Downtown Kingston).

> **Case2:** *We use it to check usage in case we need to increase or decrease our budgetary projections. And we also use it to record after-hours usage for tenants that work beyond the normal work hour* (Property Manager, Downtown Orlando).

> **Case3:** *I set it to take the temperatures every second when I want and then I get 400 pages the next day. I can go back and look month by month. I have an average daily cost in there … I can look year after year and say, "This is my daily average*" (Chief Engineer, Downtown Tampa).

> **Case4:** *My interest right now is in applying for the green energy fund to help pay for some of the projects that we are doing on the hall. And the application requires that we show evidence that we are saving energy and greenhouse gases. So I am using that information to back up my application* (Associate Director, NE Tampa).

Preliminary Model Refinement: Details of BAS Complements

BAS complements included statements made about the complementary resources and capabilities that were used to enhance the value created by the BAS. These statements were broken down into four subcategories: *IT resources; vendor support*; *building features*; and *equipment features*.

IT resources included statements made about IT devices that enhanced value created by the BAS. These include: (1) hardware resources, for example *sensors*; (2) software resources, for example the custom energy billing software; and (3) network devices, for example the *IP network* over which the equipment are connected to the BAS. The following statements from the six cases were interpreted as evidence of this construct:

Case1: *There are **sensors** everywhere that can be used to accept inputs and control each space. Each set of users gets to control the temperature in their space. So you get a "customized" central air* (Facilities Manager, Downtown Kingst*on*).

Case2: *The tenants use different **computer software** – nothing to do with the Trane. When they complain the Trane sends an email to my **phone*** (Chief Engineer, Downtown Orlando).

Case3: *I have had to put more **memory** in the computers, so it can do more. If you don't do that, eventually, it's not going to work* (Chief Engineer, Downtown Tampa).

Case4: *There is a disturbed air temperature **sensor for each unit** – probably 350 in all the residents' rooms* (Building Engineer, NE Tampa).

Case5: *Our current system usually shows question marks where information is missing. It means that the system doesn't know. For example, a tenant cut a **cable** to one of the **sensors** and my **computer** showed a question mark. I then had to go track down that device. When I found it, it wasn't reporting so I had to trace it back to the connection* (Building Engineer, SW Tampa).

Case6: *The difficulty with the system is: obviously **temperature sensors** go out of whack and they need to be calibrated frequently. Temperature, humidity… because those are the systems that provide a feedback and one sensor can throw all of your systems completely off* (Building Engineer, St. Petersburg).

Vendor support included statements made about vendor resources that were available to the facilities teams and that enhanced value created by the BAS. Examples include site visits, seminars and technical calls facilitated by the vendors. The following statements from the six cases were interpreted as evidence of this construct:

Case1: ***There were several iterations. He showed us a template** -- how it looked from the screens, the way it was designed. It's basic software that you can build on. So we critiqued it, the functions, user-friendliness, and etcetera. We went back and made changes to the design. We looked at how it interfaced with the different hardware, and then he would come back with any requests and say "here's what you asked for", and soon* -- *to eliminate the mistakes.* He went back and forth *until we got the end product* (Building Engineer, Downtown Kingst*on*).

Case2: *We have a **really strong relationship with Trane** and so if anything needs to be adjusted or if we need information on the system for managing the property they are more than willing to help us learn the system* (Property Manager, Downtown Orlando).

Case3: ***Trane offers classes** that we go to periodically. They have one just for the EMS system, and then they have for other things related to the chiller plant, the chillers, air handlers* (Building Engineer, Downtown Tampa).

Case4: *We got a* ***walkthrough and then one-on-on****. I've had* ***the rep work with me*** *on doing global queries for the system like looking at every piece of equipment attached to the system. He showed me how to look at the data. I also call them on a need basis – in some cases there were problems so that I needed to know* (Building Engineer, NE Tampa).

Case5: ***They come out every quarter or six months and review each piece of equipment*** *to ensure it is giving the right information. They take temperature readings across to ensure -- to calibrate them – it's a part of the* ***contract*** (Building Engineer, SW Tampa).

Case6: *Usually what I do is that I'll pull technicians from other campuses that know how to work a specific system. Or if I don't have that knowledge in-house, then I'll contract out with an outside contractor.* ***Trane is available****. We usually can get something done within 24 hours easily. Or they are over the phone, "hey this happened, my whole database just crashed!* (Facilities Manager, St. Petersburg).

Building features included statements made about building-related resources and attributes that enhanced value created by the BAS. These included: the building design, interior design, physical location, occupancy level and other factors related to the building and its use. The following statements from the six cases were interpreted as evidence of this construct:

Case1: *We have* ***segmented*** *the cooling. So, rather than have all spaces at the same temperature, we have locally controlled temperatures… allows discrete air management, so everyone is not freezing. Nor is everyone burning up because of the different user needs* (Facilities Manager, Downtown Kingst*on*).

Case2: ***The building is old*** *and that hinders energy efficiency and other things* (Chief Engineer, Downtown Orlando).

Case3: *This building here being an older building has about* ***6-9 zones per floor****, so you can only damper it down so much. If somebody is hot it's going to affect a lot of people* (Building Engineer, Downtown Tampa).

Case4: *I think that in Florida, all buildings suffer from too much heat gain so it's hard to get comfortable because of a lack of control for our* ***windows*** *especially those on the* ***south side and west*** (Architect, NE Tampa).

Case5: *The* ***building envelope is sealed*** *well and that helps. We have a maintenance program for the roof and that helps to keep the moisture out which helps with the energy savings. All 4 buildings are sealed and have new roofs. They're all insulated so that improves the energy efficiency. The doors and windows have all been resealed so that helps. I anticipate a drop in the cold spikes during the winter because the cold air is not coming in* (Building Engineer, SW Tampa).

Case6: ***Roofs*** *are important -- if you lose your insulation, you lose energy. Our energy costs are down because we have good insulation in our roof* (Facilities Manager, St. Petersburg).

Equipment features included statements made about equipment-related resources and attributes that enhanced value created by the BAS, for example the efficiency of the equipment, the type of energy they consume and the level of intelligence in their digital controllers (equipment controllers are connected to the BAS). The following statements from the six cases were interpreted as evidence of this construct:

> **Case1:** *To mitigate that electricity cost, what we have done is to* ***use purely solar energy in one chiller****. So, rather than having three fuel-based chillers, we have only two. The system is designed such that the solar-based chiller must be at capacity before the others kick in. Bear in mind that one chiller cannot run the building; but it must be at capacity before the fuel-based chillers come in. In that way we minimize the amount of fuel that we use in cooling* (Facilities Manager, Downtown Kingst*on*).

> **Case2:** *We have all the drives in the building. And these are* ***variable frequency drives****. And what is unique about this building is that it's an older building and all the equipment is kind of dated. But just about everything is on variable frequency drives from the make-up air which brings fresh air into the building to every air handler in the building … The equipment is very important. The BAS can only do so much – it controls only what equipment can be controlled. It is a combination of the equipment and the BAS that gives optimal energy conservation* (Building Engineer, Downtown Orlando).

> **Case3:** *It connects the two zones for the domestic pump – the high-rise and the low-rise. There are two different pumps. The one for the low-rise, it feeds up to the 20th floor, and then from 21 up there's a second pump. They are on* ***frequency drives*** *and it controls the frequency drive by the pressure of the pump in each zone. It works to ramp them up or slow them down* (Building Engineer, Downtown Tampa).

> **Case4:** *We have all the drives in the building. And these are* ***variable frequency drives****. And, what is unique about this building is that it's an older building and all the equipment is kind of dated. But just about everything is on variable frequency drives from the make-up air which brings fresh air into the building to every air handler in the building … The equipment is very important. The BAS can only do so much – it controls only what equipment can be controlled. It is a combination of the equipment and the BAS that gives optimal energy conservation* (Building Engineer, NE Tampa).

> **Case5:** *We have an outside air system with recovery units with five towers on the dual hall building – two on the hall in focus and that brings in outside air to keep our air quality good. There are* ***outside air units that channel the air down to be distributed to the residents' rooms equally*** (Building Engineer, SW Tampa).

> **Case6:** *We use 90 percent of our billing because we put onto* ***everything on drives*** *to only use the energy that's needed to supply that area or whatever is needed to be supplied. So if you have a* ***VSD*** [variable speed drive]*it could be running at 20%; rather than, if it was a direct drive, it would be*

> *running at 100 percent just to cool one little area so that you're burning so much energy* (Facilities Manager, St. Petersburg).

Preliminary Model Refinement: New BAS Value Construct

The analysis revealed clear evidence of benefits unanticipated in the preliminary model. Initially, a new construct – *BAS value* – was created to umbrella references to the unanticipated outcomes as well as the existent *environmental value* construct. Once it was recognized that the statements referenced more than one type of benefit, the statements were grouped into themes that represent distinct dimensions of value. Some of these were found to be cost savings other than those realized from electric energy conservation; therefore the *economic value* construct was expanded to include two new dimensions and placed within the BAS value group as a dimension.

Finally, a new construct – *energy conservation* – included statements made about both the environmental and economic value included in the preliminary model – value realized from conservation of electric energy.

Preliminary Model Refinement: BAS Value: New Value Dimensions

This section presents the details of the findings related to the three sets of IT value mentioned above – *tenant safety and comfort; strategic value*; and the economic value unrelated to cost savings from energy conservation.

Preliminary Model Refinement: BAS Value: New Dimensions of Economic Value

References to cost savings other than those realized from electric energy conservation were also found in the data. These statements were grouped into two sub-categories representing dimensions of *economic value*: *facility preservation*; and *labor demand*. The *economic value* construct was expanded to include these two as new dimensions.

Labor demand included statements made about the reduced demand for maintenance manpower which creates direct economic cost savings for the organization. Two reasons given for the reduction in demand were: (1) less need for manual starts and stops of equipment resulting from *equipment automation*; and (2) less need for site visits to equipment based on *equipment information*. The following statements from the six cases were interpreted as evidence of this construct:

> **Case1:** *How I would put this is that for a building of this nature we would have hired a management company. In the old building we had a management company that came in and set everything. We had a lot of persons on call just to operate. We eliminated a lot of those. Moving into this building we would have had to hire even more persons, yet we were able to scale back. One engineer can manage the building* (Facilities Manager, Downtown Kingst*on*).

> **Case2:** *We possibly would have needed one more engineer to manage if we didn't have the system. I know the Chief Engineer can dial in remotely so even when he's gone, so he has access to the system* (Property Manager, Downtown Orlando).

> **Case3:** *In 1973, they had to have a person here running the building 24/7, to switch on and switch off. Now I can have less staff – I save money there too* (Property Manager, Downtown Tampa).

> **Case4:** *It reduces movements. I don't have to go to every spot to check on things because the system shows me what's going on at the various spots without me going. Without the system we would have more physical movement for maintenance and less accuracy. Before the system, there were four engineers. When I started in 1985, I replaced one of the engineers and then there were two of* us (Associate Director, NE Tampa).

> **Case5:** *Oh yes, I mean, we had a fulltime engineer that only did HVAC, so I would have to say we are saving money because it's not causing us salary* (Property Manager, SW Tampa).

> **Case6:** *If I didn't have the system someone would have to come in here with a temperature sensor and basically say, "okay yes its hot" come over here with a ladder open it up, go up to the VAV, make sure that the VAV is opening up enough and if that's fine then they have to go out by the air handler take a look … I would need more staff* (Facilities Manager, St. Petersburg).

Facility preservation included statements made about reduced building and equipment repair costs which represents direct economic savings for the organization. Two major reasons for reduced repair costs were: (1) less wear and tear on building equipment; and (2) less damage to the building due to, for example, water damage and reduced mildew and mold. The following statements from the six cases were interpreted as evidence of this construct:

> **Case1:** *We had a burst pipe the other day, in the middle of the night. Someone came on the floor and detected the leak. Mark was able to access the system remotely to shut off the pump from the party where he was drinking. What it meant was that we saved damage and the cost of it. We still had a lot of damage, but it could have been that much worse because then we would have had to leave from where we were to come in and manually shut it down. Mark just went into the system and turned off the valve, had the system shut down the pump* (Facilities Manager, Downtown Kingst*on*).

> **Case2:** *Just about everything is on Variable Frequency Drives -- from the make-up air which brings fresh air into the building to every air handler in the building. They're all on drives. So they may be running at 100% now and in 20 minutes it may drop down to 30% which, in effect, saves you a lot of energy and also saves wear and tear on your equipment* (Building Engineer, Downtown Orlando).

> **Case3:** *The equipment lasts longer now because it doesn't work as hard, especially now that all my pump motors, and all my fans and everything all have DFDs on them. So instead of running 100% for 12 of 20 hours each day, they're running at 50%, and they're running for 9 hours a day* (Chief Engineer, Downtown Tampa).

> **Case4:** *It prevents students who want to run the temperatures down to 55 degrees in their rooms -- which some students do. And that cold air produces humidity which turns into mold and mildew problems you know ... We used to have quite a few mold and mildew problems, uncontrolled temperature ranges where we get anything from hot to cold which caused a lot of mold and mildew. We're much better than we used to – we do not get mold and mildew calls there* (Building Engineer, NE Tampa).

> **Case5:** *Another feature of the BAS is that you get to monitor and know that the system is actually working. So if you have something down, especially a part that will make another part of the system work harder or not work, then you can see that from one place. So you see; with the time clock system you don't. If a tenant calls, you don't know why. If one part of the system goes down and another is working harder to maintain temperature setpoints, you don't know. And so it cuts down the wear and tear on the equipment* (Property Manager, SW Tampa).

> **Case6:** *When I turn off my unit at night, the likelihood of that belt lasting longer is there – it's definitely there. The likelihood of the air handler lasting longer is higher* (Facilities Manager, St. Petersburg).

Preliminary Model Refinement: BAS Value: New Value Dimensions: Tenant Value

Another major benefit of the BAS revealed during the data analysis is the creation of a safe and comfortable indoor climate for building tenants. The construct representing this set of data – *tenant safety and comfort* – included statements made about the creation of safe and comfortable indoor climatic conditions such as those associated with building lighting and air conditioning, as well as convenient use of external facilities such as electronic access. *Tenant safety and comfort* represents a new dimension of the *BAS value* construct that further refines the preliminary model. The following statements from the six cases were interpreted as evidence of this construct:

> **Case1:** *From a safety perspective, what we have done is actually tied the fire alarm access control system – which is the door function – to the BAS. So, for example, if a fire alarm goes off, we have a different system interacting. If a fire alarm goes off all the doors open* (Facilities Manager, Downtown Kingston).

> **Case2:** *There's an analog signal that opens the gate and another that closes it. This is mainly for safety. It's a private garage and you don't want people loitering* (Building Engineer, Downtown Orlando).

> **Case3:** *There's chill water temperature control and damper controls for air flow and the speed drive and CO_2 sensors and fresh air because you also don't want to let more fresh air run in than you need because of the humidity. High humidity is not good for indoor air quality* (Building Engineer, Downtown Tampa).

> **Case4:** *Having control of temperatures ..... Being able to maintain the entire building at comfortable levels where you're not warm in one area and freezing in another area so that there are clashes and then we have mold developing. The system enables us to control the temperatures in that building* (Associate Director, NE Tampa).

> **Case5:** *We have a particular temperature we like to keep spaces at – 73 to 74 degrees. That seems to be the temperature at which most people are comfortable. When you get above 74 degrees, most people get hot, and below 73 they get cold. So 73 degrees is the temperature we would like to maintain the area at* (Building Engineer, SW Tampa).

> **Case6:** *We used to have the sick building syndrome. We were all bottled up and so you would only get a small amount of outdoor air and you had all these people in this small space and you would recirculate the air over and over again and people were starting to get sick. That's the reason we have the system flush out the buildings and use more out-door air* (Facilities Manager, St. Petersburg).

Preliminary Model Refinement: BAS Value: New Value Dimensions: Strategic Value

Strategic value was revealed as a benefit of the BAS during the data analysis. The construct is used to capture references to knowledge that (especially) property managers realize from the system implementation – knowledge that enables them to improve their management of the facilities in different ways. The construct – *strategic value* – represents a new dimension of the *BAS value* construct that further refines the preliminary model. References to these knowledge benefits were grouped into three sub-categories that represent the respondents' uses of the knowledge: *customized energy billing*; *green fund qualification*; and *user learning*.

Customized energy billing included statements made about managers' abilities to create customized energy bills for services such as air and light requested by tenants beyond the hours agreed in the lease (before and/or after hours agreed to in the tenants' leases). The tenant requests for the services were made via a software system connected to the BAS historical energy data. The software allowed tenants to override preset BAS-controlled equipment shutdowns via the network for after-business service. The data were captured and analyzed and detailed billing reports downloaded monthly by the managers from the BAS.

Evidence of this construct is found only in three cases – Case2, Case3 and Case5. These cases involved BAS implementations in leased office complexes with paying tenants. The construct was evident in all three cases. The following statements from the three cases were interpreted as evidence of this construct:

> **Case2:** *On the weekends, in case something comes up, they* [tenants] *can call up and say they want two extra hours of light and air. And they get it. That's also something the Summit* [BAS] *does. Every month we download the calls and charge for them* (Building Engineer, Downtown Orlando).

> **Case3:** *Lighting and air conditioning they don't get billed for – that's part of their rent. Every tenant pays a portion of the electric bill at the end of the year as part of their rent. It's called bill-backs. It's charged based on their square footage; so everybody is evenly charged, except for tenants that have extra equipment which is considered outside of office, which we've got 30 something meters that we bill-back a month* (Chief Engineer, Downtown Tampa).

> **Case5:** *We control tenants' overtime air so the tenants can ask for air when it's not billing time, such as during afterhours. And we get reports so we can bill the tenants for that extra air* (Property Manager, SW Tampa).

Green fund qualification included statements about how the system enables managers to qualify for grants and certifications by providing data that, when analyzed, are used to substantiate claims of decreased energy consumption in their organizations. The BAS data were used to look at past performance.

The data include statements related to managers in the process of applying for "green funds" and LEED building certifications, as well as managers that have obtained LEED certification and energy star ratings for their buildings by tracking their energy use with the BAS trend data.

Evidence of this construct is found only in four cases – Case2, Case3, and Case4; however there is no clear reason why this this is so. The following statements were interpreted as evidence of this construct:

> **Case2:** *It helped us toward our LEED certification – having it in place gave us points toward our certification* (Property Manager, Downtown Orlando).
>
> **Case3:** *Our energy management system is key in saving us energy on a daily basis, to qualify us for both LEED and energy star. Leasing is a benefit of having the energy star. We have about 35 percent of our building that is leased to TSA – government. We have to be energy star to get the government. You have to have the energy star. It just helped us a little more when we're leasing to companies that have that requirement. For some companies that's a requirement* (Property Manager, Downtown Tampa).
>
> **Case4:** *My interest right now is in applying for the green energy fund to help pay for some of the projects that we are doing on the hall. And the application requires that we show evidence that we are saving energy and greenhouse gases. So I will be using that information to back up my application. Actually it's funding that students provide – the Green Energy Fund and I compete for the fund. It's something new for me and I think it's a great idea* (Architect, NE Tampa).

User learning included statements made about knowledge gained from experience with the BAS implementation. Statements captured for this construct indicate that *user learning* increased over time and enhanced operational efficiency; in particular, *energy conservation* and *tenant comfort & safety*. In cases where auto-reconfigurable systems were implemented, this experience-based knowledge enabled users to override the system settings that were counter-productive to the creation of BAS value. *User learning* was very prevalent and occurred in all six implementation cases. The following statements provided evidence of this construct:

Case1: ***We have made changes****. A major one was to have all the equipment interconnected. If you send off an alarm* [fire], *the alarm now goes throughout the entire building as opposed to the floor on which it was sent off. Another is, in terms of the air flow [pause] I think that was to allow the system to terminate the air flow to areas where there was no activity* (Facilities Manager, Downtown Kingst*on*).

Case2: *Information… by taking a look at the system, if you know what you're looking form, I can pretty much tell if every major system in this building is working. I can tell if the domestic water pumps are working, because I have no alarms. I know that the air is working because I can physically see because we have the sensors and the graphics are cool – it actually shows the fans running. The vast amount of information you can get with just a glance. I mean, I can walk in here, and in five minutes, without moving, I can tell* (Building Engineer, Downtown Orlando).

Case3: *So the computer is doing that automatically all the time, but you still need to go back and check it to make sure that it's running properly.* CO_2 *sensors can fail or get out of calibration so we have to go through and test them once a year. The system is only as good as the operator. So if you don't have a qualified operator that knows how to maximize the system's capability, you won't get the percentage savings* (Chief Engineer, Downtown Tampa).

Case4: *It tells me the problems in the system and makes me know them even before the students even realize they have a problem. So problems can be fixed before the students even realize they have a problem* (Building Engineer, NE Tampa).

Case5: *Those sensors tell me what the temperature in that area is. We average that to get the average temperature on the floor. Then we can adjust the air conditioning based on what the average temperature is. I can sit there and check every single piece of equipment and adjust each from the computer. And if there is a piece of equipment that has something wrong, I know which piece it is and I can go directly to it and fix it or get it fixed – preferably before the tenant arrives* (Building Engineer, SW Tampa).

Case6: *Staff members are in there every day or very frequently. This is how they get to understand how the system is working, what trends are going on… They're tasked with making sure that whoever is in charge of a system is looking at the system for operability -- making sure that all the systems are working properly as energy efficient as possible. We've learned from previous experiences that we had this huge area that no one could figure out and sometimes it was something as simple as someone putting an override.* (Facilities Manager, St. Petersburg).

The Emerging Model

In the sections above, I have presented the support found for the original model. I have also presented discoveries made during the data analysis of details of the proposed constructs and new constructs. These latter – the discoveries – have been used to refine the preliminary model proposed. The final model is now presented in Figure 5-3.

This new model captures the refinements to the model that have been made based on the results of the analysis.

Potential Differences across Cases

The data indicated that some of the key constructs differ across the cases could potentially impact the level of *BAS value* across the cases and over time. In this section, I discuss some of the differences seen across the cases in the *BAS implementation* and *BAS value* constructs. Statements from the cases are used to support this discussion.

Differences: BAS Implementation

The findings showed that one way in which *BAS implementation* differs across the cases is in terms of the number of pieces of equipment that is connected to the system. This difference in

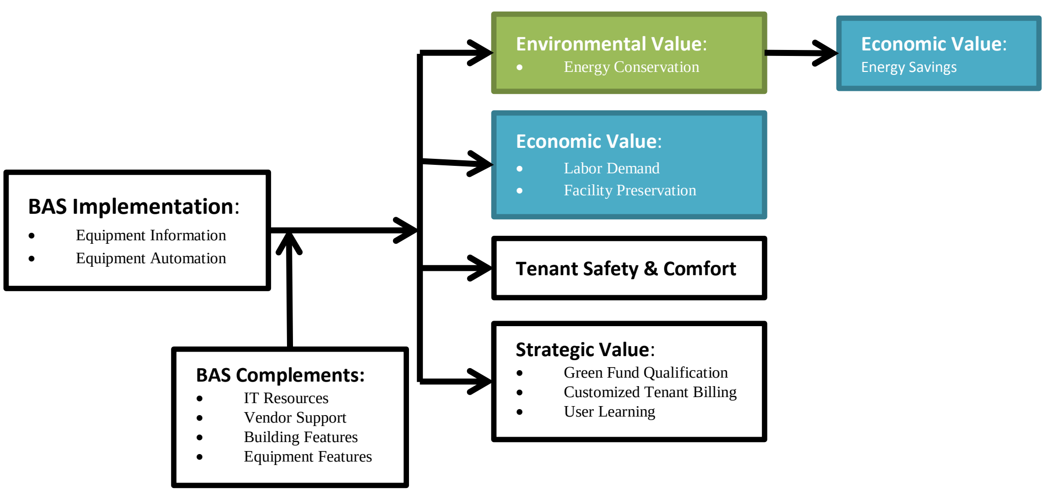

Figure 5-3: Final: The Resource-Based View of the Sustainable Organization

the number of connected equipment could result in a difference in the level of building equipment shutdowns across the cases and consequently a difference in the level of energy consumption in the building. It could also result in differences in the level of information that the system can provide (based on the number of equipment for which information is provided), and thus a difference in the knowledge available to the teams. Therefore, the greater the number of equipment -- HVAC, water pump, etc. – that is connected to the system, is the more automation – periodic and strategic shutdowns that occur, and the more information that managers and engineers can access. Table 5-1 shows the *extent of BMS implementation* at the six case sites.

Table 5-3: Results: #Pieces of Equipment Controlled and Monitored

Extent of BAS Implementation: Equipment Automation/Information								
Case	**HVAC**	**Overtime Energy**	**Light**	**Water Pump**	**Fire Alarm**	**Electronic Access**	**Elevator**	**Alternate Energy (Solar & Wind)**
Case1	✓		✓	✓	✓	✓	✓	✓
Case2	✓	✓	✓	✓		✓		
Case3	✓	✓		✓			✓	
Case4	✓							
Case5	✓	✓						
Case6	✓		✓					

Differences: BAS Value

The findings showed that *BAS value* varies across the cases in various ways and is somewhat tied to the value dimension that is created. There are three dimensions of *BAS value*: *environmental value*; *economic benefits*; and *strategic value*. The finals suggest differences as follows.

Differences: BAS Value: Environmental Value

For *environmental value*, a potential difference was seen in Case1. The reference is made to the CO_2 equivalent of the reduction in *energy conservation*:

> My report shows the savings we make on CO_2 emissions by producing solar power. So we know that ozone depletion and other environmental hazards have been reduced (Go Green Team (BAS Chief Engineer).

Differences: BAS Value: Economic Value

Economic value dimensions showed potentially differences in terms of the economic cost savings produced by the reduction in each dimension. For example:

> **For *energy conservation* – reduction in energy costs***: looking at our electricity bill: when I first got here it was $160-190,000 a month. Now we're down between 60 and 80,000* (Chief Engineer, Downtown Tampa).
>
> For ***facility preservation* – reduction in repair costs***: We saved damage and the cost of it. We still had a lot of damage, but it could have been that much worse* … (Facilities Manager, Downtown Kingston).
>
> For ***labor demand* – reduction in labor costs***: We used to have an engineer for every 50,000 sq. ft. Now it's nothing if you have ½ million sq. ft. with one engineer. Now they're saving money on employees* (Chief Engineer, SW Tampa).

Tenant safety & comfort could differ in terms of the number of complaints that maintenance staff, including managers, get:

> ***Tenant safety & comfort* – reduction in number of complaints**: *I know that the number of complaints has decreased and the way the system functions would probably have something to do with that* (Property Manager, Orlando).

Differences: BAS Value: Strategic Value

There are no references that showed how the strategic value could differ across the cases.

CHAPTER 6: DISCUSSION OF RESULTS

Introduction

In this research I developed a research model by using the stakeholder theory (Freeman 1984) to extend the resource based view (RBV) of the firm (Wernerfelt 1984). The resulting model, *the resource based view of the sustainable organization (RBV-SO)*, was used to examine the environmental and economic value of green IT implementation. The resulting model is shown in Figure 5-3 in the preceding chapter.

Scholars have recently called for research that examine issues at the intersection of information systems (IS) and environmental sustainability (Elliot 2011; Melville 2010; Watson et al. 2010b). This stream of research – now known as green IT research -- is critical in that it contributes knowledge of whether and how organizations are contributing to sustainable development by implementing initiatives that benefit, rather than just exploit, the natural environment.

In response, some researchers have explored the antecedents of green IT implementation (Cai et al. 2013; Kuo et al. 2010; Molla 2013), while others have explored the value created by green IT (Ko et al. 2011; Meacham et al. 2013; Ryoo et al. 2013). Overall however, the area remains relatively unexplored despite the potential contributions that IT can make to sustainability issues in organizations, especially to reduce the negative impact of organizational processes.

This study responds to the call for green IT research. It focuses on the environmental and economic value created through the conservation of electric energy in buildings. Green IT research in this area was deemed important given the statement by the US Energy Information Administration (USEIA) that approximately 40 percent of the energy used in the US over the last three years was consumed in building operations. This study explored the building automation system (BAS) -- a green IT system used to conserve building energy.

The findings of this study suggest that implementation of the BAS does not only create environmental and economic value as anticipated, but also creates social value and strategic value for the organization -- sustainable value.

The rest of this chapter proceeds as follows. In the next section I discuss sustainable value and how it is created by BAS implementation. I follow with a presentation of the emergent model focused on the creation of sustainable value.

Insights on BAS Implementation as a Source of Sustainable Value

Sustainable value is defined as having three value dimensions: ***social value*** – value that impact people's wellbeing; ***environmental value*** – benefits that impact the wellbeing of the natural environment; and ***economic value*** – profits (Hart et al. 1995; Bansal et al. 2000). These three are consistent with contributions to what Elkington (1998) defines as organizations' triple bottom line performance that is used in corporate sustainability reports. In addition to involving three-dimensional value, the creation of sustainable value also involves the creation of strategic (long-term) value that enable organizations to develop sustainable future competencies (Hart et al. 2003; Van Marrewijk 2003a).

In IT research, one path to sustainability has been shown as the use of IT to develop technological resources and expertise that distinguish an innovating organization from its competitors Kettinger 1984). In this discussion, sustainable value is discussed both in terms of the three dimensions of value – economic, environmental and social – that BAS implementations enable, as well as in terms of the strategic or long-term benefits that are created by the system implementations.

The green IT literature (although sparse) shows some evidence that green IT results in economic value by increasing process efficiency (Meacham et al. 2013; Ryoo et al. 2013). However, within the green IT context, process efficiency entails: (1) reduced economic costs or *cost efficiency*; and (2) conservation of the natural environment or *eco-efficiency* (Dyllick et al. 2002; Watson et al. 2010b). Green II research has also shown that social value in terms of employee safety results from green IT implementation (Watson et al. 2010). Thus the literature shows that green IT implementations can create the three dimensions of sustainable value.

Within the current study, there is also evidence across all the cases that green IT – the BAS –enables increased eco- and cost-efficiency, creates social value and positions the implementing organizations to create strategic value. The details of these are discussed in terms of the value created by the two sources of BAS implementations – BAS information and BAS automation.

Insights: BAS Automation and Sustainable Value

There was evidence across all the cases that BAS automation enabled the creation of **environmental value** through energy conservation. For example, the following statement made by a building engineer:

> **Eco-efficiency (CO_2 Emissions)**: *We're using less energy from the Grid* -- *that means that we're potentially reducing the amount of CO_2 that is generated* (Building Engineer, Downtown Kingston).

There was also support across all the cases for the proposition that BAS automation enabled the creation of **economic value** through energy conservation – in particular, through shutdowns as well as through staggered start times. For example, the following statements:

> **Cost Efficiency (Periodic Shutdown)**: *We are shut down basically six hours at night for five nights a week and then we're shut down probably over half the weekend. So we're saving 50, 60 hours a week easily, and those things aren't cheap to run* (Building Engineer, St. Petersburg).

> **Cost Efficiency (Staggered Startups in Peak Hours)**: *Every 15 minutes the utility company pulses my meter to check how much energy drive I have and I get charged a peak load every month based on that; so if I don't sequence my start time it could cost me 15 or 20 thousand dollars a month. And that's the other reason you want the computer system, to maximize and limit your load* (Chief Engineer, Downtown Tampa).

There were also statements in some cases that supported the creation of other **economic value** through reduction of maintenance costs including reduced labor demand and facility repairs. For example, the following statements:

> **Cost Efficiency (Labor Demand):** *Oh yes, I mean, we had a fulltime engineer that only did HVAC, so I would have to say we are saving money because it's not causing us salary* (Property Manager, SW Tampa).

> **Cost Efficiency (Facility Repairs)**: *The equipment lasts longer now because we don't have to work it as hard, especially now that all my pump motors, and all my fans and everything all have DFDs on them. So instead of running at 100 percent 12 hours a day, they're running at 50 percent, and they're running for 9 hours a day* (Chief Engineer, Downtown Tampa).

The study also showed evidence that green IT also **immediately** enabled **social value** – safety and comfort (tenant value) for building tenants. Like energy conservation, this value dimension was supported across all the cases investigated. A sample statement shared by a chief engineer interviewed in the study is as follows:

> **Tenant Value -- Safety and Comfort**: *In the mornings, the drives are going to be running at 25-30% which makes it comfortable* (Chief Engineer, Downtown Orlando).

Finally, although not available across all cases, the data suggest that BAS automation can enable **long-term economic value** through potential revenue gains for the implementing organizations. One such was the potential to retain tenant leases by maintaining tenant satisfaction (with indoor building conditions). A facilities manager interviewed in the study shared the following insight on BAS automation and tenant satisfaction:

> **Reduced Complaints – Tenant Satisfaction**: *Minimizing the complaints is one thing … we're also using the system to drive down the complaints* (Facilities Manager, St. Petersburg).

And a property manager of leased buildings interviewed in the study shared the following insight on tenant satisfaction and maintaining leases:

> **Tenant Satisfaction -- Positioning for Tenant Leases:** *It helps us with our tenant's comfort which affects our leases, and that makes our business. If I can keep my tenants doing their business without having to think about the comfort of the building – that's my goal* (Property Manager, Downtown Tampa).

The data also suggest that BAS automation can also enable organizations to avoid both building fines and lawsuits and thus indirectly create **economic value** in the future. A building engineer interviewed in the study shared as follows:

> **Lawsuits and Fines**: *I'm a building engineer and my job basically entails two things: protect the assets; and service the assets. That encompasses everything that I do. Protection is making sure that all life safety equipment is up to date, up to code, and working, because we've got 100 to 1,500 people in the building and God forbid that something that I did or didn't do would cause them to perish. That's my number 1 concern – the safety of the tenants of this building. Also, a big concern is not bringing any liability to the owners of this building which is in and of itself easy to do, because if you do something or take it upon yourself to do something, you could easily cause your owners to be liable, and that's a pretty good way to not have a job. That's a pretty important issue as well* (Building Engineer, Downtown Orlando).

Thus, the study showed that BAS automation enabled sustainable value as follows: it enabled **environmental value** and **economic value** through energy conservation; it enabled additional economic value through reduced facility repairs costs and reduced maintenance labor cost; and it enabled **social value** by increasing the comfort and safety of the building tenants. Also, although there is less evidence for these, the study shows that BAS automation enables implementing organizations to create **strategic value** by retaining and attracting leases and by avoiding fines and penalties.

Insights: BAS Information and Sustainable Value

In a case study of a green IT implementation by UPS, Kohli (2007) showed that automation ought not to be the only focus of IT implementations. That is to say that when they position IT implementations solely as cost reduction initiatives, organizations deny themselves the opportunity to capitalize on the information capabilities of IT resources. The author proposed that while organizations will benefit from cost-cutting through automation, they should also look at the revenue creation capabilities, many of which come from exploiting IT information. This research has also shown that, in focusing solely on that just automation, organizations can deny themselves the opportunities available to create value available from information. The current study also highlighted different types of strategic value potentially available from BAS information.

BAS information was shown in this study -- although not across all cases – to have the potential to enable managers to position their organizations to continuously and increasingly create strategic value -- sustainable value. For example, the BAS was shown to enable managers to accurately determine and report overtime energy usage by individual contract and therefore bill their tenants for energy used outside of the regular hours included in their lease contracts:

> **Overtime Energy Billing:** *We control tenants' overtime air so the tenants can ask for air when it's not billing time, such as during afterhours. And we get reports so we can bill the tenants for that extra air* (Property Manager, SW Tampa).

A potential strategic impact of this information value is the potential to gain tenant trust due to the ability to verify the accuracy of these additional monthly charges and thus retain tenant leases.

Other strategic value gained from BAS information according to the data included the potential to generate revenue and to improve maintenance efficiency over time using knowledge gained from analysis of the BAS information. For example, this study showed that organizations are potentially able to create economic value by: using BAS information to substantiate their energy reduction claims to **qualify for green funds**; **qualifying their buildings for various** certifications that can help managers to position their organizations to attract new leases; and **improve their ability to configure the systems** more effectively and thus realize continuous and increasing three dimensional value through BAS automation. Samples of statements in support of these are as follows:

> **Green Fund Qualification:** *My **interest right now is in applying for the green energy fund** to help pay for some of the projects that we are doing on the hall. And **the application requires that we show evidence** that we are saving energy and greenhouse gases. So I will be using that information to back up my application* (Architect, NE Tampa).
>
> **Building Certification and Attracting Tenant Leases:** *Our energy management system is key in saving us energy on a daily basis, to qualify us for both LEED and energy star. Leasing is a benefit of having the energy star. We have about 35 percent of our building that is leased to TSA – government. We have to be energy star to get the government. You have to have the energy star. It just helped us a little more when we're leasing to companies that have that requirement. For some companies that's a requirement* (Property Manager, Downtown Tampa).
>
> **User Learning for Improved Maintenance Value:** *We've learned from previous experiences that we had this huge area that no one could figure out and sometimes it was something as simple as someone putting an override. Now I'm doing the override report weekly* (Facilities Manager, St. Petersburg).

Finally, Bansal (2005) speaks about the difficulty of asserting what environmental impact is created by organizations engaging in initiatives that are designed to create environmental value. This led the author to describe sustainability as "*defined ambiguously*" with "*high externalities*" and sustainability initiatives as having "*outcomes that are often unknown*". (p198). However, the findings of this study suggest that green IT implementations have measurable impacts which can be calculated and reported using the systems' information capabilities. Therefore, the outcomes of green IT system implementations can be well-defined and the extent of value realized can be known.

In multiple cases, respondents described how they were able to access details of how energy was conserved (how environmental value was created). For example, they were able to access information on the events concerning particular pieces of equipment that were shut down and for how long they were. In one organization – Case1 -- respondents discussed the ability of the system to enable savings in emissions. In five of six of the cases, there was no emphasis seen regarding the natural environment and the environmental value created by the systems. For example, the following statement shows how the system is able to report on equipment activities:

> **Details of Energy Conservation -- Environmental Value**: *I also run reports that tell what time the chillers kick on, what time they kick off, so I know how many hours I'm down and how many are hours they're running. From that I can tell how much energy we are saving by how many hours we are cutting off* (Building Engineer, St. Petersburg).

In one case -- Case1-- Downtown Kingston, an emphasis on the natural environment was evident in the statements made by all the respondents. In that case, the BAS implementation included calculations of the actual emissions savings and these were displayed as key performance indicators on a dashboard. This use of the system suggests that in addition to creating environmental value through automation, BAS information can also be used to determine and report on the details of how value is created, as well as the extent of the value created:

> **Extent of Environmental Value Created**: *My report shows the savings we make on CO_2 emissions by producing solar power* (Building Engineer, Downtown Kingston).

Within Case1 again, there was evidence of the ability of the BAS to integrate alternate sources of energy – in this case, wind and solar power -- into the building operations and also measure and report the environmental impact of the electric energy conservation that resulted:

> *The BAS has primarily reduced our emissions because of the reduction it has allowed in the power we draw from light and power company. It allows us to integrate the wind and solar power*

efficiently. My report shows the savings we make on CO_2 emissions by producing solar power; so we know that ozone depletion and other environmental hazards have been reduced (Building Engineer, Downtown Kingston).

Despite the measurement and reporting of the environmental impact of the implementation in Case1, there was no evidence that the information was used, for example, to substantiate the organization's eligibility for sustainability awards or green funds, nor to brand the organization as "green." Rather, one employee saw in it the potential to change employee behavior to achieve greater environmental value:

> *I would say that the integration of the systems has allowed us to have data that we can analyze and, based on the report, make adjustments that increase efficiencies over time and slowly have staff adapt to certain settings that save energy* (Building Engineer Member, Downtown Kingston).

Thus, the study showed that BAS automation enabled sustainable value by: enabling managers to position their organizations to retain existing and attract new lease contracts through customer satisfaction and trust; enabling managers to attract revenue available from green funds; enabling engineers and managers to develop dynamic capabilities that can lead to continuously increased social, environmental and economic performance; and enabling managers to measure and monitor their performance and also brand their organizations as green.

Summary: BAS Implementation and Sustainable Value Creation

Overall, the findings suggest that BAS automation and BAS information together create three-dimensional and strategic value. However, BAS information does not appear to be as highly exploited as BAS automation as a source of value for the organizations -- the results showed: that energy analyses were used only in three cases – in the leased office complexes; that only five of six cases used the information to qualify for green funds; and only one organization discussed the environmental value of the BAS and used it to measure the carbon impact of the implementation. This is consistent with the perceptions of Zuboff (1985) and Kohli (2007) that this dimension of the IT duality is less exploited. Figure 6-1 depicts the emergent model focused on sustainable value creation from the two implementation dimensions.

Despite the apparent underutilization of the information, all teams members interviewed appeared to perceive the BAS implementations as successful especially because of the social and economic benefits enabled by the system automation.

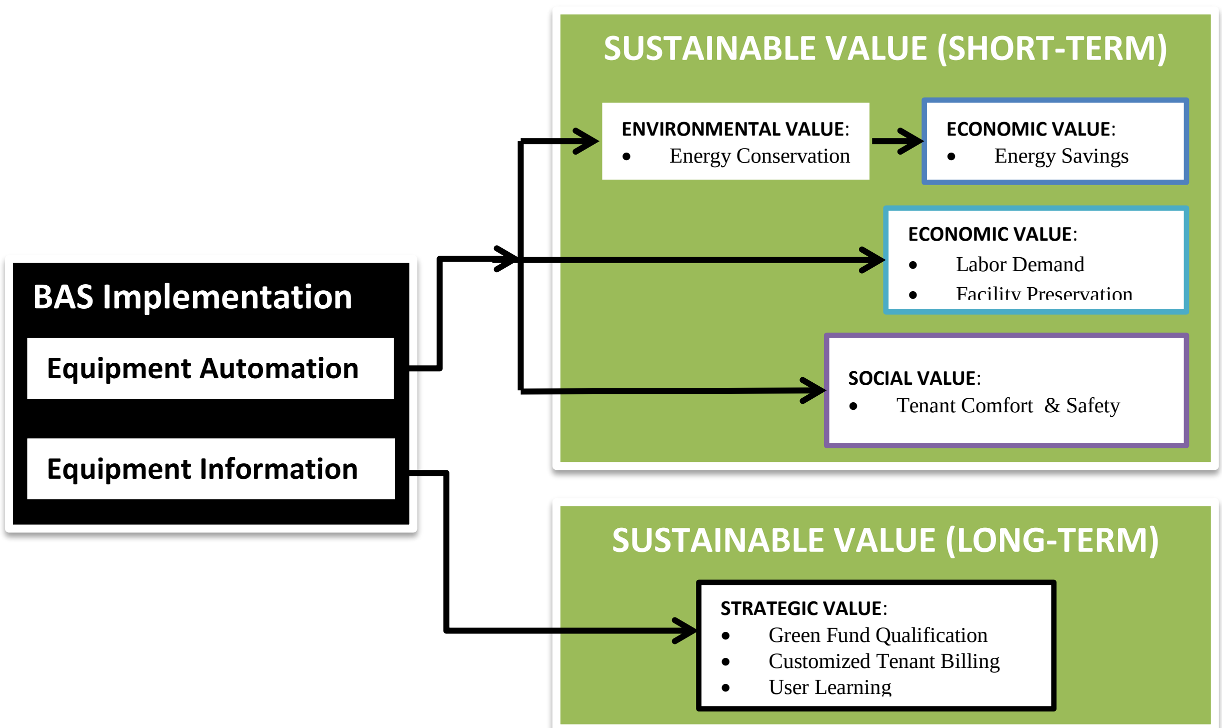

Figure 6-1: Sustainable View: Resource-Based View of the Sustainable Organization

CHAPTER 7: CONCLUSION

Introduction

This study has provided insights on some of the key resources that enhance the value created by BAS implementations. These included IT resources other than the BAS, vendor support and building and equipment features that enhance the value created by the BAS.

In this chapter I discuss the validity of the emerging model. I follow with a discussion of the implications for research and practice, and end with a discussion of the research limitations and directions for future research.

Validity and Structural Dimensions of the Emerging Model

A certain level of validity and soundness of a model developed in a qualitative research may be claimed if certain techniques are employed in these studies. These techniques include the use of multiple cases as sources of evidence that converge on the same facts or findings, as well as other techniques that increase the robustness and validity of the findings. Incorporating these techniques is expected to substantially increase the overall quality of the findings of a study (Cdata-Dube et al. 2003; Eisenhardt 1989; Yin 1994).

In Table 7-1, I present the techniques that are recommended and highlighted those that have been employed in this research. In the upcoming subsections, I summarize the techniques used to achieve model validity.

Achieving Model Validity: Key Techniques

Table 7-1: Conclusion: Case Study Quality Enhancing Tactics: Yin (1994)

Quality Focus	**Techniques**	**Research Phase**
Construct Validity	***Use multiple sources***	Data collection
	Establish chain of evidence	Data collection
	Have key informant review case study report	Composition
Internal Validity	***Conduct pattern matching***	Data analysis
	Build explanations	Data analysis
	Conduct time series analyses	Data analysis
	Build logic models	Data analysis
External Validity	Use rival theories within single cases	Research design
	Use replication logic in multiple case studies	Research design
Reliability	***Use case study protocol***	Data collection
	Develop case study database	Data collection

Construct Validity

Construct validity refers to the extent to which a measure adequately represents the underlying construct that it is supposed to measure. In the case of qualitative research, this would refer to the concepts rather than measures. There are four types of construct validity: face validity; content validity; convergent validity; and discriminant validity.

My focus was on achieving discriminant and convergent validity. To do so, I ensured that data were collected from respondents in multiple case organizations and at multiple levels within each organization hierarchy. In this way I sought to ensure that there were several implementation scenarios, as well as different sources (cases) and within those different sources, differences in the sources (respondent types) so that there would be the potential to have distinctions and similarities within the data. In doing so, I had greater confidence that the data had the potential to allow me to establish patterns that were trustworthy – statements that represent similar themes were the same constructs, and statements that represent different themes were different constructs.

In analysis, I engaged in establishing a ***chain of evidence***. Because I did an across-case analysis, I was able to use the findings from previous interviews and cases to provide a basis for the next interview and case. The next interview/case analyzed was then used to support (or not) the evidence found up to that point for the propositions. Thus I confirmed the validity of the findings regarding the constructs and propositions.

Internal Validity

In order to establish internal validity or causality, researchers need to establish the presence of three conditions: (1) association between the cause and effect variables; (2) temporal precedence of the cause variable; and (3) a level of certainty that no other plausible alternative explanations exist (Bhattacherjee 2012; Trochim et al. 2001). These were established to different extents during the data analysis.

My approach involved the use of a preliminary theory-based model. This model served to establish the expectations, based on prior theory, of the associations that were to be found in the data. Using ***pattern matching*** I checked for the presence of the model propositions in the data across the multiple users in the multiple cases I investigated. In this way I linked the theoretical patterns from the preliminary model to the actual patterns observed within the operational reality of the BAS implementation across the multiple cases.

Even when new value constructs were found, the general idea was, according to the theory, that IT enables value. Therefore, any value that was interpreted as enabled by the BAS was used to refine the model. In this way, the statements within the data that matched the theoretical statements were extracted as evidence of the existing and new propositions and internal validity was somewhat ensured.

External Validity

External validity refers to the level of generalizability that can be claimed regarding the findings of a study. External validity is said to be established when the following are met: (1) population validity -- *generalizing* to and across populations; (2) ecological validity -- *generalizing* across settings; (3) temporal validity -- *generalizing* across time; (4) treatment variation validity -- *generalizing* across variations of the treatment; and (5) outcome validity -- *generalizing* across related dependent variables (Bhattacherjee 2012; Trochim et al. 2001).

In order to achieve population validity, I followed replication logic and, in keeping with the requirements of such, I collected data that were expected to be in some ways similar (to achieve literal replication and also, in some ways different (to achieve theoretical replication), depending mainly on the users' implementation experiences – whether they were information- versus automation-centric, as well as their expected implementation value outcomes – whether they were strategic or operational. I iteratively compared and contrasted the experiences of these pairs of users as I analyzed the results of their interviews.

Other distinctions among the cases also assisted in establishing external validity (see Chapter 4 – Data Collection). These distinctions were useful in achieving ecological and treatment variation validity. All the distinctions sought were useful in broadening the base of data for analysis and strengthening the generalizability of the model and the findings in general.

Reliability

Reliability refers to the assessment of consistency achieved in measuring the measures of a construct – the repeatability of the results. According to Yin (2004), qualitative researchers need to demonstrate the repeatability – the ability to gain the same results -- of aspects of a study such as the data collection procedures.

In data collection, one way in which I tried to ensure reliability was in the development and use of a comprehensive case study protocol before collecting data. This way, the users were asked the same questions when the data were being collected. This was compromised in the use of probing questions and the use of open-ended questions. Nevertheless, the data collection was ensured to have a certain level of repeatability and the data that level of reliability.

In the process of analysis, I also took care to organize and present the data, the findings and queries of the findings very logically and meaningfully so as to ensure that I have the evidence of what I performed for other researchers to review. I also created several versions of a case study database as I analyzed each case and reviewed and revised the findings. Although no other researchers were involved in the process, I was able to compare findings over time, and with greater understanding of the data as the process ensued, to review, and if necessary, refine the interpretations.

Implications for Research

The first implication of this research is the availability of a framework that can be applied in the investigation of future studies of intelligent green IT value.

Focused as it is on green IT value, this dissertation contributes to important areas of IS research which suffer from a lack of investigation – green IT research, in particular green IT value research.

The study responds to recent calls have been issued for research in this area (Watson 2010; Melville 2010; Dedrick 2010) that applies existing theories, or develops new ones in the investigation of green IT. This research has therefore contributed to the emerging body of green IT knowledge.

Finally, the analysis conducted in this study has revealed details of the investigated and also new constructs that have the potential to provide insights into the development of potential measurement items and questions for surveys of the implementation impact of the BAS. It is possible that some of these ideas, for example some of the IT roles, may also be useful in the study of other green IT systems, especially smart systems.

Implications for Practice

The main implication for practice is the knowledge of how the implementation of the BAS should be managed to maximize sustainable value creation. With respect to this, the study provides several insights that are useful for practitioners. For example, the study provides insights from across the various cases as to how the information can be used to position organizations to create strategic value. It also reveals insights into the key complementary resources that enhance value creation such as building zones, window positioning, vendor contract terms and vendor competence, the availability of multiple and well calibrated sensors and the level of insulation in the walls and roofing.

Another practical implication is the need for BAS information to be incorporated into the overall strategic plans of the implementing organizations. In this way, the information may be exploited on a wider scale -- beyond achieving facilities maintenance efficiencies.

In many cases, practitioners were found to be unaware of the revenue benefits available from BAS information and therefore tended to focus mainly on BAS automation and that primarily for tenant comfort and energy cost reduction. More work needs to be done to encourage use of the BAS information capabilities especially to increase awareness of the organizations' environmental impact and the impact the BAS has in reducing that impact. Organizations would not only understand and celebrate their success, but also share it so others may follow:

> *We wanted to be among the forerunners in changing the culture. I will venture to say that though we are champions. We don't take pride yet in where we are, not that we see any company ahead of us, but we are looking to be that team. We look far ahead that right now we want to do green and to get people on board -- employees, community, eventually the entire Jamaica.*

Research Limitations

A major limitation of this study is the use of a single coder in the analysis process. Whereas multiple coders would enhance the robustness of the findings, there is difficulty in acquiring coders who were both available and willing to invest time in understanding the domain so that coding can be done effectively.

A second limitation is that user perceptions, rather than actual quantities, were used to test the propositions. No quantitative data could be accessed from the teams for the economic costs and environmental costs.

There were also limitations of the sample in terms of: all participants perceived their implementations as successful -- no adverse factors were discussed; and only in leased buildings was there seen monitoring of the use of overtime energy. Analytical and case-to-case generalization was achieved across the current group of cases; however, especially the fact that the information was so under-utilized among the cases suggests the need for greater inclusion.

Directions for Future Research

Future research could therefore seek to use the findings of this research to conduct a quantitative investigation especially one that includes quantitative rather than perceptual measures of the green IT value constructs.

Future research could also investigate the impact on green IT (BAS) value creation of external forces such as government regulations, environmental issue salience, and market forces, as well as the impact of time on the development of the strategic capabilities developed from the BAS information value.

Finally, the use of cross-sectional data appears to severely limit what could be a very interesting value outcome of BAS implementations -- organizational learning as a dynamic capability. The findings suggest that organization learning involves both the *BAS-configured control* systems – machine learning, as well as the BAS users; however, the data were unable to confirm this. The use of longitudinal data and the application of the dynamic capabilities theory could lead to greater insight into the effect of this capability on green IT value.

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APPENDICES

Introduction

The appendices are as follows:

- Appendix A to F present the summary of the literature review as well as detailed tables representing each category of variables found within the review.
- Appendix G presents the interview protocol followed in the data collection.

Appendix A: Green IT Implementation: Green IT Resources

This category includes the organizational resources that use digital technology to capture, process, store, display or communicate information and that were deployed specifically to create environmental value.

Table A-1: Green IT Implementation Category of Variables

	Variables	Definition	Source
Green IT Resources	Green modified ERP	ERP system modified to monitor environmental sustainability of organizational processes	Meacham et al. 2013
	Green strategic IT	Technologies that range from e-commerce and logistics type technologies, to data centers and storage, to software. Investments in greening IT systems and their usage, using IT to support greening efforts, and using IT to communicate and raise environmental awareness.	Bai et al. 2013
	Sensor system Smart power grid Vehicle-to-grid	Green IS that improve energy efficiency	Hertel et al. 2013
	Green IS investments	Sources of environmentally friendly low-cost energy, enabled by increased use of IS.	
	Green IT	Not just energy-efficient gear, but systems that enable energy efficiency in the business functions they support.	Cai et al. 2013
	Logistics software	System that develops capability to transport goods and raw materials so that, for example, "fully loaded trucks arriving at the plant with raw materials and parts are returned with products to the customers" (p398).	Høgevold 2011
	Collaboration /teleconferencing IT	Installed to reduce business travel (Høgevold 2011)	Høgevold 2011 Kuo e al. 2010 Molla et al. 2012
	IT controller - HVAC	Increases energy efficiency using algorithms that control indoor environment using setpoints designated by users.	Kofoworola et al. 2009
		Impact: air economizer and night-flushing – use of outside air for free cooling.	Scheuer et al. 2003
	Server consolidation Desktop virtualization Server and storage virtualization and consolidation	Enable greater agility, flexibility and efficiency of ICT infrastructure with a possible achievement of energy savings and minimal deployment of ICT devices (Alena et al).	Alena et al. 2012 Kuo et al. 2010
		improves IT utilization while reducing power consumption and carbon emissions (Molla)	Molla et al. 2012
	Green practices-IS alignment	The degree to which the IT function supports the goals and priorities of green practices (GPIS)	Ryoo et al. 2013
	IT capability	The firm's ability to mobilize, deploy and use IT-based resources such as IT infrastructure or human IT resources to improve the firm's business processes.	Benitez-Amado 2012

Appendix B: Green IT Implementation: Antecedents

This category includes the variables that were found to influence green IT implementation across the three implementation stages investigated: adoption; use; and procurement.

Table A-2: Green IT Implementation - Antecedents

	Antecedent	Definition	Source
Green IT Implementation Antecedents	Green IT properties (+)	Ability of IT to meet the principles of Green ICT during use and when discarded, for example, the IT products Energy Star rating.	Alena et al. 2012
	Eco-friendliness of suppliers (+)	Extent to which a product is burdened with mainly negative effects when entering into the business	
	Cost reduction (+)	Expectations of ability to sell products or services with the lowest cost in the firm's industry	Cai et al. 2013
	Differentiation (+)	Expectations of unique features for its products and services	
	"Doing the right thing" (+)	Initial awareness of environmental impact spurred line-employee to advocate for environmental impact reduction (to managers)	Høgevold 2010
	Top-level management support (+)	The process towards sustainable business operations requires long-term commitment and so must be anchored and supported by the top-level management and owners of the company	
	Legitimation pressures (+)	Pressures from **government, local community and external stakeholders**, to comply with norms and regulations in order to survive by avoiding penalties and lessen risks	Kuo & Dick 2010
	Social responsibility pressures (+)	Concern the organizations' employees have for social good.	
	Organizational factors (+)	Capability of the organization to adapt quickly to the changing contexts in which they operate	
	Eco-efficiency (+)	Expectations of improvements in the eco-sustainability of IT and the wider enterprise while at the same time pursuing economic objectives of cost reduction	Molla et al 2012
	Eco-effectiveness (+)	The desire to implement practices and technologies to improve the eco-sustainability of IT and the wider enterprise out of deep concern for the natural environment or in order to set norms and become a thought leader in industry	
	Eco-responsiveness (+)	Association of a business with market accepted norms of reducing emission, recycling, and reuse	
	Eco-legitimacy (+)	The desire to avoid regulatory and social pressures that threaten the firm's legitimacy	
	Energy Usage (-)	Environmental measures of the raw material used in the **construction of the IT**. These were combined with social and economic measures in order to evaluate and choose among green IT alternatives.	Bai, Sarkis 2013
	Total Toxicity of IT Materials (-)		
	% Recycled Material Usage (+)		

Appendix C: Green IT Implementation: Complementary Green Resources

Complementary resources are organizational resources that, when used along with the IT resources, change the extent of the value produced by use of the IT.

Table A-3: Green IT Implementation – Non-IT Green Resources

	Variables	Definition	Source
Complementary Green Resources	Green approaches to IT	Practices applied to IT devices and systems to optimize energy consumption. These include: o IT energy consumption measurement o Rightsizing IT equipment o Powering down IT equipment.	Alena et al. 2012
	Non-IT energy conservation strategies	Other strategies used in addition to the HVAC system for savings of between 40 and 50% energy usage: periodic load shedding; low window-to-wall ratios; window glazing with low solar heat gain coefficients; and increased indoor set-point temperatures.	Kofoworola et al. 2009
	No skylights	Reducing entrance of heat in the building	Scheuer et al. 2003
	IT innovation	IT use that represents the first use of a technology among firms in the same industry, or that results in a new product or service	Ko et al. 2011
	Corporate environmental profile	Public awareness that the organization meets the requirements that: o there should be corporate environmental awareness and consideration throughout the product's life cycle; o the number of hazardous work processes and waste should be minimized; and o materials used in the products should be recyclable	Høgevold 2010
	Long-term company differentiation	Public awareness of company profile	
	Recyclable and renewable raw materials	Materials used to ensure eco-friendly disposal ("*cradle to grave and beyond*") and reduce the negative impact of the product.	
	External expert consultants	Experts used to measure organization, product and value chain carbon footprint and to audit corporate environmental reports.	

Appendix D: Green IT Implementation: Green Capabilities

Green capabilities refer to abilities to conserve natural environmental resources or minimize waste and emissions.

Table A-4: Green IT Implementation – Green Capabilities

Variable		Definition	Source
Green Capabilities	IT energy efficiency	Improvements in energy consumption achieved by lowering power consumption utilizing various activities and technologies based on integrating new approaches to power and cooling with green IT.	Alena et al. 2012
	IS-enabled energy efficiency	The ability to realize environmentally friendly, low-cost energy through increased use of IS.	Hertel et al. 2013
	Information sharing	The ability to synchronously share real-time information with suppliers and customer.	Meacham et al. 2013
	Green practices-marketing coordination	The ability of marketing/manufacturing and green practices functions mutually understand each other's capabilities and align their respective goals and activities based on such understanding.	Ryoo et al. 2013
	Green practices-manufacturing coordination		
	IT capabilities	Improve HVAC energy efficiency	Kowoforola et al 2009
	IT capabilities	Air economizer and night-flushing with outside air for conserving energy	Scheuer et al 2003
	Employees' awareness	Employees knowledge of the environmental impact of their business travel plans	Hogevold 2011
	Logistics Optimization	The system information facilitates improvement of the transportation of goods and raw materials so that, for example, "*fully loaded trucks arriving at the plant with raw materials and parts are returned with products to the customers*" (p398). It also helps with product design and packaging to optimize the available space on the truck .	
	Consultants' expertise	Expertise of external consultants in: • measuring carbon footprint through the value chain • developing neutral product documentation for customers • conducting eco-management and audit	
	Customer knowledge	• Customer awareness of the product capabilities and of the environment - facilitated by, and resulting in (respectively): o products fact sheets explaining product recyclability o customer demand for products' carbon footprint documentation	
	IT innovation	o first use a technology among firms in the same industry, or to use it such that it results in a new product or service.	Ko et al.
	Proactive corporate environmental strategy	Firm's ability to implement environmental management practices voluntarily in advance of future environmental regulations and social trends, designing or altering the behavior of all functional departments, business processes and products to prevent negative environmental impacts of business activities on the natural environment. Leads to competitive advantage.	Benitez-Amado 2011

Appendix E: Green IT Implementation: Green IT Environmental Value

Environmental value refers to implementation outcomes that benefit the environment and thus contribute to environmental sustainability.

Table A-5: Green IT Implementation – Environmental Value Outcomes

Variable		Definition	Source
Green IT Environmental Value	Energy market dependence (+)	The extent to which IT can enable reduction of a firm's dependence on fluctuating energy markets.	Hertel et al. 2013
	Corporate independence	The extent to which a firm is independent of the market for energy.	
	Energy balance	The availability of energy-producing environmental resources.	
	Product transportation fuel savings	Savings in fuel generated when fully loaded trucks, arriving with raw materials and parts, return with products to the customers.	Høgevold 2011
	Employee travel eco-impact improvement	Reduction in employees' business travel.	
	Low Carbon footprint products	Improvement in environmental impact of firm products due to the use of recyclable &renewable raw materials and reduced transportation fuel consumption	
	Energy demand	Energy consumed by a building and/or various equipment in the operations phase.	Kofoworola et al. 2009
	Energy demand	The energy consumed in the operations phase of a building.	Scheuer et al. 2003
	Organization environmental performance	Environmental performance relates to the ability to reduce air emissions, effluent waste, and solid wastes and the ability to decrease consumption of hazardous and toxic materials and to decrease the frequency of environmentally related accidents.	Meacham et al 2013
	Environmental performance	Improvements in a firm's environmental footprint.	Ryoo et al. 2013

Appendix F: Green IT Implementation: Green IT Economic Value

Environmental value refers to implementation outcomes that provide economic benefits for the organization and thus contribute to organization profitability.

Table A-6: Green IT Implementation – Economic Value Outcomes

Variable		Definition	Source
Green IT Economic Value	Energy savings	The energy saved by the HVAC IT controllers and other organizational resources and strategies.	Kofoworola et al. 2009
	Energy cost savings	The extent to which IT use results in savings in the firm's energy cost.	Hertel et al. 2013
	Exposure to fluctuating energy prices	The extent to which a firm faces fluctuating energy prices on the market.	
	Transportation cost savings	Cost savings from reduction in fuel consumption.	Høgevold 2011
	Reduced employee travel costs	Cost savings from reduction in employee travel	
	Competitive product brand	Increased customer patronage: "*Customers … are beginning to require documentation of products' carbon footprint... In particular, larger customers are concerned with the environmental impact of the products to be bought, and choose products with a proven track record of environmentally friendly production*."	
	Competitive bidding position	Ability to tender for competitive bids: "*According to top-level management, the carbon footprint of the products is one of the criteria in all of the bidding competitions in Norway and is regarded by the sales organization as an important factor in the decision process in approximately 80 percent of bidding competitions*."	
	Higher profit ratios	Return on Assets (ROA) -indicator showing the ability of a firm using its own assets to generate sales. Return on Sales (ROS) - indicator of firm's operational efficiency. Operating Income to Assets (OI/A) and Operating Income to Sales (OI/S) - how much net profit is derived from every dollar of total asset (or sales).	Ko et lal. 2011
	Lower cost ratios	Refers to ratio of Cost of Goods Sold to Sales which measures the percentage of sales used to pay for expenses. The higher the cost ratio is, the less profitable is the organization.	
	Firm performance	Sectorial excellence - the degree to which a firm is better than its competition in terms of sectorial positioning or performance.	Benitez-Amado 2011
	Economic performance	The decrease of cost for materials purchasing and energy consumption, fee for waste treatment and waste discharge, and fine for environmental accidents.	Ryoo et al. 2013

Appendix G: Interview Protocol

The interview protocol focused on four key aspects as noted in the questions below:

1. **Details regarding the facilities team member:**
    1. What is your position?
    2. Please describe your qualification/experience.
    3. How long have you been at the company?
    4. How long have you been in Facilities Management?
2. **Details regarding the building:**
    5. Please state the building purpose and size:
3. **Details regarding the BAS implementation:**
    6. What is the name of the BAS that is implemented?
    7. How long have you has it been since the system was implemented?
    8. What is involved in the system implementation -- what equipment is connected to the system for monitoring, for example: HVAC; Lighting; other?
    9. Do you use reports from the system?
    10. Please describe the BAS reports, for example, how often they are used and what they are used for.
4. **Details regarding the BAS outcomes:**
    11. Please describe some key outcomes of the system use. Are there:
        i. Environmental outcomes?
        ii. Economic outcomes?
        iii. Other outcomes