ORGANIZATIONAL DYNAMICS LEADING TO THE IMPLEMENTATION OF SUSTAINABLE DESIGN IN BUILDING CONSTRUCTION

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Title

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

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ABSTRACT

This study focused on construction project organizational dynamics, leading to implementation of sustainable construction. Data were derived from a questionnaire responded by construction industry practitioners. Results identified the need for promoting sustainable construction by cost and value benefits to the industry rather than environmental and social benefits. This approach promotes the interest of people who will not be conceived by the environmental reasoning behind sustainable building. Also the factors that ranked relatively low were those that do not provide considerable benefits to the organization during the construction phase. Higher initial investment, and uncertainties of the time to recover it appear to be barriers to implementation of sustainable construction, although construction professionals were of the opinion that lower life-cycle cost and increased building value could easily repay it. The results of this study would benefit future construction-project participants who encounter organizational challenges in implementing sustainable designs in their project.

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DEDICATION

To my parents for their faith, support and encouragement towards my education.

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LIST OF ABBREVIATIONS AND SYMBOLS

μ .... Population Mean

$\overline{X}$ .... Sample Mean

σ^2 .... Sample Variance

AGC .... Associated General Contractors of America

BREEAM .... Building Research Establishment Environmental Assessment Methods

BRI .... Building Related Illness

CEO .... Chief Executive Officer

CI .... Confidence Interval

CLT .... Central Limit Theorem

CNBR .... Cooperative Network of Building Researchers

ENR .... Engineering News Record

GDP .... Gross Domestic Product

H_0 .... Null Hypothesis

H_a .... Alternate Hypothesis

HVAC .... Heating Ventilating and Air Conditioning i .... Response Category index

IBM .... International Business Machines Corporation

iid .... Identically distributed and independent

iiSBE .... International Initiative for Sustainable Built Environment

LEED .... Leadership in Energy and Environmental Design

n .... Number of Respondents

N .... Total Number of Respondents

NSF .... National Science Foundation

RII .... Relative Importance Index

SBS .... Sick Building Syndrome

USA .... United States of America

USGBC .... United States Green Building Council

W_i .... Weight Assigned to the i^{th} Response

X .... Number of Respondents for the i^{th} Response

X .... The Ranks

Z .... Score

Z_{obs} .... Score observed

CHAPTER 1. INTRODUCTION TO THE STUDY

1.1. Significance of the Study

The construction industry is one of the main contributors to the depletion of natural resources and a major cause of negative environmental side effects such as air and water pollution, solid waste, deforestation, and global warming. Globally, the awareness of environmental impacts is growing, and many movements seeking to address sustainability concerns are gaining momentum.

The world today faces many complex problems, such as inefficient energy consumption and a greater reliance on foreign oil, a loss of open space and habitat, inequitable distribution of economic resources, and the loss of a sense of community. These combined pressures, along with the challenges faced specifically by stakeholders of the built environment, have led to a growing awareness about the need for change. Sustainability as a possible strategy is beginning to permeate the construction industry as a response to this need for change.

> Achieving sustainable development is perhaps one of the most difficult and one of the most pressing goals we face. It requires on the part of all of us commitment, action, partnerships and, sometimes, sacrifices of our traditional life patterns and personal interests. (Mostafa Tolba – Chairman of the commission of sustainable development, http://www.usgbc.org)

> Sustainable construction techniques provide an ethical and practical response to issues of environmental impact and resource consumption. Sustainability assumptions encompass the entire life cycle of the building and its constituent components, from resource extraction through disposal at the end of material's useful life. Conditions and processes in factories are considered, along with the actual performance of their manufactured products in completed buildings. . . . green building design relies on renewable resources for energy systems; recycling and reuse of water and materials; integration of native and adapted species for landscaping; passive heating, cooling, and

ventilation; and other approaches that minimize environmental impact and resource consumption. (Kibert, 2007, pp. 5-6)

The concepts of sustainability, efficiency and green building are becoming issues that have gained greater emphasis as international concern over global warming and climate change that have grown in volume. Al Gore's *An Inconvenient Truth* revealed startling statistics about the state of the earth - eight of the hottest years ever recorded have occurred in the last 10 years and 90% of world's glaciers are in recession. Considering that globally, an estimated 60% of all materials go into the construction industry (60% of global timber products and 90% of hardwoods end up in building construction) and 60% of the world's energy is used to heat, light and ventilate buildings, it has been argued that focus should turn away from the automotive and aerospace industries as the main contributors to global warming, towards man's approach to construction and buildings, and where possible sustainable development should be considered on all projects (Sell, 2007, p. 6).

If sustainable building techniques are incorporated into these projects, benefits can include resource efficiency, healthy buildings and materials, ecologically and socially sensitive land use, transportation efficiency, and strengthened local economies and communities (Sell, 2007).

Construction is an essential part of any country's infrastructure and industrial development. The construction industry contributes to a major part of any country's Gross Domestic Product (GDP). If we look at the GDP and the contribution of construction to GDP from the world's biggest economy, the United States, and the two world's fastest-growing economies, India and China, we can see the importance of construction to economic development (Table 1).

Table 1.1. GDP and construction's contribution to GDP from the world's biggest economies.

Country	2008 GDP (Trillion USD)	Construction
China	4.222	16%
India	1.237	8.5%
USA	14.33	8.0%
World	69.49	6.7%

The interactions that take place in a construction-project organization in the early stages of any project serve to evaluate all possible methods to make the project cost effective, economical, functional, aesthetically appealing, etc. Certain project participants may suggest sustainability while others may be interested in standard construction. For example, sustainable construction may result in a higher initial cost. In the long run, for the operational and maintenance costs, sustainable construction proves to cost less than standard construction. Considering the technological aspect of sustainability, clients may be skeptical about the performance of these new technologies. At the same time, it may be difficult to find contractors and builders who are experts in sustainable construction. The survival of sustainable concepts by overcoming such challenges in the organizational interactions may lead to a sustainable project. Organizational dynamics that are based on such interactions play an important role in the decision-making process leading to a sustainable design or a standard design. As such, it is important to identify aspects of sustainability which influence those organizational interactions.

1.2. Objectives of the Study

The objectives of this research study are to identify

1) Significant factors that influence the decision of construction-industry personal to either implement or disregard sustainable designs in their projects.
2) Barriers to implementation of sustainable constructions.

1.3. Survey Methodology

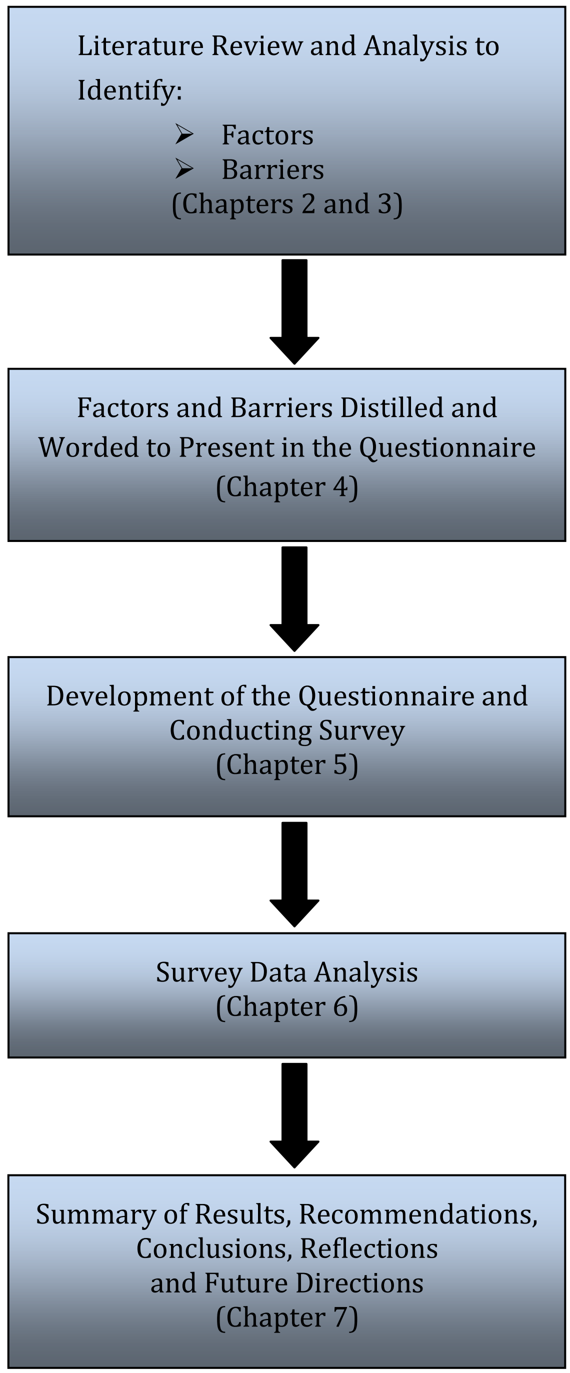


Figure 1.1. Flow chart showing the research methodology.

The data for this paper were collected from the literature and a questionnaire. A literature review was first performed; then, a well-structured survey was administered to construction professionals, followed by quantitative analysis and results. The respondents were mainly architects, engineers, contractors and builders, developers, and consultants who have a strong interest or involvement in the field of sustainable building. The procedure for this study is illustrated in Figure 1.1. It includes:

- Identifying the research study
- Reviewing the literature
- Collecting and analyzing literature data
- Identifying the factors and barriers as well as preparing the questionnaire
- Establishing the questionnaire structure
- Collecting data via the questionnaire
- Checking the data for their completeness and consistency
- Evaluating and analyzing the data
- Results and recommendations

1.4. Survey Responses

Through the questionnaire, the study collected 28 responses from construction professionals around the globe. Respondents were asked to indicate their preference level on a Likert scale that ranged from 1 to 4. These respondents represented the construction information of 28 different construction projects. Refer to Chapter 5 for details.

1.5. Analysis of Data

The data were analyzed in two different ways intended to get two different results:

- One was to find whether the factors discussed in the questionnaire are significant enough to influence the thought process of construction professionals to adopt sustainable design for a project.
- The other was to rank the factors according to their significance.

The approach used to prove the significance of factors was the Central Limit Theorem, and the Relative Importance Index (RII) was used to perform statistical analysis that ranked the factors according to their significance. See Chapter 6 for details.

CHAPTER 2. SUSTAINABLE BUILDINGS: FROM A STRATEGIC PRESPECTIVE

From a business perspective, can green buildings affect high-level organizational outcomes, such as profitability, customer satisfaction, and innovation? According to the U.S Green Building Council (USGBC), many of its members believe sustainable building design will become a more common practice once the human benefits are identified. Primarily, the productivity gain as an important business perspective is believed to be associated with high-quality environments. A broader perspective that links building design, organizational performance, and human factors helps in understanding the organizational benefits of green buildings (Heerwagen, 2000). Recent research on the biophysical foundations of organizations also suggests that a better understanding of business-society-nature links could provide beneficial insights about sustainable buildings and business strategy (Gladwin et al, 1995).

Improvement in strategic organizational performance through building design is a topic of growing interest among designers and building owners. A number of case studies about companies that have consciously used building design to foster strategic goals, such as increased productivity, reduced operating expenses, and improved corporate image. Many of these companies also cite building design as a factor in their concerns about attracting and retaining high-quality workers. Although the results presented in these case studies are intriguing, the studies have been conducted in-house without external scientific review or application of quality-assurance methodologies for data collection and analysis

(Heerwagen, 2000). From the vast literature search done on sustainable constructions, the author interpreted that the areas of strategic performance and human resources are clearly in need of scientific inquiry if the results are to be taken seriously in the business world. This understanding of the need for scientific inquiry triggered some questions in the mind of author to rationalize the strategic benefits of sustainable constructions. These questions later helped with the development of the questionnaire used for this research study. The questions asked by the author to reason the strategic and human-resource benefits of sustainable construction were as follows:

1) Is sustainable construction preferred over conventional construction?
2) Does sustainable building projects tend to generate very positive publicity?
3) Does government takes any initiative to promote sustainable constructions?
4) To what extent is the construction industry aware of sustainable construction techniques?
5) How prepared is the construction industry to accept and execute sustainable construction?
6) Is sustainable construction ideal for specific types of buildings?
7) Is adopting sustainable construction financially feasible?
8) What are the environmental benefits of sustainable construction?

The following section explains the discussion about the benefits of sustainable designs and its connection with strategic performance and human-resource development.

2.1. Strategic Performance, Human Resource Development, and Sustainable Design

The past decade marks a shift from thinking about facilities as a way to house the workforce to thinking about the entire building portfolio of a company in strategic terms (Horgen et al., 1999). In part, the above mentioned shift in thinking is due to the re-engineering and downsizing of the past decade; but more importantly, CEOs are beginning to think of their buildings as a way to achieve strategic corporate goals (Heerwagen, 2000). Although the theory and research in this area has not specifically addressed sustainable design, there is reason to believe that sustainability may become a strategic asset in the future (Hart, 1995; Johnson, 1996; Weinberg, 1998; Magretta, 1997; Russo and Fouts, 1997). Strategic performance relates sustainable design to financial outcomes, stakeholder relations, and business process improvements (Heerwagen, 2000).

On the other hand, human-resource development focuses on improved indoor environmental quality and its relationship to human-factor outcomes. The impact of strategic performance and human-resource development on sustainable design is illustrated using Figure 2.1.

2.1.1. Owner or Management Benefits

The benefits of green building design focus mainly on interior environmental quality as well as individual performance, health, comfort, and overall satisfaction. Sustainable practices have gained increasing attention in the mainstream organizational management literature, including the *Harvard Business Review* (Magretta, 1997) and the

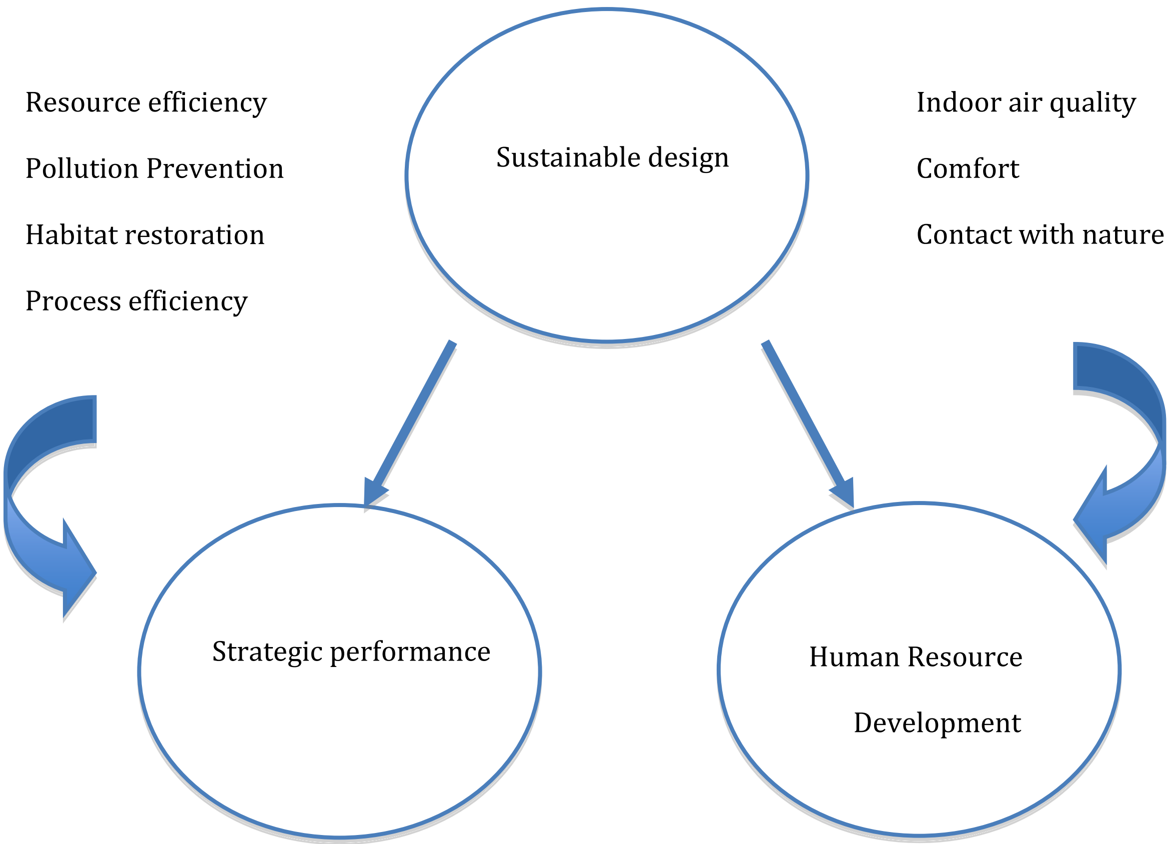


Figure 2.1. Impacts of sustainable design on strategic performance and HR development.

Source: Adapted from Heerwagen et al. (2000).

Academy of Management (Hart, 1995; Russo and Fouts, 1997). These studies provide evidence that sustainable design and operations associated with increased resource efficiency and pollution prevention can have far-reaching impacts on an organization, including:

- Increased building value (Public Technology, Inc., 1996)
- Reduced regulatory inspection load
- Enhanced community livability
- Enhanced relationships with stakeholders

- Process innovation associated with the quest for resource efficiency
- Improved ability to market to pro-environmental consumers
- Reduced operating costs

The above-identified impacts provided the input for a section, “Owner Related Factors,” in the survey. Refer to Figure 2.2.

In terms of benefits for sustainable buildings, strategic performance and human-resource development is divided into four different sections (Heerwagen, 2000). The need for this subdivision is to categorize various factors which are identified as benefits of sustainable design. Even though these sections are subdivided under strategic performance and human-resource development, they are interconnected with each other. This interconnection is illustrated using Figure 2.2. This division of sections was useful in developing the questionnaire for this research study. The four sections to which strategic performance and human-resource development were divided are as follows:

1) Owner or Management benefits
2) Construction Organization/Owner benefits
3) Performance, Efficiency, and Environmental Benefits
4) Financial Benefits

The following sections elaborate the above-mentioned benefits.

2.1.2. Construction Organizational or Contractor Benefits

From a contractor’s perspective, market growth of green buildings is likely to be a critical factor in the strategic performance of a contractor’s organization. According to Sink (1985), there appears to be considerable agreement on the domains across which success is measured. In order to understand the potential connection between sustainable buildings and organizational success, it is important to consider what constitutes high performance at organizational levels. Decisions made inside a contractor's organization about whether to offer sustainable design to clients plays an important role in the organization's success in the context of the increasing popularity of sustainable buildings. From the contractor's perspective, the concept of "success" for adopting and offering sustainable designs includes:

- Reduced construction project duration
- Customer satisfaction
- Market differentiation (Landman, 1999)
- Regulatory advantage by being early adopters of sustainable construction (Landman, 1999)

The above-identified viewpoints provided the input for a section, "Contractor Related Factors," in the survey. See Figure 2.2.

2.1.3. Environmental, Performance, and Efficiency Benefits

Proponents of sustainable design argue that green technologies and design strategies will reduce environmental risks and enhance interior environmental quality, thus being more conducive to human health and productivity than buildings that use standard practices (Browning and Romm, 1995). Common green-building benefits likely to influence the decisions of construction professional to adopt a sustainable design include:

- Reduced use of resources, especially water and energy (Heerwagen, 2000)

- Habitat restoration and the use of native plantings in landscape design (Heerwagen 2000)
- Integration of the natural environment with the building environment (Heerwagen 2000)
- Decrease the environmental burden of the project (Public Technology, Inc., 1996)
- Lower site-clearing costs

Discussions with managers and members of the design team for a new green building in Holland, Michigan, also suggest that sustainable technology transfer and learning may be a hidden benefit of sustainable design and construction, especially when techniques and technologies are new. If these benefits are accrued at the local level, then the transfer of skills to other building projects can benefit the community as a whole (Heerwagen, 2000). Some of the performance benefits associated with sustainable technology include:

- Capacity for innovation
- Quality of work life (including employee work attitudes and job satisfaction)
- Operational efficiency

Apart from technology-transfer benefits, some other performance benefits of sustainable construction include:

- Product quality
- Employee retention
- Social responsibility

The above-identified benefits provided the input for two sections, “Owner Related Factors", "Environment, Efficiency Related Factors,” in the questionnaire. Refer to Figure 2.2.

2.1.4. Financial Benefits

Heerwagen (2000, p. 4) states:

> When it comes to facility decisions, costs are almost always the predominant consideration. This is due primarily to the ease of documenting cost reductions compared with the difficulty of documenting benefits and value. Furthermore, productivity benefits or other organizational outcomes may not be immediately apparent, whereas the cost reductions are.

This presents a dilemma for decision-makers who have one ear focused on shareholders and the other on their internal operations. They want to use facilities to enhance organizational effectiveness and productivity, but often do not want to make investments in the kinds of changes needed until they have proof that the investments will payoff. The success of sustainable design to be adopted for a project during the decision-making process depends on various cost factors, such as:

- Ease of obtaining finance options for sustainable constructions
- Lower site-clearing costs
- Future cost benefits
- Reduced liability and insurance costs associated with reduced health risks for building occupants
- Lower life-cycle cost

Some of the above-identified factors provided the inputs for a section, “Cost Related Factors,” on the survey. See Figure 2.2.

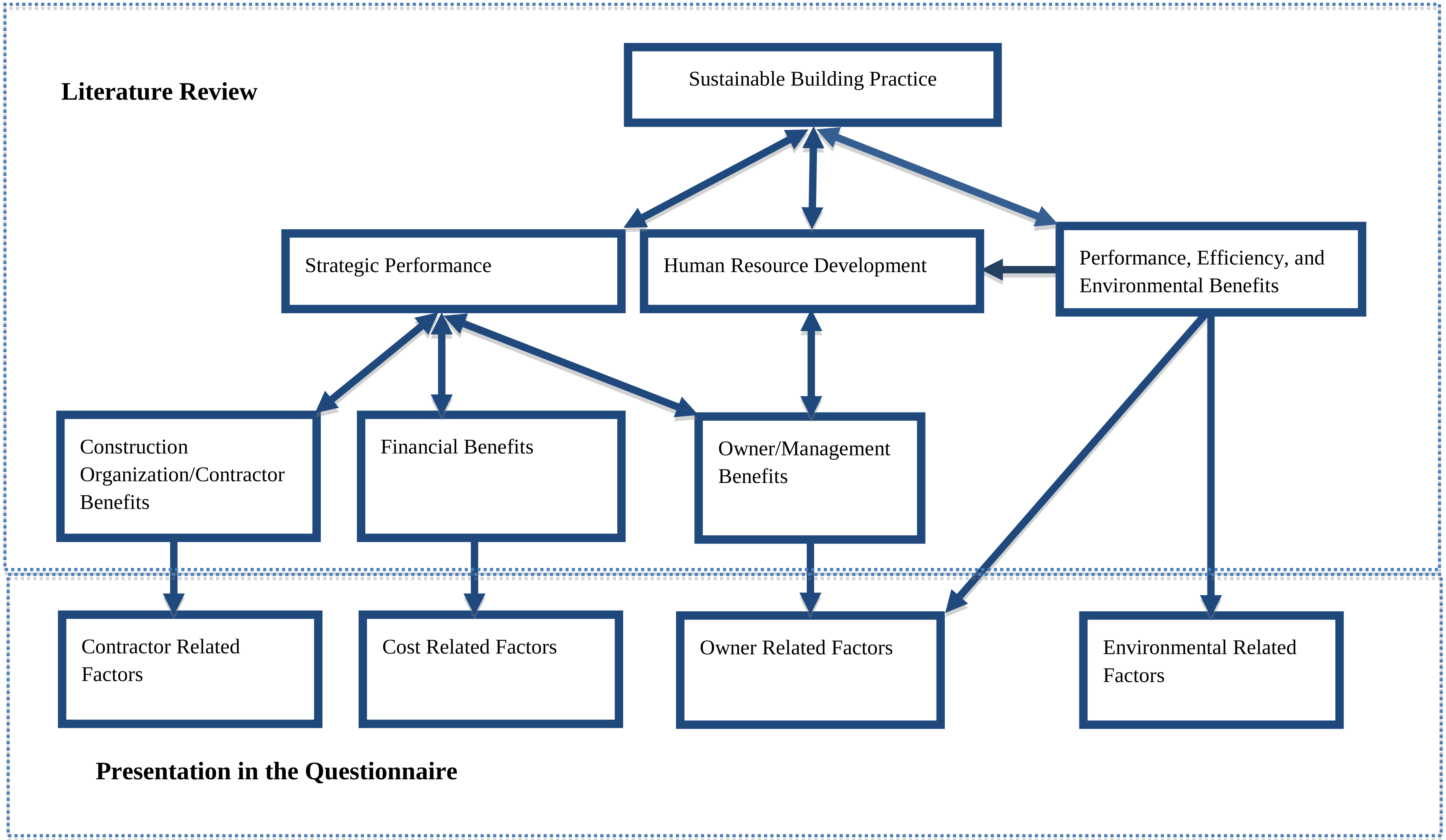


Figure 2.2. Literature review and questionnaire section tree diagram.

All the benefits mentioned in Sections 2.1.1, 2.1.2, 2.1.3, and 2.1.4 clearly show both the strategic and human-resource development benefits of sustainable construction. No wonder CEOs are beginning to think of their buildings as a way to achieve strategic corporate goals.

2.2. The Structure of the Questionnaire

There are many relevant benefits of sustainable construction identified in Section 2.1. All of the above-mentioned sections (2.1.1, 2.1.2, 2.1.3, and 2.1.4) were categorized as four sections on the questionnaire (see Appendix A and refer to Chapter 4 for details). These identified factors are discussed in detail in Chapter 4. Apart from the above four sections, a fifth section addresses the barriers of sustainable construction (see Appendix A and refer to Chapters 3 and 4 for details).

CHAPTER 3. BARRIERS TO IMPLEMENTATION OF SUSTAINABLE CONSTRUCTIONS

Over the past decade, in particular, sustainable development has become an important aspect of the real-estate and construction industries. There are many ways in which sustainability issues can be incorporated into the design, construction, operation, and deconstruction of buildings. Importantly, sustainability represents an important link between society and built-environment professionals (Wilkinson and Reed, 2007). Sustainability has far-reaching facility decisions, positive impacts on the built environment. It is of common knowledge that such positive impacts would only be possible if sustainability can overcome certain barriers described in this chapter.

With reference to real estate and the built environment, most of the discussion about sustainability is focused upon advances in sustainable technology. Regardless of the efficiency levels of new technology, unless the barriers to sustainability are identified and suitably addressed, the built environment will not be as sustainable as it could be. Hence, it is necessary to identify the main barriers to sustainability.

Sustainability is the means by which we strive to achieve sustainable development. Goodland (1995) argued that sustainability had three interconnected dimensions: environmental, social, and economic. There is a well-known concept shared by Elkington (1994) who named it the “triple bottom line” as illustrated in Figure 3.1.

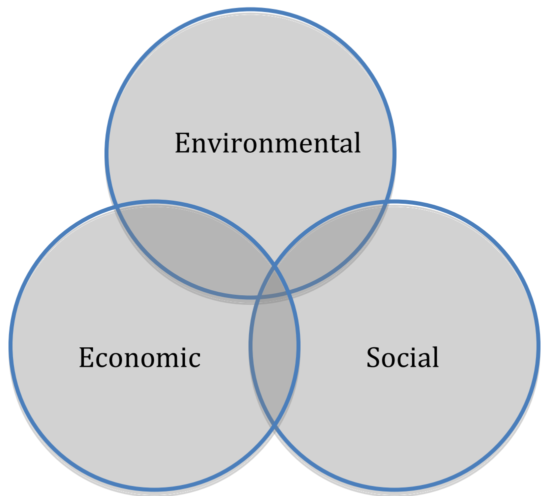


Figure 3.1. Triple bottom line concept (based on Wilkinson and Reed, 2007).

The "triple bottom line" approach seeks to rationalize development that promotes economic growth, but maintains social inclusion and minimizes environmental impact. (Wilkinson and Reed, 2007) developed alternative models of sustainable development based on the "triple bottom line" approach in the "Three Pillars" model. In this model, sustainability is viewed as the assimilation of economic activity, social well-being, and environmental integrity.

3.1. Key Barriers of Sustainability Identified Through Environmental, Social, and Economic Dimensions of the Built Environment

Due to the constant state of change in a built environment, there are almost an infinite number of barriers to identify and address. Because the starting point is the accepted "triple bottom line" approach based on social, environmental, and economic factors, consideration is given to these three main groups of barriers that align with the "triple bottom line": social barriers, environmental barriers, and economic barriers. These barriers are discussed below.

3.1.1. Social Barriers

Social barriers are sometimes referred to as 'behavioral barriers' because they are comprised of attitudes and beliefs which then act as barriers to action. (Wilkinson and Reed, 2007) state that, for many professionals involved in the built environment, if an analysis goes beyond their education and knowledge base to decide on a sustainability issue, the most common answer would be lament that "we don't know enough." This lack of knowledge puts the construction practitioners in great uncertainty. It can be argued that stating the lack of knowledge or lack of information is a weak excuse for inaction and is a major barrier for sustainability (Wilkinson and Reed, 2007).

Building projects cannot be done along sustainable lines without the owner's or developer's full support for sustainable concepts. A 1996 survey that the *Environmental Building News* did of its subscribers turned up to be a proving result for the above statement; those respondents cited client resistance as one of the major impediments to sustainable practice.

Similarly, another important social barrier is how the media present and cover the advantages of sustainability. Mass media is a powerful medium which can send messages to the public about the environmental impacts, such as climate change and global warming as well as a need for sustainable development. Considerable media support for sustainable development helps to increase public support for sustainability.

Within an organization, the presence of leaders who motivate and empower others can bring about changes in terms of adopting the idea of sustainability. If no such leaders exist within an organization, the change will be slow.

Also, the acceptance of sustainability brings with it, to a great extent, the reality of conflicting interests. According to (Wilkinson and Reed, 2007), the benefits of a sustainable community to be gained in the long run are not likely to compensate most people for the prospective loss of a job or an election in the short term. Hence, it is necessary to maintain a balance between time horizons and conflicting interests.

In summary, social barriers to sustainable property development can be summarized as follows:

- Lack of expressed interest from owners/developers
- Lack of technical understanding on the part of contractors/subcontractors
- Lack of technical understanding on the part of designers, engineers, and other team members (Landman, 1999).
- Lack of training in sustainable construction (Landman, 1999).
- Perceived lack of empowerment (Wilkinson and Reed, 2007)
- Lack of public support
- Time horizons and conflicting interests (Wilkinson and Reed, 2007)

3.1.2. Economic Barriers

Economic barriers to sustainable development are powerful and include financial gain motives. There is much skepticism, especially among investors about how to value sustainability for property. For many years, green or sustainable economists have argued that there is a lack of widely available and understood cost-comparison data, especially from a full-cost accounting perspective (Pearce et al, 1989). The Pearce Report was a concise and persuasive statement about the key contributions that economics could make to reform environmental policy, advocating policy on the criteria of "sustainability," valuing environmental effects, and making use of market incentives (Wilkinson and Reed, 2007).

Economic barriers to sustainable property development can be summarized as follows:

- Financial gain motive (Wilkinson and Reed, 2007).
- Higher initial investment
- Long-term recovery of initial investment not reflected on the project (Landman, 1999)

3.1.3. Environmental Barriers

Like the social and economic barriers, there are environmental barriers. Over time, various programs and policies have been introduced with the aim of reducing resource consumption. While producing indirect benefits such as environmental and habitat restoration, the construction industry still identifies certain factors as environmental barriers to sustainable construction.

Environment barriers to sustainable property development are as follows:

- Lack of a clear demonstration about the advantages of introducing environmental measures (Wilkinson and Reed, 2007)
- Failure to identify lead agencies and coordinate policies appropriately (Wilkinson and Reed, 2007)

- Lack of availability of green building materials locally (Landman, 1999).
- Insurance and liability problems due to the use of non-standard materials for construction (Landman, 1999).

The above-mentioned items were the key barriers to implementing sustainable construction. These barriers were distilled to avoid overlap and were included on the questionnaire in the “Barriers to Sustainable Construction” section. These barriers and their importance are discussed in detail in Chapter 4.

CHAPTER 4. DISCUSSION OF INFLUENCING FACTORS AND BARRIERS

This chapter discusses, in detail, the justification for inclusion in the questionnaire, the factors and barriers identified in Chapter 2 and 3. Table 4.1 present these factors and barriers distilled to avoid duplication and reworded to be clearly presented in the questionnaire to construction practitioners who had been involved in decision making on adoption of sustainable construction. The identification of these factors and barriers were mainly based on the literature in the field of study (listed in Table 4.1), while six of them were derived by judgment based on careful examination of findings from the literature review to identify to additional factors and barriers that should be included in the questionnaire.

Factors that influence the decision-making process for the successful implementation of sustainable construction (refer to Chapter 2 for details) were categorized under four sections as given below. The first two sections refer to the perspectives of the two major stakeholders. Third and fourth refer to major areas of interest that concerns the implementation of sustainable design. Apart from these four sessions, a fifth section addresses the barriers to sustainable construction (refer to Chapter 3 for details). The first column of Table 4.1 which represents the structure of the questionnaire is based on this categorization.

1) Owner-related factors
2) Contractor-related factors

3) Energy efficiency, resources, and environment-related factors

4) Cost-related factors

5) Barriers to implantation of sustainable construction

Table 4.1. Influencing factors and barriers tabulated according to their category.

Category	Influencing Factors	References
Owner/Developer related factors	Increased building value	Public Technology, Inc., 1996
	Availability of a design team with sustainable design skills	(Judgment based on literature)
	Process innovation associated with the quest for resource efficiency	Roodman and Lenssen, 1995
	Higher quality of work life (including employee work attitudes and satisfaction)	Browning and Romm, 1995
	Higher operational efficiency, creativity, and productivity by the employees	Public Technology, Inc., 1996
	Increases the compliance of the project design standards with the environmental regulations of building-control authorities.	(Judgment based on literature)
	Social responsibility	Landman, 1999
	Enhanced community livability through improved environmental and social quality of life	Public Technology, Inc., 1996
	Enhanced relationships with stakeholders (e.g., clients, tenants, employees, partners, contractors, etc.)	Heerwagen, 2000
	Improved ability to market to pro-environmental consumers	Public Technology, Inc., 1996
Contractor-related factors	Reduce the construction project duration	(Judgment based on literature)
	Market differentiation: can broaden the market by attracting new clients.	Landman, 1999
	Regulatory advantage by being early adopters of sustainable construction	Landman, 1999
	Easy-to-find information on sustainable building practices	Lockwood, 2006
Energy Efficiency and resource-related factors	Reduced use of resources, especially water and energy	Heerwagen, 2000
	Decreased environmental burden of the project	Public Technology, Inc., 1996
	Habitat restoration and use of native plantings in landscape design	Heerwagen, 2000
	Integration of the natural environment with the building environment	Heerwagen, 2000

Table 4.1. continued …

Table 4.1. (continued)

Category	Influencing Factors	References
Cost-related factors	Ease of obtaining finance options from the bank for sustainable projects	Public Technology, Inc., 1996
	Lower site-clearing costs	(Judgment based on literature)
	Future cost benefits	Landman, 1999
	Reduced liability and insurance costs associated with reduced health risks for the building occupants	Heerwagen, 2000
	Lower life-cycle cost	Public Technology, Inc., 1996
Barriers	Lack of expressed interest from developers/owners	Hittinger, 1999
	Lack of technical understanding on the part of contractors and subcontractors	Landman, 1999
	Lack of technical understanding on the part of designers/engineers and other project team members	Landman, 1999
	Lack of training and education in sustainable construction	Landman, 1999
	Insurance and liability problems due to the use of non-standard materials for construction	(Judgment based on literature)
	Lack of availability of green building materials locally	(Judgment based on literature)
	Higher initial investment	Wilkinson and Reed, 2007
	Long-term recovery of initial investment not reflected	Landman, 1999

The following sections describe each item presented in Table 4.1 and explain why it is important. These factors were presented in the questionnaire under the given headings.

4.1. Owner-Related Factors

4.1.1. Increased Building Value

Green buildings' high efficiency and performance can result in higher property values and potentially lower lenders' credit risk. Lower operating costs associated with more efficient systems can lead to higher net income for a building. In addition to increasing a building's net operating income or value, green building measures may allow building owners to charge higher rents or achieve higher rates of building occupancy if tenants view green properties as more desirable. Currently, voluntary rating programs are under development for commercial buildings in the United States. As these programs are introduced into the marketplace and gain the acceptance of building owners and tenants, they could impact the value of properties. Prospective tenants will be able to rate buildings based on such measurable features as natural daylight; better indoor air quality; and lower energy, water, and waste costs. If enough buildings are rated for environmental performance, those that perform better will start to realize market advantages (Public Technology, Inc., 1996).

4.1.2. Availability of a Design Team with Sustainable Design Skills

The availability of a design firm that is knowledgeable in environmental design guidelines is an important component of green building development. This factor is important for the activities of the design team from the pre-design stage to all subsequent stages of the project. Various aspects of sustainable design, such as energy efficiency and renewable energy, direct and indirect environmental impact, indoor environmental quality, resource conservation and recycling, and community issues along with other activities that occur in the pre-design phase, including programming, budget analysis, and site selection, set the stage for successful construction of a green building (Public Technology, Inc., 1996). Thus, the availability of a design firm with sustainable design skills is an important factor that leads towards the decision for the implementation of sustainable design for a project.

4.1.3. Process Innovation Associated with the Quest for Resource Efficiency

Building construction consumes 40% of the raw stone, gravel, and sand used globally each year; 55% of the wood cut for non-fuel uses is for construction. Buildings also account for 40% of the energy and 16% of the water used annually worldwide. In the United States, about as much construction and demolition waste is produced as municipal garbage while 30% of newly built or renovated buildings suffer from sick building syndrome, exposing occupants to stale or mold- and chemical-laden air (Roodman and Lenssen, 1995). As severe as these problems are, combinations of ancient techniques and available technologies can eliminate almost all the damage new buildings do--making buildings healthy and reducing utility bills dramatically while still preserving the amenities people expect. This quest for resource efficiency leads to process innovation like sustainability concepts in organizations.

4.1.4. Higher Quality of Work Life

Proponents of sustainable design argue that green technologies and design strategies will enhance interior environmental quality and, thus, be more conducive to human health and productivity than buildings that use standard practices (Browning and Romm, 1995). Sustainable concepts give greater attention to construction, maintenance, and operation of buildings to reduce the buildup of microbial agents, especially in HVAC systems and construction materials. The benefits of green building design that focus on interior environmental quality and individual performance, health, comfort, and overall satisfaction of the employees are critical components for improving the operational efficiency the organization (Heerwagen, 2000).

4.1.5. Higher Operational Efficiency

An organization's most significant financial commitment is usually to its employees. Many employers spend at least as much on salary-related expenditures as they do constructing an entire company building. In many organizations, salaries and associated benefits consume the majority of the annual operating budget. The purpose of a building is not only to provide shelter for its occupants, but also to provide an environment conducive to the high performance of all intended occupant activities. Recent studies have shown that buildings with good overall environmental quality, including effective ventilation, natural or proper levels of lighting, indoor air quality, and good acoustics, can increase worker productivity by 6-16% (Public Technology, Inc., 1996, p.15).

4.1.6. Increases the Compliance of the Project Design Standards with the Environmental Regulations of Building Control Authorities

Although the provision of buildings and the built environment is essential to our quality of life and to local and national economies, there is a high price to be paid in terms of environmental lkldamage and the use of large resource quantities. The construction industry should clearly address these issues as well as the established and emerging sustainable construction techniques used to minimize the environmental impact of the sector. Various government authorities worldwide have adopted different methods (legislation, control, design and specification, and management) to protect the environment from the impact of construction and the built environment. These authorities have developed various environmental and green legislations for construction. Adopting a sustainable design increases the compliance of a project with such legislation and standards.

4.1.7. Social Responsibility

Sustainable building has a number of social benefits, such as air- and water-quality protection, soil protection and flood prevention, soil waste reduction, and natural resource conservation. People benefit from environmental improvements not only for health and aesthetic reasons, but also as taxpayers. For example, reducing water, energy, and material use and setting buildings close to public transportation decrease the demand for costly expansions of infrastructure, such as water treatment plants, utilities, landfills, and roads. The owners and developers are the people who have a major role in the decision-making process of a project. Considering all the social benefits of sustainable construction, it becomes the responsibility of owners and developers to implement sustainable construction techniques in their projects (Landman, 1999).

4.1.8. Enhanced Community Livability

Keeping a building site in harmony with its surroundings is vital not only to our environment, but also to our sense of community. Promotion and implementation of green-building practices within a community can generate new economic-development opportunities. These opportunities can take a variety of forms, including new business development to meet the demand for green products and services, resource efficiency improvement programs that enable existing businesses to lower operating costs, development of environmentally oriented business districts, and job training related to new green businesses and products (Public Technology, Inc., 1996).

4.1.9. Enhanced Relationships with Stakeholders

Studies provide evidence that sustainable design and operations associated with increased resource efficiency and pollution prevention can have far-reaching impact on an organization to enhance the relationship with the stakeholders (Heerwagen, 2000). Renovation and construction projects, and maintenance programs are necessary to improve the nation's building stock. These efforts depend on reliable sources for quality building products. Limitations on the availability of some building-material resources are beginning to occur. For some products, prices are rising faster than inflation as the availability of raw materials starts to decline. Products selected for construction not only consume resources and energy, but also produce air and water pollution as well as solid waste during their manufacture. Once installed, they may require maintenance or periodic replacement. When a building is demolished, the products and materials usually are disposed in landfills. Therefore, building materials that minimize the use of natural resources and are durable or reusable contribute to sustainable building practices (Public Technology, Inc., 1996). Thus, the sustainable building practices which are resource efficient and environment friendly improve the quality of life for the occupants, the employees, and the shareholders. Apart from the above benefits, sustainable construction also provides monitory benefits for the project.

4.1.10. Improved Ability to Market to Pro-Environmental Consumers

Green-building programs can be a first step to helping local stakeholders—policymakers, businesses, citizens, financiers, homeowners, and building owners—understand the economic and environmental wisdom of adopting sustainable principles for their communities. Many successful green-building initiatives are being developed and implemented at the local level across the United States (Public Technology, Inc., 1996). The environment friendly characteristics of the sustainable buildings make it easier for developers and owners to market their property.

4.2. Contractor-Related Factors

4.2.1. Reduces Construction Project Duration

Collaborative working should be a core requirement for each element of every project. Putting it into practice through team working and partnering requires a real commitment from all parties involved, but it brings benefits that far outweigh the effort involved. Thus, higher operational efficiency is always an important factor for any project. This higher operational efficiency can be achieved mainly through higher employee satisfaction, a higher quality of work life, and higher operational efficiency. Sustainable construction, which often does not require complicated design and resources, reduces the work stress of the project team. The above mentioned benefits in turn, improves the quality of work life, leading to higher employee satisfaction for the project team. This will increase the operational efficiency of the project team which, in turn, will reduce the construction project’s duration.

4.2.2. Market Differentiation

Developers as well as design or construction firms have the opportunity to broaden their market by attracting new clients who want to hire firms with demonstrated experience in sustainable building. This marketing technique creates positive publicity for the project (Landman, 1999).

4.2.3. Regulatory Advantage by Being Early Adopters of Sustainable Construction

By being early adopters, building professionals can stay ahead of the game; by making gradual, voluntary changes, they will be prepared for some new regulations and will not suffer the burden of having to adapt suddenly. Their leadership may also serve to prevent some new regulations. Proactive professionals commonly point out that meeting current codes simply means that, if the building were built any worse, it would be illegal (Landman, 1999).

4.2.4. Ease of Finding Information on Sustainable Building Practices

Before 2000, companies generally regarded green buildings as interesting experiments but unfeasible projects in the real business world. Since then, several factors have caused a major shift in thinking. Several government-initiated energy and environment design rating programs, such as LEED (Leadership in Energy and Environmental Design) by the U.S Green Building Council in Washington, DC; building research establishments environment assessment methods (BREEAM) by the United Kingdom; Australia’s green star; and many other countries and programs, were created.

These programs provided enough information for the people who were interested in green-building techniques (Lockwood, 2006).

4.3. Energy Efficiency, Resources and Environmental Factors

4.3.1. Reduced Use of Resources, Especially Water and Energy

As the world's population continues to expand, the implementation of resource-efficient measures in all areas of human activity is imperative. The built environment is one clear example for the impact of human activity on resources. Buildings have a significant impact on the environment, accounting for one-sixth of the world's freshwater withdrawals, one-quarter of its wood harvest, and two-fifths of its material and energy flows. Approximately 50 % of the energy use in buildings is devoted to producing an artificial indoor climate through heating, cooling, ventilation, and lighting. Estimates indicate that climate-sensitive design using available technologies could cut heating and cooling energy consumption by 60 % as well as lighting energy requirements by at least 50 % in U.S. buildings Water conservation and efficiency programs have begun to lead to substantial decreases in the use of water within buildings. Water-efficient appliances and fixtures, behavioral changes, and changes in irrigation methods can reduce consumption by up to 30 % or more (Public Technology, Inc., 1996).

4.3.2. Decrease the Environmental Burden of the Project

Sustainable development is the challenge of meeting the growing human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future life and development. Green buildings, as many know, have a less negative impact on the environment than standard buildings. Their construction minimizes site grading, saves natural resources by using alternate building materials, and recycles construction wastes rather than sending truck after truck to landfills (Public Technology, Inc., 1996).

4.3.3. Habitat Restoration and Use of Native Plantings in Landscape Design

In areas with low rainfall or seasonal droughts, up to 60 % of total seasonal water usage can be attributed to irrigation. Typical urban landscapes consist of non-native or un-adapted plant species, lawns, and a few trees. Non-native plants increase the demands for water, especially during the growing season, thereby depleting local water supplies and driving the need for larger-capacity centralized facilities that may lie dormant during periods of low water use. Native plants have become adapted to natural conditions of an area, such as seasonal drought, pest problems, and native soils. Landscape designs that emphasize native trees, vines, shrubs, and perennials also help to maintain the biological diversity of a region and to preserve the character of regional landscapes. Habitat restoration helps to provide environments for wildlife displaced by development. Constructed landscapes that mimic ecological habitat models can decrease life-cycle maintenance costs, enhance wildlife survival, and blend edges of adjoining urban and rural areas (Public Technology, Inc., 1996).

4.3.4. Integration of the Natural Environment with the Building Environment

Environmentally sound site selection and design are evolving processes that integrate local needs with the existing natural environment and pre-existing infrastructure. Designers of local government projects should be especially aware of such issues as access to the site by public transportation, the impact of development on the surrounding community, and inclusion of public amenities such as recreational green space. Local governments can encourage the reuse of existing or abandoned properties and can develop green-building strategies to promote revitalization of existing urban communities by working with state and federal agencies to revise zoning regulations and to provide financial assistance and incentives for development initiatives (Public Technology, Inc., 1996).

4.4. Cost-Related Factors

4.4.1. Ease of Obtaining Finance Options for Sustainable Construction

Just five or six years ago, the term “green building” evoked visions of tie-dyed, granola-munching denizens walking around barefoot on straw mats as wind chimes tinkled near open windows. Today, the term suggests lower overhead costs, greater employee productivity, less absenteeism, and stronger employee attraction and retention. Companies as diverse as Bank of America, Genzyme, IBM, and Toyota are constructing or have already have moved into green buildings. Green is not simply getting respect; it is rapidly becoming a necessity as corporations as well as home builders, retailers, healthcare institutions, governments, and others push green buildings into the mainstream over the next 5-10 years (Public Technology, Inc., 1996). This increasingly wide popularity of sustainable building techniques makes financial institutions and investors interested in sustainable building practices.

4.4.2. Lower Site-Clearing Costs

The application of green-building concepts can yield savings during the construction process. Because the green construction has specific requirements for site clearing and grading, it considerably minimizes the square footage areas to be cleared and disturbed while still meeting construction, design, and economic needs and requirements. By minimizing site disruption by movement of earth and installation of artificial systems, considerable savings can be made for site-clearing costs.

4.4.3. Future Cost Benefits

The decisions made during the first phase of building design and construction can significantly affect the costs and efficiencies of later phases. Viewed over a 30-year period, initial building costs account for approximately 2% of the total while operations and maintenance costs equal 6% and personnel costs equal 92%. Recent studies have shown that green-building measures taken during construction or renovation can result in significant operational savings as well as increases in employee productivity (Landman, 1999). Thus, sustainable construction provides cost benefits in the long term.

4.4.4. Reduced Liability and Insurance Costs Associated with Reduced Health Risks for Building Occupants

The past decades' conventional office design, construction, and operational practices have decreased the quality of the indoor office environment, resulting in new health concerns and associated economic costs and liability. Sick Building Syndrome (SBS) and Building Related Illness (BRI) have become more common in the workplace, increasing building owner and employer costs due to sickness, absenteeism, and increased liability claims. Legal actions related to Sick Building Syndrome and other building-related problems have increased. Incorporating sustainable construction techniques will greatly reduce the risk of environmental pollution and waste production which, in turn, will reduce the vulnerability of human beings to environmental hazards. Environmental policy is replete with difficult decisions that affect the health and well-being of present and future generations. There are always fewer risks on the health of occupants when going with green construction (Heerwagen, 2000). This reduce health risks reduces the chances of having legal actions against the organization from the occupants which, in turn, will reduce the insurance cost for the project.

4.4.5. Lower Life-Cycle Cost

A building's "life" spans its planning; its design, construction, and operation; and its ultimate reuse or demolition. Often, the entity responsible for design, construction, and initial financing of a building is different from the people o`perating the building, meeting its operational expenses, and paying employees' salaries and benefits. However, the decisions made during the first phase of building design and construction can significantly affect the costs and efficiencies of later phases. Recent studies have shown that green-building measures taken during construction or renovation can result in significant operational savings as well as increases in employee productivity. Therefore, adopting sustainable design lower the lifecycle cost of the building (Public Technology, Inc., 1996).

4.5. Barriers to Sustainable Constructions

4.5.1. Lack of Expressed Interests from Developers and Owners

This barrier is considered to be a major one for implementing sustainable concepts in construction. In a 1999 survey conducted by the Architectural Practice Research Project at the Catholic University of America, architects cited client apathy as the main reason why most projects are not being designed sustainably (Hittinger, 1999). Respondents to that survey indicated that fewer than 10% of their clients requested sustainable design even though those designers often presented their clients with sustainable designs for their projects anyway; fewer than 30% of those designs were selected by their clients and implemented. The survey shows that, even in cases where building professionals were taking the initiative to promote sustainable building, public disinterest was in the way. A similar 1996 survey that the *Environmental Building News* did of its subscribers turned up similar results; those respondents cited client resistance as one of the major impediments to sustainable practice (Environmental Building News, 1996).

4.5.2. Lack of Technical Understanding on the Part of Contractors and Subcontractors/Lack of Technical Understanding on the Part of Designers, Engineers, and Other Project Team Members/Lack of Training and Education in Sustainable Construction

Green buildings are often the result of a more integrated planning, design, and construction process than the linear development process of conventional buildings (Landman, 1999). For this reason, design/build firms tend to hold a process advantage in sustainable building. Interdisciplinary cooperation can lead to the discovery of solutions that single team members could not have discovered on their own. For example, an integrated or "whole systems" approach allows team members to see that the added expense of envelope upgrades can be more than made up by the resulting ability to downsize the chiller. Because sustainable building considerations should generally be incorporated early in the programming and design process, owners/developers and architects may have the most control over what sorts of sustainable elements are in the plans and specifications; but this knowledge will not be carried out if communication, training, or the interest is not there on the part of the construction management and crew. The idea of a "green team" is typically that all "stakeholders," including trades people (subcontractors), maintenance/custodial staff, and prospective occupants, be brought on board early on so that everyone understands, contributes to, and feels ownership over the process. Hence, proper technical knowledge about sustainable construction techniques is necessary for the designers, engineers, contractors, and subcontractors for the successful implementation of sustainability. This can be done through proper training and education. A lack of proper training and education leads to improper technical knowledge about sustainability on the part of the construction professionals which often becomes a barrier for the implementation of sustainability concepts during construction.

4.5.3. Insurance and Liability Problems Due to the Use of Non-Standard Materials for Construction

Sustainable buildings use some materials that are not standard but are environment friendly. Resource efficiency is the major criterion for sustainable designs which leads to the usage of salvaged, refurbished, or remanufactured materials Includes saving a material from disposal and renovating, repairing, restoring, or generally improving the appearance, performance, quality, functionality, or value of a product. These non-standard materials may not offer a warranty to customers. The use of non standard materials may lead the insurance companies to not be interested in sustainable buildings.

4.5.4. Lack of Availability of Green-Building Materials Locally

The availability of green-building materials locally can be a barrier for implementing sustainability. Resources and materials are the backbone of any construction. Local availability of materials plays a major role in construction. It can significantly reduce the construction cost. Sustainable building practices use materials that are mostly green in nature. These materials may not be widely used or available for construction in certain areas. The non-availability of green building materials locally may make the owners less interested in sustainable design.

4.5.5. Higher Initial Investment/Long-Term Recovery of Initial Investment Not Reflected

Cost plays an important role in construction. The developers, owners, and contractors often try to cut the project cost in every possible way. The initial investment is always important for any building construction. The most criticized issue about constructing environment friendly buildings is the price. Photo-voltaic, new appliances, and modern technologies tend to cost more. Most green buildings cost a premium of 2% more than conventional buildings. This is not a big cost difference for smaller projects, but when it comes to bigger projects, it makes a considerable difference. Some project owners may not find going green to be financially beneficial even though sustainable buildings yield 10 times as much over the entire life of the building. In most cases, the long-term recovery of initial investments is not reflected in sustainable constructions.

CHAPTER 5. CONDUCTING THE SURVEY

This research study used a structured, worldwide survey to figure the:

- Factors that affect the decision-making process of a project team to adopt sustainable design (refer to Chapters 2 and 4).
- Barriers to implementation of sustainable construction were also identified and made part of the study (refer to Chapters 3 and 4)

The scope of the study was limited to the construction of buildings, including residential, commercial, industrial, and infrastructural type buildings. Experienced construction practitioners, including owners, contractors, architects, designers, construction managers, and civil engineers, were invited to participate.

5.1. Questionnaire Design

Through the literature review and analysis, this study determined a total of 23 factors that play an important role in adopting sustainable construction. The study also identified 8 barriers of sustainable construction. All the factors were compiled into 5 categories (refer to Table 4.1 and Chapter 4). The respondents were asked to consider a project where the project participants were making decisions to implement sustainable features. In addition, specific questions regarding the project were asked:

- Project typology: The respondents were asked to mention the type of project they considered to answer the survey: whether it was a commercial, industrial, residential, or any other type of project. This information helped identify the popularity of sustainability in different sectors of society.

- Respondent: The respondents were asked to mention the position they held during the project. They were also asked whether they belonged to the client, contractor, architect, designer, or any other group. This information helped to compare the responses given by different groups who play important roles in a project's organization.
- Project duration: A question about the duration of the project was also included on the survey. The respondents were asked about the year of commencement for the project and the year of completion. This information helped to identify whether sustainable construction yielded any time benefits.
- Project cost: Project cost was another specific question. The respondents were asked about the overall cost of the project, both planned and actual. This information helped to identify whether the sustainable projects tended to produce cost overruns.

Spaces for respondent comments were added to the questionnaire to obtain any additional factors and barriers which the respondents felt were relevant. Answers to these questions were helpful in analyzing the survey results.

For all the factors, respondents were asked to indicate their preference level on a Likert scale from 1 to 4. A two-point Likert scale was not used because it becomes a yesor-no question. The author wanted to investigate opinions at a greater depth. A Likert scale with an odd number of points was not used to keep the respondents from giving a neutral response. Six or more points in the scale were not given because it was not expected that most respondents would be able to give an accurate opinion to that detail. Hence, a four-point scale was adopted, giving the respondent chances to indicate the opinion from non-significant (rank = 1) to highly significant (rank = 4). A copy of blank questionnaire is attached in Appendix A.

5.2. Survey Methodology

The scope of the study was limited to the construction of buildings, including residential, commercial, industrial, and infrastructural type buildings. Experienced construction practitioners, including owners, contractors, architects, designers, construction managers, and civil engineers, were invited to the study. The contacts and business addresses of survey participants were obtained based on various sources available, such as:

- Associated General Contractors of America (AGC)
- Cooperative Network of Building Researchers (CNBR)
- Engineering News Record (ENR)
- International Initiative for Sustainable Built Environment (iiSBE)
- Internet resources
- Personal contacts

The questionnaire was sent in late January 2010 and distributed to various construction professionals in different countries. Table 5.1 shows the detailed numbers for the survey questionnaire recipients and respondents.

Table 5.1. Numbers of request recipients and respondents for the research survey.

Description	Individual emails	CNBR	iiSBE
Requests Sent to Complete the Questionnaire on the Internet	250	2700	30
Responses received	72		
Responses used	28		

The quantitative data from the survey were subjected to analysis using statistical methods: Central Limit Theorem (CLT) and Relative Importance Index (RII). Analysis would yield

- The significance or non-significance of factors and barriers
- RII rankings of factors and barriers

5.3. Survey Responses

Analyzing the data from the surveys was one of the most significant aspects of the entire study because it involved

- Checking data for
    - Completeness
    - Consistency
- Developing a spreadsheet with numerical rankings by the respondents
- Performing calculations to find significant factors using CLT and RII

The research study collected 28 responses through the structured questionnaire from construction professionals around the globe. These responses represented the construction information of 28 different projects. Table 5.2 represents the types of projects and percentages of responses. Table 5.3 represents the kind of respondents and the percentages for each kind.

Table 5.2. Types of projects.

Type of Project	Percentage of Responses
Commercial	43%
Residential	36%
Industrial	14%
Infrastructure	7%

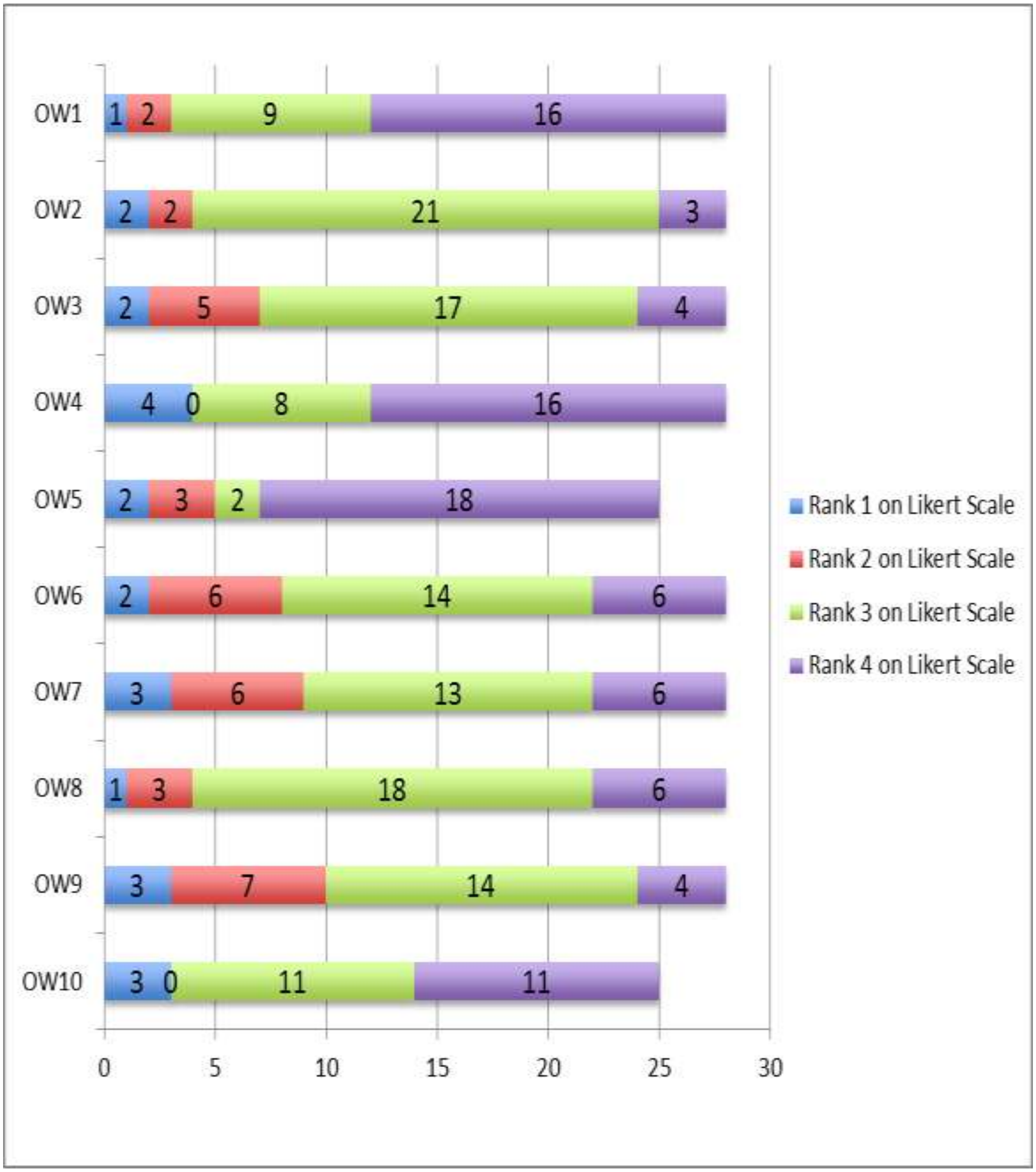
Table 5.3. Categories of respondents.

Respondents	Percentage
Client/Owner	45%
Contractor	25%
Architect	17%
Designer	13%

In their responses, according to the manner in which the questionnaire was structured, the respondents indicated opinions on the following broad categories explained below. The responses are discussed below with the aid of figures. The responses were received in the following five categories. Refer to Table 4.1.

5.3.1. Factors Influencing Owner's/Developer's Decision

The respondents were asked to rank the factors that influence the owner's or developer's decision to adopt sustainable design, as identified in Chapter 4. Figure 5.1 shows the raw data received on the four-point Likert scale. The analysis and discussion of the data are given Chapter 6.

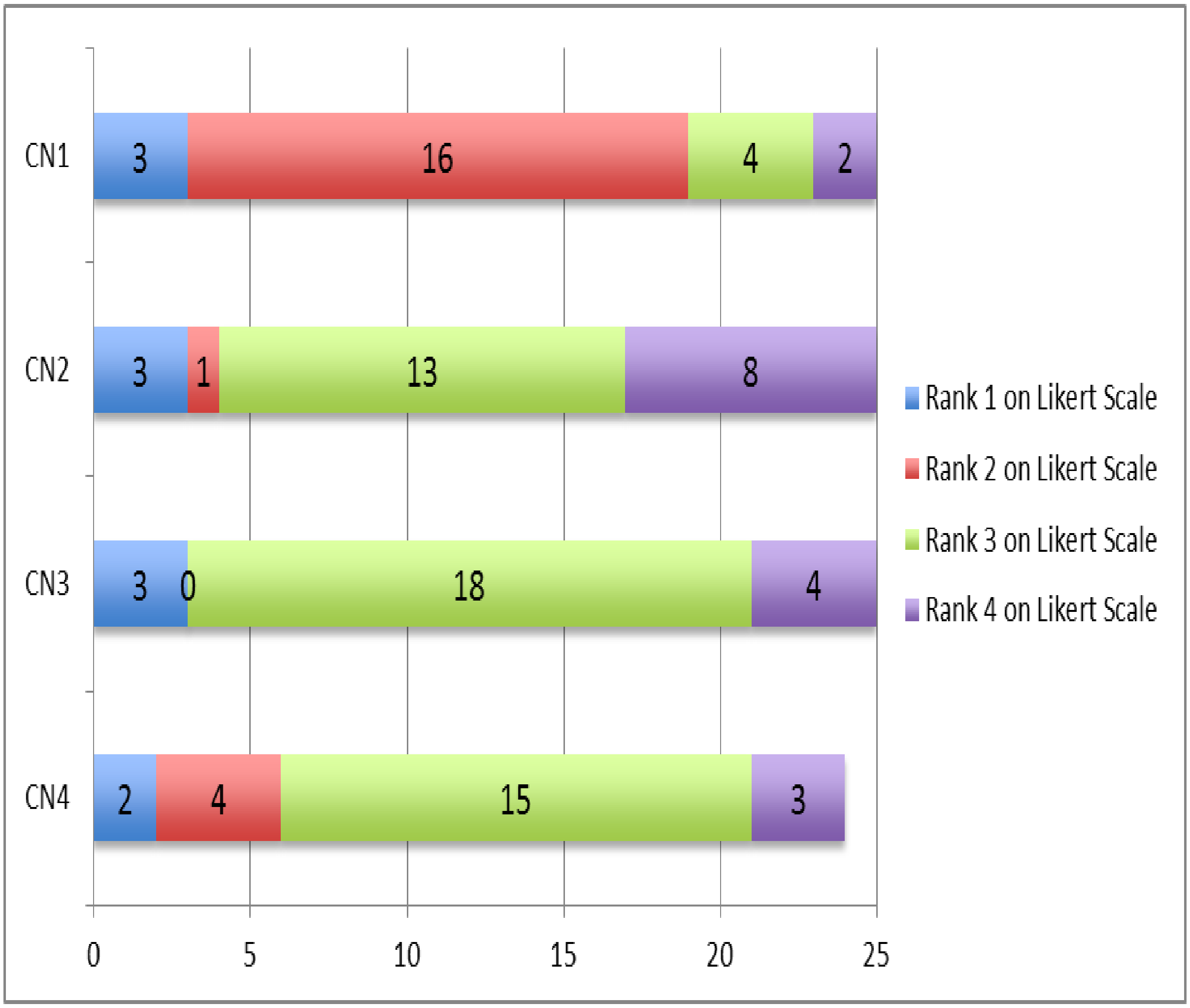


OW1	Increased building value
OW2	Availability of a design team with sustainable design skills
OW3	Process innovation associated with the quest for resource efficiency
OW4	Higher quality of work life (including employee work attitudes and satisfaction)
OW5	Higher operational efficiency, creativity, and productivity by the employees
OW6	Increased compliance of the project design standards with the environmental regulations of building-control authorities.
OW7	Social responsibility
OW8	Enhanced community livability through improved environmental and social quality of life
OW9	Enhanced relationships with stakeholders (e.g., clients, tenants, employees, partners, contractors, etc.)
OW10	Improved ability to market to pro-environmental consumers

Figure 5.1. Bar chart showing owner-related factors and the number of responses.

5.3.2. Factors Influencing Contractor's Support

The respondents were asked to rank the factors that influence the contractor's decision leading to sustainable construction, as identified in Chapter 4. Figure 5.2 shows the raw data received on the four-point Likert scale. The analysis and discussion of the data are given in Chapter 6.

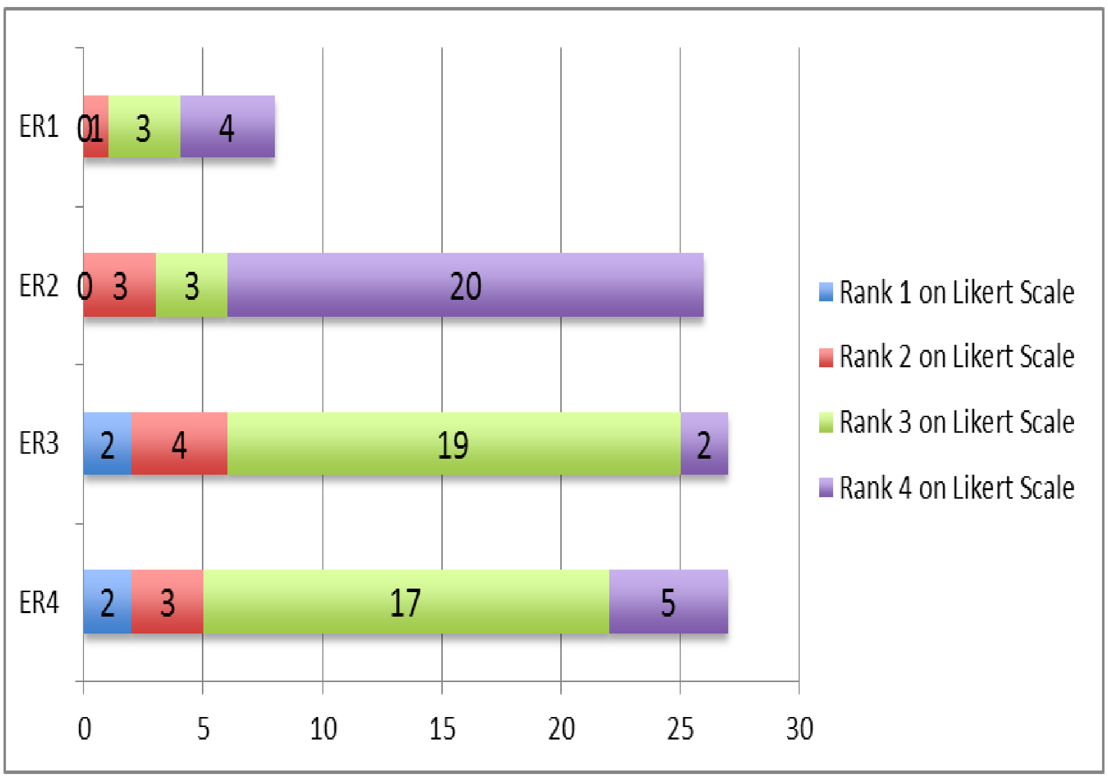


CN1	Reduce the construction project duration
CN2	Market differentiation: can broaden the market by attracting new clients
CN3	Regulatory advantage by being early adopters of sustainable construction
CN4	Easy to find information on sustainable building practices

Figure 5.2. Bar chart showing contractor-related factors and the number of responses.

5.3.3. Energy Efficiency, Resources, and Environment-Related Factors

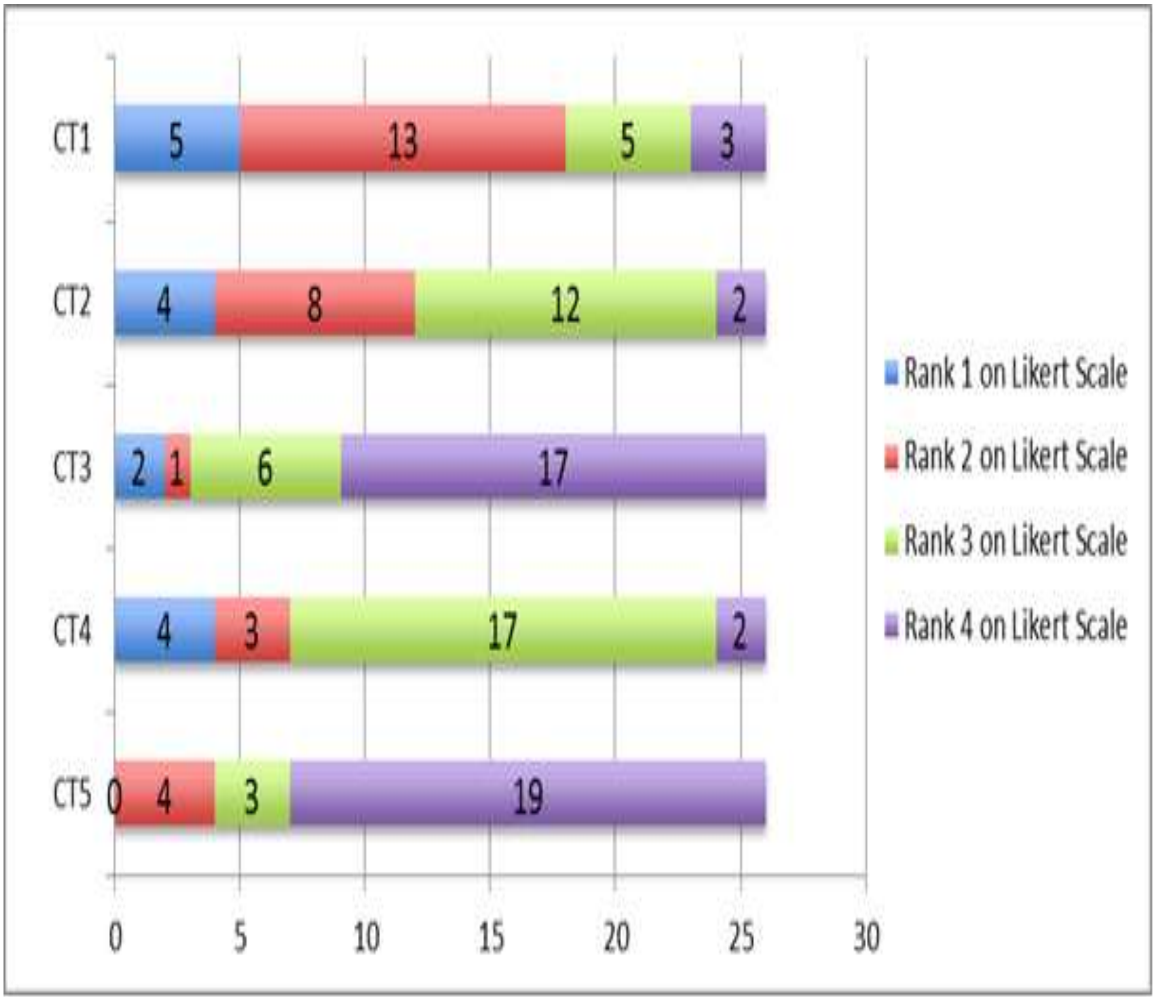
The respondents were asked to rank the factors related to energy efficiency, resources, and the environmental aspect of sustainable design influencing the construction organization in their decision making to choose a sustainable design or a conventional design. Figure 5.3 shows the raw data received on the four-point Likert scale. The analysis and discussion of the data are given in Chapter 6.



ER1	Reduced use of resources, especially water and energy
ER2	Decreased environmental burden of the project
ER3	Habitat restoration and use of native plantings in landscape design
ER4	Integration of the natural environment with the building environment

Figure 5.3. Bar chart showing contractor-related factors and the number of responses.

5.3.4. Cost-Related Factors

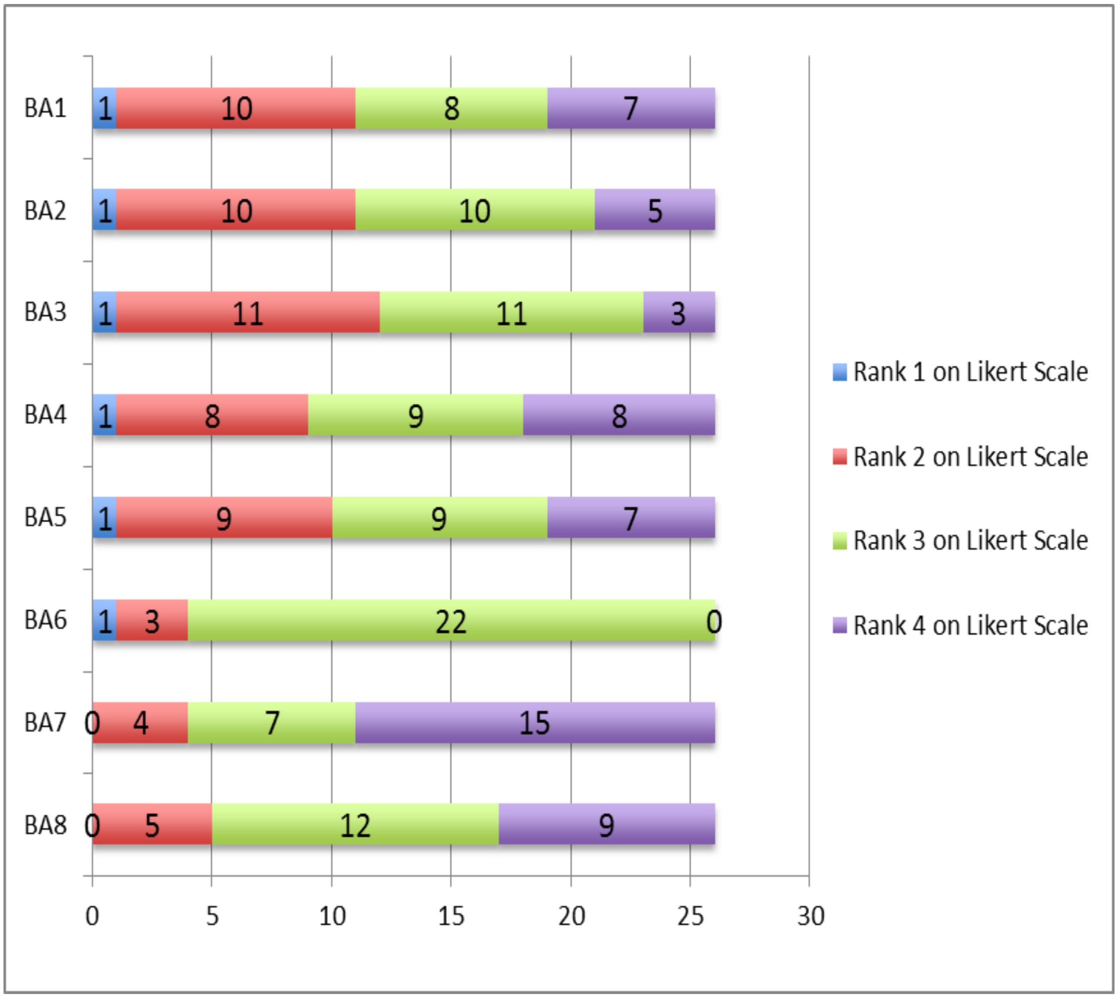


CT1 Ease of obtaining finance options from a bank for sustainable projects
CT2 Lower site-clearing costs
CT3 Future cost benefits
CT4 Reduced liability and insurance costs associated with reduced health risks for building occupants
CT5 Lower life-cycle cost

Figure 5.4. Bar chart showing the cost-related factors and the number of responses.

The respondents were asked to rank the factors related to the cost of sustainable design which influences the construction organization in its decision making to choose a sustainable design or a conventional design. Figure 5.4 shows the raw data received with the four-point Likert scale. The analysis and discussion of the data are given in Chapter 6.

5.3.5. Barriers to Implementing Sustainable Construction



BA1	Lack of expressed interest from developers/owners
BA2	Lack of technical understanding on the part of contractors and subcontractors
BA3	Lack of technical understanding on the part of designers/engineers and other project team members
BA4	Lack of training and education in sustainable constructions
BA5	Insurance and liability problems due to the use of non-standard materials for construction
BA6	Lack of availability of green-building materials locally
BA7	Higher initial investment
BA8	Long-term recovery of initial investment not reflected

Figure 5.5. Barchart showing the barriers and the number of responses.

The questionnaire was designed to find if there are any factors that act as a major barrier for sustainable constructions. The study was conducted such that certain factors that might become a barrier for sustainable design were identified; the respondents were asked to rank the significance those factors that are most likely to become barriers to sustainable projects in general. The factors were represented on a scale of 1 to 4, with 1 being non-significant and 4 being highly significant. The following section shows all the factors and the survey responses to those factors with the aid of figures.

CHAPTER 6. ANALYSES AND DISCUSSION OF RESULTS

6.1. Selection of Analysis Methods

The survey results were analyzed in two different ways to satisfy two research objectives.

- Find whether the factors in the questionnaire are significant enough to influence the thought process of construction professionals to adopt sustainable design for a project.
- Rank the factors according to their significance.

As such, two different analysis methods were used.

1) The approach used to prove the significance of factors was the Central Limit Theorem, null hypothesis testing. For example Al-Khalil and Al-Ghafly (1999) used it in a similar context. The central limit theorem was selected for the analysis because the sample used was relatively large (greater than 20). For a relatively large sample even if the distribution of the original population is unknown, the sampling distribution of the mean will be approximately normally distributed with original mean and original standard deviation divided by the square root of sample size. Since the sample used for this study is relatively large (sample size 28), the distribution is always normal and also since we are making inference on the population mean using the sample mean, we can assume normal distribution using Central Limit Theorem. Hence according to the Central Limit Theorem the sample mean is normally distributed with the

parameters μ and σ^2 where μ is the original mean and σ^2 is the original variance. This always works if we have a relatively larger sample. Exception happen only when the expected values do not exists. Since this is not true for the sample used for this study, CLT provides distribution of the sample mean which can be used for hypothesis testing and drawing inference.

2) The study adopted the Relative Importance Index (RII) method used by Abd El-Razek et al. (2008), Aibinu and Jagboro (2002), Chan and Kumaraswamy (1997), Faridi and El-Sayegh (2006), Iyer and Jha (2005), Murali and Wen (2007), and Odeh and Battaineh (2002) to perform statistical analysis that ranked the factors according to their significance.

Sections 6.2 and 6.3 present the theory and sample calculations pertaining to the analysis methods.

6.2. Central Limit Theorem

$X =$ The ranks

$n =$ Number of respondents

$X_i = 1,2,3,4$

$X_1, X_2, \ldots\ldots\ldots\ldots, X_n \approx^{iid} F(\mu, \sigma^2)$

$\overline{X} \approx^{appr} N\left(\mu, \frac{\sigma^2}{n}\right)$ ← Distribution

$H_0 : \mu = 2.5$ ← Null Hypothesis

$H_a : \mu > 2.5$ ← Alternate Hypothesis

$Z_{obs} = \frac{\overline{X} - 2.5}{\sqrt{\frac{\sigma^2}{n}}}$ ← Test statistic

$P - \text{value} = \underline{P}(Z > Z_{obs})$

where μ is the population proportion and 2.5 is the null hypothesis proportion. (Respondents were asked to rank on a scale of 1 to 4, hence (1+2+3+4)/4 = 2.5.)

Assuming Z = 1.96 for 95% confidence,

Rejection region when ($Z < -1.96$ or $Z > 1.96$). Reject H_0 if Z lies in this region.

For clarity, sample calculations are presented in Section 6.2 for an example that was found

- Significant factor
- Non-significant factor

6.3. Relative Importance Index Method

The Relative Importance Indices are calculated using the formula:

$$RII = \frac{\sum_{i=1}^{4} W_i X_i}{4N} \times 100\%$$

Where,

W_i = Weight assigned to the ith response; W_i = 1,2,3,4; and i = 1,2,3,4

X_i = Number of respondents for the ith response

i = Response category index1,2,3,4

N = total number of respondents. Finally, the index is multiplied by 100 to be calculated as a percentage multiply the index.

The RII value ranges from 0 to 100%. The significance of the factors increases as the RII value increases. A higher RII value indicates that the factor is highly significant, and a lower RII value indicates that the factor is less significant. The RII values are then used to determine the significance ranks for each factor. For clarity, sample calculations are presented in Section 6.2 for an example showing the RII value.

6.4. Examples of a Test Using Central Limit Theorem to Find the Significance of Factors

The statistical test was performed according to the formula mentioned above, and the examples of the results are shown in Table 6.1. All the Zs that are greater than 1.96 mean more than the average score for a particular factor, hence it is proven to be significant. For instance, according to the respondents, a factor influencing the owner's decision, increased building value, is a significant factor, whereas a cost-related factor, easiness to obtain financing options, is not a significant factor. Analysis of both these factors is shown below as sample calculations.

6.4.1. Increased Building Value

$\overline{X} = 3.43, \qquad \mu = 2.5, \qquad n = 29, \qquad \sigma = 0.79$

Assume 95% CI for μ.

$\infty = 0.05$, $(1 - \infty)\ 100 = 95$

$\overline{X} \pm Z_{\infty/2}\sqrt{\sigma^2 / n}$

$$3.43 \pm 1.96\left(\frac{0.79}{\sqrt{29}}\right) = 3.43 \pm 0.294 = (3.136,\ 3.724)$$

Therefore, we are 95% confident that μ lies between 3.136 and 3.724.

Test statistics,

$$Z_{obs} = \frac{\overline{X} - 2.5}{\sqrt{\frac{\sigma^2}{n}}}$$

$$= \frac{(3.43 - 2.5)}{\sqrt{\frac{0.79}{29}}} = 6.2$$

Rejection region when (Z <–1.96 or Z > 1.96)

Z = 6.2 lies in the rejection region, hence the null hypothesis rejected. There is no sufficient evidence to prove alternate hypothesis wrong.

Hence, the significance of the factor was proven. In other words, increased building value is a significant factor influencing an owner's decision for implementing a sustainable design in construction.

6.4.2. Ease of Obtaining Finance Options

$\overline{X} = 2.2$, $\mu = 2.5$, $n = 26$, $\sigma = 0.91$

Assume 95% CI for μ.

∞ = 0.05, (1– ∞) 100 = 95

$$\overline{X} \pm Z_{\infty/2}\sqrt{\sigma^2 / n}$$

$$2.2 \pm 1.96\left(\frac{0.91}{\sqrt{26}}\right) = 2.2 \pm 0.28 = (1.92, 2.48)$$

Therefore, we are 95% confident that μ lies between 1.92 and 2.48.

Test statistics,

$$Z_{obs} = \frac{\overline{X} - 2.5}{\sqrt{\frac{\sigma^2}{n}}}$$

$$= \frac{(2.2 - 2.5)}{\sqrt{\frac{0.91}{26}}} = -1.685$$

Rejection region is ($Z < -1.96$ or $Z > 1.96$)

$Z = -1.685$ does not lie in the rejection region. Hence, there is no sufficient evidence to reject the null hypothesis.

Therefore, the significance of the factor is not proven. In other words, ease of obtaining a financing option from banks for sustainable projects is not a significant factor influencing a project member's decision for implementing sustainable design in construction.

6.5. Identification of Significant and Non-Significant Factors: Central Limit Theorem

The factors that are identified as significant and non-significant are tabulated below. Refer Table 6.1.

Table 6.1. Owner/ Developer-related factors.

Testing H_0: $\mu = 2.5$ vs. H_a: $\mu > 2.5$, where μ represents the average scale. Z is the test statistic.

Factors	Result	Comment
Increase building value	Z = 6.2 Reject H_0	Significant factor
Availability of design team with sustainable design skills	Z = 3 Reject H_0	Significant factor
Process innovation associated with the quest for resource efficiency	Z = 2.2 Reject H_0	Significant factor
Higher quality of work life	Z = 3.93 Reject H_0	Significant factor
Higher operational efficiency, creativity, and productivity by employees	Z = 4.7 Reject H_0	Significant factor
Increases the compliance of project design standards with environmental regulations	Z = 2.24 Reject H_0	Significant factor
Social responsibility	Z = 1.6 No evidence to Reject H_0	Non-significant factor
Enhanced community livability	Z = 4.14 Reject H_0	Significant factor
Enhanced relationships with stakeholders	Z = 1.12 No evidence to Reject H_0	Non-significant factor
Improved ability to market to pro-environmental consumers	Z = 3.66 Reject H_0	Significant factor

Table 6.2. Factors affecting contractor support.

Testing H_0: $\mu = 2.5$ vs. H_a: $\mu > 2.5$, where μ represents the average scale. Z is the test statistic.

Factors	Result	Comment
Reduce construction project duration	Z = -1.96 No evidence to Reject H_0	Non-significant factor
Market differentiation	Z = 2.9 Reject H_0	Significant factor
Regulatory advantage by being early adopters of sustainable construction	Z = 2.59 Reject H_0	Significant factor
Easy to find information on sustainable building practices	Z = 1.82 No evidence to Reject H_0	Non-significant factor

Table 6.3. Energy efficiency, resources, and environment-related factors.

Testing H_0: $\mu = 2.5$ vs. H_a: $\mu > 2.5$, where μ represents the average scale. Z is the test statistic.

Factors	Result	Comment
Reduced use or resources, especially water and energy	Z = 14.09 Reject H_0	Significant factor
Decreased environmental burden of the project	Z = 8.51 Reject H_0	Significant factor
Habitat restoration and use of native plantings in landscape design	Z = 2.078 Reject H_0	Significant factor
Integration of a natural environment with the building environment	Z = 2.79 Reject H_0	Significant factor

Table 6.4. Cost-related factors.

Testing H0: μ = 2.5 vs. Ha: μ > 2.5, where μ represents the average scale. Z is the test statistic.

Factors	Result	Comment
Ease of obtaining finance options from the bank for sustainable projects	Z = -1.68 No evidence to Reject H_0	Non-significant factor
Lower site-clearing costs	Z = -0.23 Reject H_0	Significant factor
Future cost benefits	Z = 2.1 Reject H_0	Significant factor
Reduced liability and insurance costs associated with reduced health risks for the building occupants	Z = 0.905 No evidence to Reject H_0	Non-significant factor
Lower life-cycle costs	Z = 7.2 Reject H_0	Significant factor

Table 6.5. Barriers to sustainable constructions.

Testing H0: μ = 2.5 vs. Ha: μ > 2.5, where μ represents the average scale. Z is the test statistic.

Barriers	Result	Comment
Lack of expressed interest from owners	Z = 1.766 No evidence to Reject H_0	Non-significant factor
Lack of technical understanding on the part of contractors	Z = 1.418 No evidence to Reject H_0	Non-significant factor
Lack of technical understanding on the part of designers	Z = 0.89 No evidence to Reject H_0	Non-significant factor
Lack of training and education in sustainable construction techniques	Z = 2.41 Reject H_0	Significant factor
Insurance and liability problems due to the use of non-standard materials for construction	Z = 2.0 Reject H_0	Significant factor
Lack of availability of green-building materials locally	Z = 3.23 Reject H_0	Significant factor
Higher initial investment	Z = 6.19 Reject H_0	Significant factor
Long-term recovery of initial investment not reflected	Z = 4.55 Reject H_0	Significant factor

6.6. Results According to Relative Importance Index Rankings (RII)

The factors that are identified as significant and non significant are tabulated according to their RII ranking in Table 6.6 and Table 6.7. Also, Figure 6.1 and Figure 6.2 represent Pareto Chart for RII of factors affecting the decision and Pareto Chart for RII of barriers to implementing sustainable construction.

6.6.1. Factors Affecting the Decision Making Sorted in Order of Rank

Table 6.6. Factors affecting the decision making sorted in order of rank.

Category Symbols:

OW – Owner related
CN – Contractor related
ER – Energy, efficiency, resources related
CT – Cost related

Category	Factors Influencing Sustainability Implementation	RII	Rank	Significance
ER	Reduced use of resources, especially water and energy	95.00	1	Significant
ER	Decreased environmental burden for the project	91.30	2	Significant
CT	Lower life-cycle cost	86.11	3	Significant
OW	Higher operational efficiency, creativity, and productivity by the employees	86.00	4	Significant
OW	Increased building value	85.70	5	Significant
CT	Future cost benefits	83.33	6	Significant
OW	Higher quality of work life (including employee work attitudes and satisfaction)	82.10	7	Significant
CN	Improved ability to market to pro-environmental consumers	80.00	8	Significant
CN	Market differentiation: can broaden the market by attracting new clients	76.00	9	Significant
CN	Enhanced relationships with stakeholders (e.g., clients, tenants, employees, partners, contractors, etc.)	75.89	10	Significant
ER	Integration of the natural environment with the building environment	73.14	11	Significant
CN	Regulatory advantage by being early adopters of sustainable constructions	73.00	12	Significant
OW	Availability of a design team with sustainable design skills	72.00	13	Significant
OW	Increases the compliance of the project design standards with the environmental regulations of building-control authorities	71.40	14	Significant
OW	Process innovation associated with the quest for resource efficiency	70.53	15	Significant
CN	Easy to find information on sustainable building practices	69.79	16	Non significant
ER	Habitat restoration and the use of native plantings in landscape design	69.44	17	
OW	Social responsibility	69.00	18	Non significant
CN	Enhanced relationships with stakeholders (e.g., clients, tenants, employees, partners, contractors, etc.)	66.90	19	Non significant
CT	Reduced liability and insurance costs associated with reduced health risks for the building occupants	66.35	20	Non significant
CT	Lower site-clearing costs	61.50	21	
CT	Ease of obtaining finance options from a bank for sustainable projects	55.76	22	Non significant
CN	Reduce the construction project duration	55.00	23	Non significant

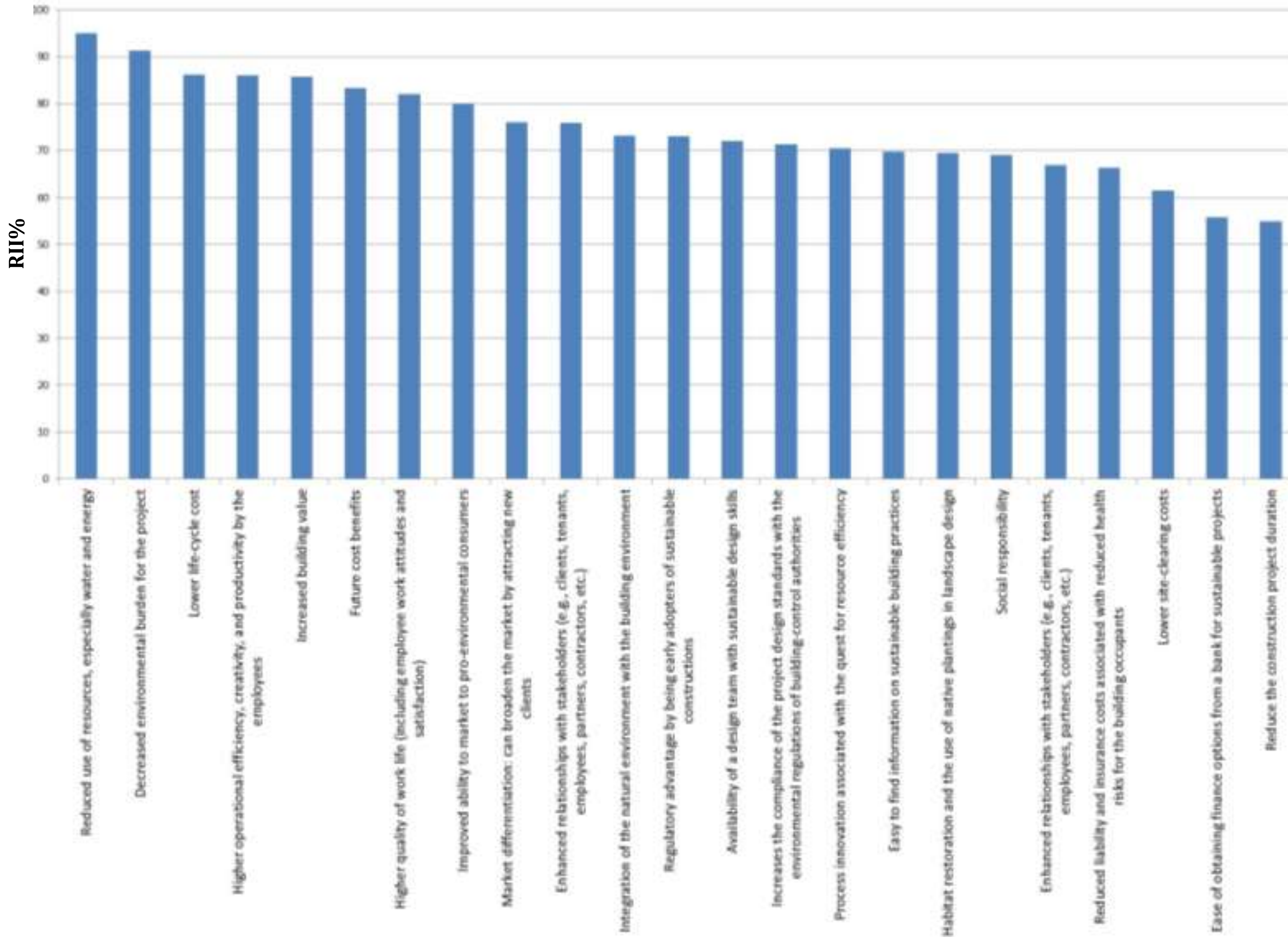


Figure 6.1. Pareto chart for RII of factors affecting the decision

6.6.2. Barriers to Implementing Sustainable Construction Sorted in Order of Rank

Table 6.7. Barriers to implementing sustainable construction sorted in the order of rank.

Category	Barriers	RII	Rank	Significance
Barriers	Higher initial investment	85.60	1	Significant
	Long-term recovery of initial investment not reflected	78.85	2	Significant
	Lack of training and education in sustainable construction	73.10	3	Significant
	Lack of availability of green-building materials locally	70.19	4	Significant
	Insurance and liability problems due to the use of non-standard materials for construction	70.19	5	Significant
	Lack of expressed interest from developers/owners	70.19	6	Non significant
	Lack of technical understanding on the part of contractors and subcontractors	68.26	7	Non significant
	Lack of technical understanding on the part of designers/engineers and other project team members	65.38	8	Non significant

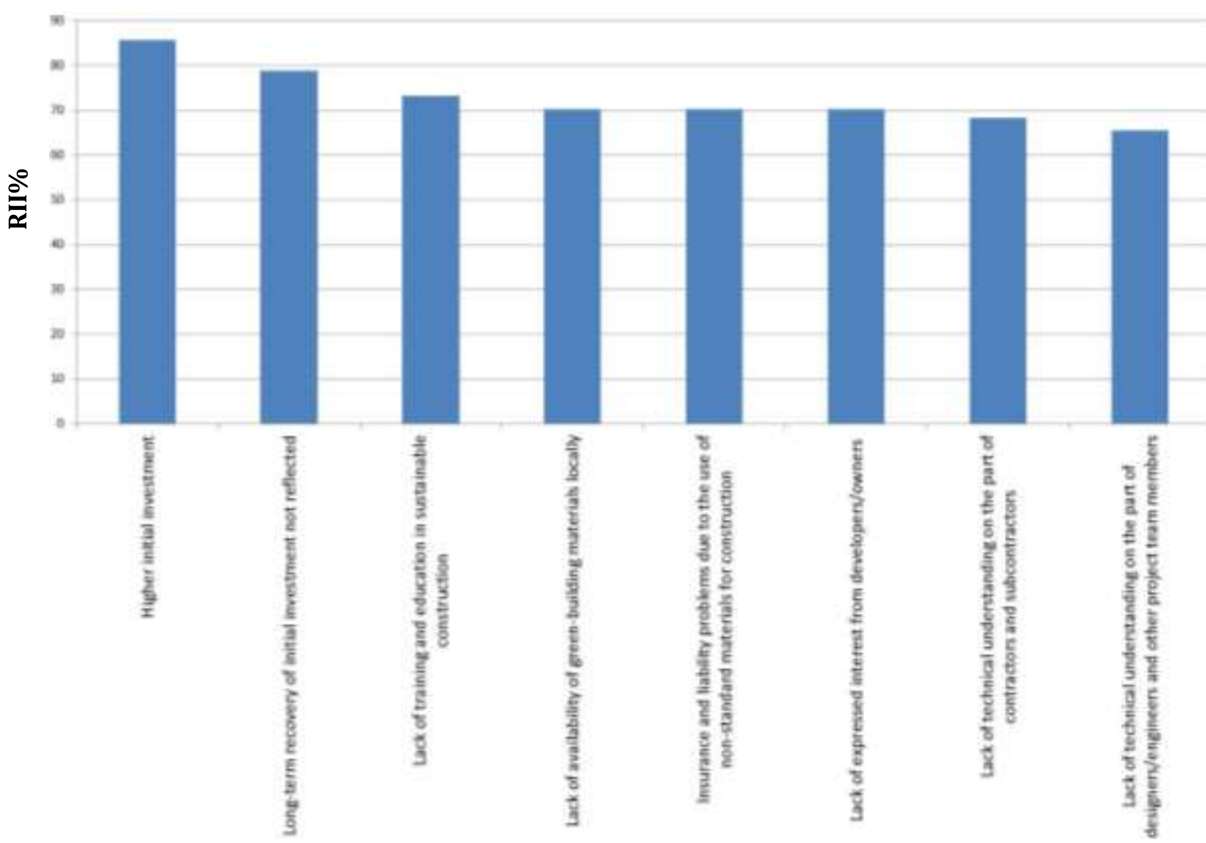


Figure 6.2. Pareto chart for RII of barriers to implementing sustainable construction

To present the results in a reader friendly manner, in the right-hand-side most columns, significance and non-significance presented in Tables 6.1 to 6.5 are repeated. It enabled reader to easily compare the results from the Central Limit Theorem and Relative Importance Index.

The above quantitative results presented both tabulated and graphically are discussed, and recommendations and conclusions are derived in the next chapter. Please refer Chapter 7.

CHAPTER 7. DISCUSSION OF RESULTS RECOMMENDATIONS AND CONCLUSION

Sustainable buildings convey different perspectives on economic, environmental, and social aspects of life. This thesis identified an array of factors that influence decision making inside a project's organization and barriers to adopt sustainable design in construction. That identification was based on the following three perspectives (see Figure 2.2):

- Strategic Performance
- Human Resource Development
- Performance, Efficiency, and Environmental Benefits

Additionally, barriers to implementing sustainability in construction too were identified. The focus of the following discussion is the results of analysis based on the Central Limit Theorem and the Relative Importance Index presented in Chapter 6.

7.1. Discussion of Results

7.1.1. Factors that Influence the Decision Making Process

The study found that factors which were identified by survey respondents as significant and important in the decision-making processes of project organizations, thus constituted the top RII ranks (see Table 6.6 and Figure 6.1), were those that provided to organizations:

- Value-added benefits
- Cost benefits

Examples of value-added benefits are (in the descending order of RII):

- Reduced use of resources
- Higher operational efficiency
- Higher quality of work life
- Improved ability to market to pro-environmental consumers
- Enhanced relationships with stakeholders

Examples of cost benefits are (in the descending order of RII):

- lower life-cycle cost
- increased building value
- future cost benefits
- market differentiation

The only factor that could be considered neither *value-added* nor *cost benefit*, but ranked high was 'Decreased environmental burden for the project.' Table 6.6 and Figure 6.1 presents that it was ranked second highest; supporting that construction professionals are very concerned of environmental burdens of their projects./

It is quite evident that the factors that were ranked relatively low were those constituting *environmental* and *social* benefits. The three factors that ranked relatively low are (in the descending order of RII):

- Integration of the natural environment with the building environment
- Habitat restoration and the use of native plantings in landscape design
- Social responsibility

The above results provide the insight that *added value* and *cost benefits* are the advantages that are appealing to construction organizations and construction professionals to adopt sustainable construction. It is also evident that the *environmental* and *social* aspects of sustainable construction are still not appealing to the construction industry.

The factors that ranked the lowest as per RII rakings were those that do not provide considerable benefits to the organization during the construction phase. These factors failed to prove their significance as per analysis conducted using the Central Limit Theorem. As per the research study the results of both Central Limit Theorem and RII ranking shows that these factors were not significant enough in influencing the decision making inside an organization to adopt sustainable design for a project. The factors that ranked the lowest are (in the descending order of RII):

- Enhanced relationships with stakeholders (e.g., clients, tenants, employees, partners, contractors, etc.)
- Reduced liability and insurance costs associated with reduced health risks for the building occupants
- Lower site-clearing costs
- Ease of obtaining finance options from a bank for sustainable projects
- Reduce the construction project duration

7.1.2. Barriers to Implementing Sustainable Construction

All barriers to the increased adoption of sustainable building practices in the building professions, identified in the questionnaire, could be characterized as either *educational* or *economic* aspects. The survey findings identify that (see Table 6.7 and

Figure 6.2), highly significant barriers to implementation of sustainable construction are (in the descending order of RII):

- Higher initial investment
- Prolonged recovery of initial investment
- Lack of training and education in sustainable constructions

The two barriers that ranked lowest are pertaining to technical capabilities of construction professionals. They are (in the descending order of RII):

- Lack of technical understanding on the part of contractors and subcontractors
- Lack of technical understanding on the part of designers/engineers and other project team members

From the above, it is apparent that higher initial investment, and the time to recover it appear to be barriers to implementation of sustainable construction. Lack of training and education in sustainable constructions was considered a barrier while stating that technical understanding on the part of contractors, subcontractors, designers/engineers and other project team members is not a challenge. The above findings on significant factors and barriers are discussed next to propose recommendations on how the sustainability in construction could be improved.

7.2. Recommendations

Presented in the preceding chapters is a study to identify significant factors and barriers which influence organizational interactions that may lead to a sustainable project. The preceding section presented a discussion of the significant direction pointed by the results. Following are recommendations based on those directions.

The survey findings show the importance of *cost* and *value* benefits are the advantages that are appealing to construction organizations and construction professionals to embracing sustainability in the construction industry. Those advocating sustainable construction, hence, need to utilize *cost* and *value* benefits as the driving factors, while gaining environmental and social benefits as byproducts.

It is important to understand that possible increased initial costs of sustainable projects are primarily a concern for clients rather than building professionals. Since clients ultimately pay for the project, they would decide the direction of the design process. Cost benefits that were ranked high by construction professionals (as discussed in Section 7.1) were:

- lower life-cycle cost
- increased building value
- future cost benefits

It is apparent that the above cost benefits are not too visible to clients and the general public as made obvious by the two barriers ranked highest in RII ranking (as discussed in Section 7.1):

- Higher initial investment
- Prolonged recovery of initial investment

Therefore, both publicity and economic incentives must be aimed at potential clients and the general public. In addition to providing incentives (e.g. federal and state incentives such as federal tax incentives for sustainable development, energy tax credits, tax-free bonds to provide funding to environmentally sustainable projects) and funding research and development (e.g., National Science Foundation (NSF) ‘Environmental

Sustainability' funding program) to lower project costs, initiatives should be taken to reduce the commonly held misperceptions of the increased cost of sustainable practices, and give more publicity on how reduction in operational costs will rapidly payback the initial investment. Around the world many stakeholders remain unaware of the viability of sustainable construction in terms of cost. Today's world need many more proactive initiations that promote sustainability in a large public scale, such as the following recommendations I wish to make based on this research experience:

- Publicize long-term life cycle savings with the help of demonstration projects
- Publicize the long-term cost savings of building/property owners who incorporated sustainable practices into their projects.
- Publicize the Value added and cost benefits of sustainable buildings to generate public interest.
- Educate people about the importance of environmental protection
- Promote the use of locally available green materials for construction
- Standardize all green construction materials to avoid insurance and liability costs

As the barrier rankings suggest, there is still a need to educate and train building professionals in sustainable practices. This barrier was identified as a significant barrier and was ranked 3 in the RII ranking (as discussed in Section 7.1). There are many programs in the universities on sustainable constructions, there are programs such as Leadership in Energy and Environmental Design (LEED) certification, and so on. These programs are relatively new, and there is a possibility that at present there are not many professional in the industry who have pursued such training. Following recommendations can, hence, be made to train construction professionals:

- Promote professional education and research programs on sustainable buildings
- Fund sustainable building research and development
- Utilizing organizations that support sustainable building to have more promotions to educate and train building professionals

7.3. Conclusions

The focus of this research was to identify significant factors and barriers which influence organizational interactions that may lead to a sustainable project. Analysis of results as presented in Chapter 6, and the discussions in this chapter yielded four major conclusions:

1) Added value and cost benefits are the advantages that are appealing to construction organizations and construction professionals to adopt sustainable construction; while environmental and social aspects of sustainable construction are still not appealing to the construction industry. Those advocating sustainable construction, hence, need to utilize cost and value benefits as the driving factors, while gaining environmental and social benefits as byproducts.
2) The factors that ranked the lowest as per RII rakings were those that do not provide considerable benefits to the organization during the construction phase. These factors failed to prove their significance as per analysis conducted using the Central Limit Theorem.

3) Higher initial investment, and the uncertainties of the time to recover it appear to be barriers to implementation of sustainable construction, although construction professionals were of the opinion that lower life-cycle cost and increased building value could easily repay it.
4) Lack of training and education in sustainable constructions was considered a barrier, although technical understanding (pertaining to sustainable construction) on the part of contractors, subcontractors, designers/engineers and other project team members was not considered a challenge.

7.4. Directions for the Future Research

This is a quantitative study that analyzed various factors for its significance and importance in influencing the decision making process inside a project organizations to adopt sustainable design. The study identified the significant factors and barriers. Sustainability being a broad area of study these results could serve to focus future studies on areas that are found significant and important.

While qualitative studies could yield very in depth results, a major challenge is the greater effort and resources demanded by that methodology. As this research has helped in narrowing the foci of future studies, further in depth qualitative studies could be conducted on how to leverage the significant factors and overcome the significant barriers. Such research could benefit the future construction project practitioners to implement sustainable design in their project.

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APPENDIX. COPY OF THE SURVEY INSTRUMENT AND IRB APPROVAL

North Dakota State University, Department of Construction Management & Engineering

Survey On Factors That Led To The Decision For Implementing Sustainable Concepts During Construction

This survey is to find facts for research study program pursued by Sooraj Mattappadan under the supervision of Dr. Darshi De Saram at the North Dakota State University.

Objective: significance of the factors that influence the decision of construction industry authorities to either implement or disregard sustainable design in their project.

GENERAL INFORMATION (OPTIONAL) PROVIDED THE RESULTS OF THIS STUDY CAN BE SEND TO YOU ON REQUEST

1. *Name:* ………………………………………………………………………………………………

   Company Name: ……………………………………………………………………………………

   Position/Title: ………………………………………………………………………………………

   Address: ……………………………………………………………………………………………

   City: ………………………………………………

   State: ……………………………… *Zip:* ……………………….

   Phone no: ……………………… *Fax No:* ………………………

   Email: ……………………………………………………………………

PROJECT DETAILS

2. *Please consider a project that you were involved in. Please mention whether it was a commercial, Industrial, Residential or any other type of building project.)*

Type of Building	…………………………………………………………………………………… ……………………………………………………………………………………

Please rank the influence of factors that led to the decision for implementing sustainable concepts during construction.

Note: Indicate your priority

Significance: ☐ *1 – Less significant* ☐ *4 – Highly significant*

1. Factors Influencing Owner's Decision

1.1. Increased building value	☐1 ☐2 ☐3 ☐4
1.2. Availability of a design team with sustainable design skills	☐1 ☐2 ☐3 ☐4
1.3. Process innovation associated with the quest for resource efficiency	☐1 ☐2 ☐3 ☐4
1.4. Higher quality of work life (including employee work attitudes and satisfaction)	☐1 ☐2 ☐3 ☐4
1.5. Higher operational efficiency, creativity, and productivity by the employees	☐1 ☐2 ☐3 ☐4
1.6. Increases the compliance of the project design standards with the environmental regulations of building-control authorities.	☐1 ☐2 ☐3 ☐4
1.7. Social responsibility	☐1 ☐2 ☐3 ☐4
1.8. Enhanced community livability	☐1 ☐2 ☐3 ☐4
1.9. Enhanced relationships with stakeholders	☐1 ☐2 ☐3 ☐4
1.10. Improved ability to market to pro-environmental consumers	☐1 ☐2 ☐3 ☐4

2. Factors affecting contractor's support

2.1.	*Reduce the construction project duration*	☐1 ☐2 ☐3 ☐4
2.2.	*Duration of the project* *(Approximate values are ok)*	*Planned* …………………………… *Actual* ……………………………
2.3.	*Market differentiation - Can broaden the market by attracting new clients.*	☐1 ☐2 ☐3 ☐4
2.4.	*Regulatory advantage by being early adopters of sustainable constructions*	☐1 ☐2 ☐3 ☐4
2.5.	*Easy to find information on sustainable building practices*	☐1 ☐2 ☐3 ☐4

3. Energy efficiency, Resources and Environmental related factors

3.1.	*Reduced use of resources, especially water and energy*	☐1 ☐2 ☐3 ☐4
3.2.	*Decrease the environmental burden of the project*	☐1 ☐2 ☐3 ☐4
3.3.	*Habitat restoration and use of native plantings in landscape design*	☐1 ☐2 ☐3 ☐4
3.4.	*Integration of the natural environment with the building environment*	☐1 ☐2 ☐3 ☐4

4. Cost Related Factors

4.1. Easiness in obtaining financing options from bank for sustainable projects	☐*1* ☐*2* ☐*3* ☐*4*
4.2. Lower site-clearing costs	☐*1* ☐*2* ☐*3* ☐*4*
4.4. Overall cost of the project, Please consider one project where sustainable concepts was incorporated (Approximate values are ok)	*Planned* …………………………… *Actual* ……………………………
4.5. Future cost benefits	☐*1* ☐*2* ☐*3* ☐*4*
4.6. Reduced liability and insurance costs associated with reduced health risks to the building occupants	☐*1* ☐*2* ☐*3* ☐*4*
4.7. Lower life cycle cost	☐*1* ☐*2* ☐*3* ☐*4*

Please rank the influence of factors that are most likely to be the barriers to implementing sustainable concepts during construction.

5. Barriers to implementing sustainable constructions

5.1. *Lack of expressed interest from developers/owners*	☐1 ☐2 ☐3 ☐4
5.2. *Lack of technical understanding on part of contractors and sub contractors*	☐1 ☐2 ☐3 ☐4
5.3. *Lack of technical understanding on part of designers/engineers and other project team members*	☐1 ☐2 ☐3 ☐4
5.4. *Lack of training and education in sustainable constructions*	☐1 ☐2 ☐3 ☐4
5.5. *Insurance and liability problems due to the use of non-standard materials for construction.*	☐1 ☐2 ☐3 ☐4
5.6. *Lack of availability of green building materials locally.*	☐1 ☐2 ☐3 ☐4
5.7. *Higher initial investment*	☐1 ☐2 ☐3 ☐4
5.8. *Long term recovery of initial investment not reflected.*	☐1 ☐2 ☐3 ☐4

Recommendations

Please list any suggestions which could be used

I. ……………………………………………………………………………………………………

II. ……………………………………………………………………………………………………

III. ……………………………………………………………………………………………………

IV. ……………………………………………………………………………………………………

The End. THANK YOU very much for the valuable time spent and the kind effort

NDSU NORTH DAKOTA STATE UNIVERSITY

Institutional Review Board

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February 4, 2010

Dr. Darshi DeSaram and Sooraj Mattappadan
Dept of Construction Management and Engineering

Re: Your project "Survey on Factors that Led to the Decision for Implementing Sustainable Concepts during Construction"

Thank you for your inquiry regarding your project. At this time, the IRB office has determined that the above-referenced protocol does not require Institutional Review Board approval or certification of exempt status because it does not fit the regulatory definition of 'research involving human subjects'.

> *Dept. of Health & Human Services regulations governing human subjects research (45CFR46, Protection of Human Subjects), defines 'research' as "... a systematic investigation, research development, testing and evaluation, designed to contribute to generalizable knowledge." These regulations also define a 'human subject' as "... a living individual about whom an investigator conducting research obtains (1) data through intervention or interaction with the individual, or (2) identifiable private information."*

While this project is clearly 'research' as defined above, it does not involve 'human subjects' because the questions in the survey do not elicit any information about individuals. Instead, the questions pertain solely to objective information regarding construction project design. This determination is based on the survey provided on 2.4.2010.

We appreciate your intention to abide by NDSU IRB policies and procedures. Best wishes for a successful project!

Sincerely,

Ted Grosz, MS, CIP
Manager, Human Research Protection Program

NDSU is an equal opportunity institution.