ABSTRACT

Title of Document: EMPIRICAL ANALYSIS OF CONSTRUCTION ENTERPRISE INFORMATION SYSTEMS: ASSESSING THE CRITICAL FACTORS AND BENEFITS

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Attaining higher levels of system integration is seen as the primary goal of enterprise information systems in construction (CEIS). Increased system integration resulting from CEIS implementation is expected to lead to numerous benefits. These benefits encompass information technology infrastructure as well as strategic, operational, organizational, and managerial aspects of the firm. By adopting CEIS, firms seek

tangible and intangible benefits such as cost reduction, improved productivity, enhanced efficiency, and business growth. However, with the challenge of integrating various business functions within the firm, certain factors become critical for achieving higher levels of integration.

Despite ample research on integrated IT systems, there are very few works in the construction field that empirically analyze the critical factors impacting the level of integration and the benefits thereof. This study seeks to address these gaps in the literature and analyzes the impact of critical factors on levels of integration and the ensuing benefits through a systematic and rigorous research design. The conceptual framework in this study draws heavily upon the theory of IT integration infrastructures, while also modifying and expanding it. This study quantifies the critical success factors that impact CEIS integration and the ensuing benefits. Furthermore, it analyzes the effects of system integration on CEIS induced benefits. It also investigates the impact of CEIS strategy on CEIS induced benefits, and identifies the relationship between CEIS strategy and system integration. Finally, it assesses the effects of CEIS induced benefits on user satisfaction and provides a CEIS implementation guide map for construction firms. The study uses multiple regression analysis and ANOVA to test these relationships.

EMPIRICAL ANALYSIS OF CONSTRUCTION ENTERPRISE INFORMATION SYSTEMS: ASSESSING THE CRITICAL FACTORS AND BENEFITS

By

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Chapter 1: Introduction

1.1 Background

Over the years, researchers have developed various models of information technology induced integration for construction firms. Computer integrated construction (CIC) has evolved as a further step of IT integration in the construction industry, with the aim to better manage construction information (Bjork 1994; Faraj et al. 2000; Froese 1996; Sanvido 1990; Yu et al. 2000). Sanvido (1990) describes CIC as the application of computer technology for "better management of information and knowledge with the aim of total integration of the management, planning, design, construction and operation of facilities." Yet, in contrast to the successful transfer of construction integrated manufacturing (CIM) research to the manufacturing industry practice, most of CIC research remains in the form of models and prototypes not fully transferred to the standard practices in construction industry. Construction industry continues to suffer from the problems related to the lack of integration of business and project related information (Bedard 2006; Rezgui and Zarli 2006).

On the other hand, enterprise resource planning systems (ERP), which evolved out of manufacturing planning systems (MRP), have sought to eradicate similar integration problems primarily in the manufacturing industry. Later, ERP vendors extended their solutions to other industries. Today, it is estimated that most Fortune 1000 firms have already adopted ERP (Jacobs and Weston Jr. 2007). The success of ERP in these firms resulted in its adoption in some large construction companies as well (Voordijk et al. 2003). ERP systems aim to achieve seamless integration of all the processes and information flowing through a firm, including but not limited to financial and accounting information, human resource information, supply chain information, and customer information (Davenport 1998). In the context of the construction industry, ERP would be defined as a computer-based business management system that integrates all processes and data of the business, including engineering/design, planning, procurement, construction and maintenance/operations (Tatari et al. 2007). As such, the level of integration has been seen as the primary goal of ERP systems. Since both CIC and ERP envision the same goal, which is to increase the integration level, I use the term *Construction Enterprise Information System (CEIS)* to denote any type of management information system that is aimed to fulfill seamless system integration in construction firms.

The increase of system integration due to CEIS implementation is expected to lead to many benefits. These benefits are not limited to information technology infrastructure only, but also encompass strategic, operational and managerial aspects of the firm (Shang and Seddon 2002). By adopting CEIS, firms seek many tangible and intangible benefits such as cost reduction, productivity improvement, enhanced efficiency and business growth.

On the other hand, with the goal of integrating many business functions within the firm, numerous critical factors become increasingly important to achieve higher levels of integration. Since the basic premise of CEIS is to increase the level of system integration, successful implementation necessitates increased levels of integration and procuring the benefits sought by the firm.

1.2 Problem Statement

Despite ample research on integrated IT systems, there are very few works in the construction field that empirically analyze the critical factors impacting the level of integration and the benefits thereof. There are a number of studies that analyze the success of information technology, project management information systems, and ERP implementations in the construction industry, but none of them concentrate specifically on the CEIS integration level as the focal point of study. Since CEIS integration level is viewed as the objective of all the enterprise information systems, it is imperative to analyze it in-depth, and identify the critical factors that affect CEIS integration level. Also, knowing the dynamics of the relationship between specific CEIS types and the extent of CEIS integration would help the construction firms to make better decisions. And most importantly, even though it is assumed that integration leads to certain benefits, the effect of CEIS integration extent on firm benefits for construction firms has not been investigated thoroughly. This study seeks to address these gaps in the literature and analyzes the impact of critical factors on levels of integration and the ensuing benefits through a systematic and rigorous research design.

1.3 Research Objectives

In order to implement CEIS successfully and achieve higher levels of integration, it is necessary to know the complex dynamics that affect CEIS integration. Hence, the following research questions are addressed to map out the process of CEIS integration and identify the key components (see Figure 1.1):

1. How do certain critical success factors impact CEIS integration and CEIS-induced perceived benefits?
2. How are CEIS-induced perceived benefits impacted by CEIS integration level?
3. What is the relationship between CEIS integration and CEIS satisfaction?
4. What is the relationship between CEIS-induced perceived benefits and CEIS satisfaction?
5. What is the relationship between the firm's adopted EIS type and CEIS integration level?
6. What is the relationship between the firm's adopted EIS type and CEIS-induced perceived firm benefits?

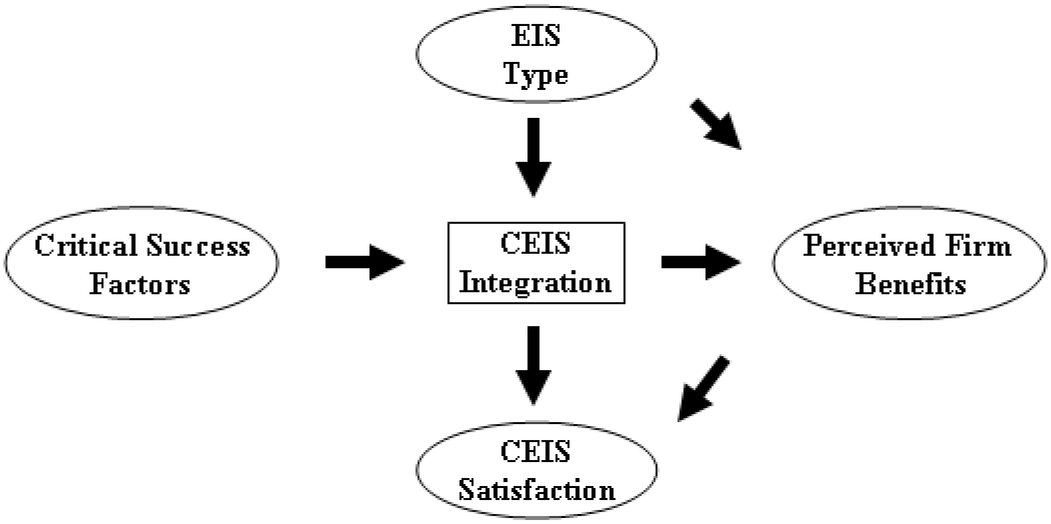

Figure 1.1 Research Framework

This research aims to provide answers to all of the above questions, from which the following objectives are postulated:

a) Identify critical success factors related to CEIS integration level and CEIS induced perceived benefits.

b) Identify the CEIS induced perceived benefits and their relationship to CEIS integration level.

c) Examine the relationship between CEIS integration and CEIS satisfaction.

d) Examine the relationship between CEIS induced perceived benefits and CEIS satisfaction.

e) Examine the relationship between the firm's adopted EIS type and CEIS integration level.

f) Examine the relationship between the firm's adopted EIS type and CEIS induced perceived firm benefits.

By answering these questions the research aims to bring a better understanding of CEIS critical success factors and benefits and associated CEIS solutions. It is expected that the results of this research would facilitate better management decisions in the adoption of CEIS in the construction industry.

1.4 Research Methodology and Dissertation Organization

This dissertation is divided into five parts. A detailed description of each part is as follows:

1) *Literature Review*

   A thorough literature review of ERP, C-ERP, construction integrated construction, and integration in construction research is provided. Enterprise information systems in construction research were studied closely. In addition, several phone interviews were conducted with professionals in the construction ERP (C-ERP). The methodology, research model and measures were selected based on the literature review and the interviews.

2) *Conceptual Framework Development*

   The conceptual framework was formalized based on theory of IT integration infrastructures, thorough literature review and analysis. A more general term, CEIS, was coined to encompass all information system solutions that are related to construction enterprise. Critical success factors that may affect the CEIS integration level and the perceived CEIS benefits were incorporated to the framework. EIS type was included to the framework in order to assess if there were any significant relationships with CEIS integration level.

3) *Survey Design and Data Collection*

A survey aimed to quantify the framework elements was developed and disseminated to the construction firms. The population to be investigated consisted of firms that utilize CEIS. Data was gathered from stakeholders with reliable working knowledge of their firms' information systems. The respondents included construction industry executives, operation managers, project managers, and IT managers.

4) *Data Analysis and Framework Validation*

In order to test the framework, the collected data was analyzed by utilizing statistical tools. The relationships mentioned in the research objectives were evaluated.

5) *Research Results*

Results of the statistical analysis were interpreted and their significance for the construction industry was addressed. Limitations of the study and research conclusions based on the results were investigated and discussed.

1.5 Dissertation Outline

This dissertation is structured into seven chapters. Chapter 1 discusses and summarizes the key points of the dissertation. It describes the research background and the research problem underlying this study. In addition, it outlines the research objectives, and the methodology. Chapter 2 reviews the relevant literature on integration, CIC, ERP, and the prior research conducted in these fields. Chapter 3 describes the formation of the CEIS integration and performance framework for the construction industry. It also explains the operationalization of CEIS related critical factors and CEIS-induced firm benefits. Particular attention is given to variable selection. Chapter 4 presents the development of the survey instrument and data collection methods. It also discusses reliability and validity of the survey instrument, descriptive analysis, and data screening. Chapter 5 analyzes the data that is gathered from the survey using statistical tools, such as ANOVA and regression analysis. Chapter 6 presents these findings and summarizes their relevance and significance for the construction industry. Chapter 7 provides a summary of the dissertation and discusses the limitations of the research. It concludes with recommendations for future research.

Chapter 2: Literature Review

2.1 Introduction

This dissertation draws mainly from scholarly literature on construction and project management research. The following is a thorough review of the scholarly literatures on the development of Enterprise Resource Planning systems (ERP) and its eventual adoption to the construction industry, Construction Enterprise Resource Planning systems (C-ERP) and their suggested benefits, integration in construction research, and finally, Computer Integration Construction research (CIC).

2.2 Enterprise Resource Planning Systems

ERP systems are defined as integrated information systems that encompass an entire company (Duplaga and Marzie 2003). With these systems, it is possible to integrate all information flowing through an enterprise, including people, functions and geographic locations (Davenport 1998; Kumar et al. 2002). Furthermore, this integration and automation is facilitated by the inclusion of best practices to facilitate rapid decision-making, cost reduction, and greater managerial control (Holland and Light 1999).

The origin of ERP is in Manufacturing Resource Planning (MRPII), a successor to Material Requirements Planning (MRP) systems (Holland and Light 1999; Klaus et al. 2000). MRP was initially designed to optimize the use of materials and to schedule industrial production. MRPII included more operational functionality, particularly in sales planning and production capacity management. MRPII evolved into ERP, a complete business management system that encompasses the whole enterprise, not only production. In the mid 1990s, ERP vendors began to customize their solutions to industries other than manufacturing.

ERP systems consist of a suite of software modules, each responsible for a different business function. These modules can be purchased separately, or they can be combined together according to the needs of the firm. These modules include accounting management, financial management, workflow management, production management, project management, logistics management, inventory management, human resources management, supply chain management, customer relationship management and others. In a typical ERP system, modules share and transfer information freely through a central database, thus an integration of functions of the firm is realized (Chalmers 1999) (see Figure 2.1).

There are several reasons why businesses choose to implement ERP systems. The most important reasons appear to be improving management control, standardizing the business process, integrating and enhancing quality of information, legacy system problems, the need for an enterprise wide system, turn of the millennium computer problems, restructuring company organization, gaining strategic advantage, and real time integration.

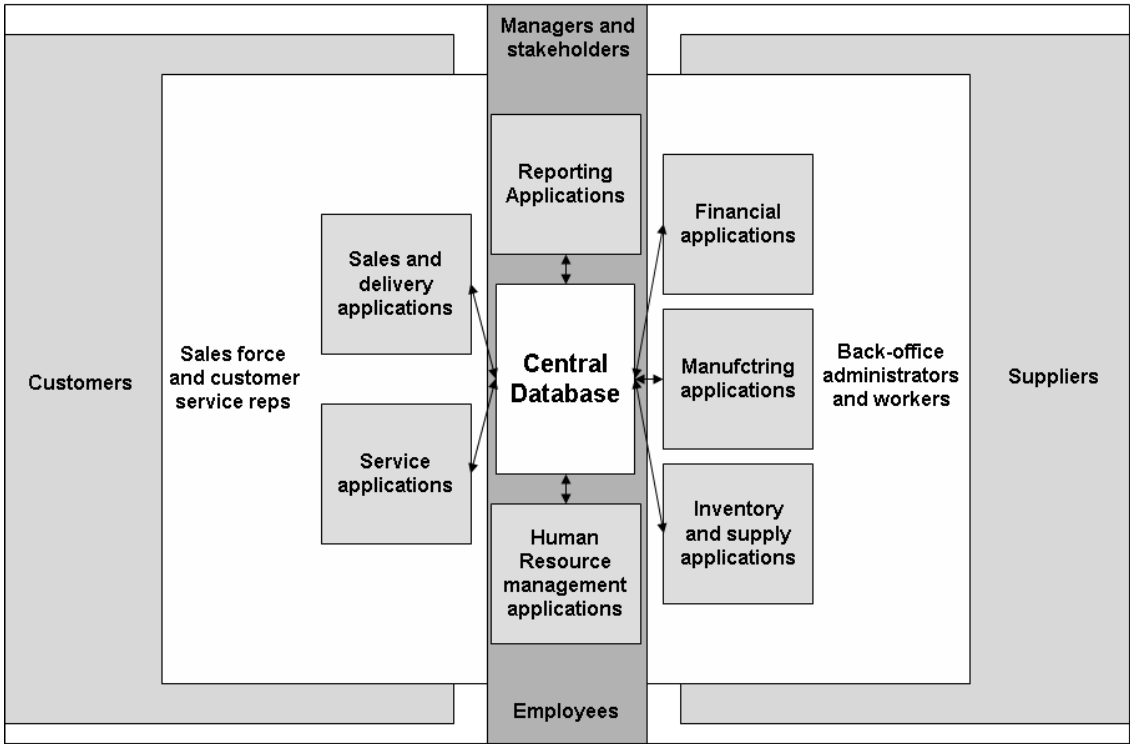

Figure 2.1 Structure of ERP system

ERP systems streamline the data flows of organizations and enable the management to directly access wealth of real-time information. The ability to take advantage of real time information is crucial for increasing productivity of businesses. Also, the replacement of legacy systems with ERP systems reduces the number of software programs in use and the needed technical support and maintenance thereof. The high cost of creating and maintaining in-house systems decreases as well (Holland and Light 1999).

On the other hand, such complex systems come with risks, both tangible and intangible. Especially in the absence of scrupulous planning, the amount of risk may increase substantially. Since the adoption of ERP systems usually necessitates significant changes in the business processes, it is important to plan and predict the various business implications of ERP systems before implementation. Furthermore, ERP implementations generally require substantial amount of time, money, and effort, and their positive impacts may take years to transpire. In a recent study, it was estimated that customers spend between three and seven times more money on ERP implementation and associated services compared to the purchase of the software license (Scheer and Habermann 2000).

2.3 Construction Enterprise Resource Planning Systems

The success of ERP in manufacturing enterprises resulted in its adoption by some large construction companies (ML Payton Consultants 2002; Voordijk et al. 2003). Yet, because of the differences in manufacturing and construction processes, ERP adoption in these companies was restricted to the integration of financial management processes only (Helms 2003). Chao (2001) analyzed and outlined the differences between manufacturing and construction industries that may prove to be significant in the nature of ERP implementations in these industries (see Table 2-1). First, the construction industry is unique in its work environment and the distributed nature of stakeholders. Although it shares many similarities with the manufacturing industry with regards to production processes and systems, its output is usually one-of-a-kind, prototype-like products. Also, the construction industry is centered on project-based operations that are carried out by many different parties which may be geographically dispersed. As diverse organizational entities, each of the project participants has different goals to accomplish in the project. Furthermore, the amount of information and its time-sensitiveness in the construction industry renders many management challenges. For these reasons, generic or standard ERP systems intended originally for manufacturing or non-construction service industries are not able to address the unique business needs of the construction industry. Extensive customization is required to respond to these specific needs. To date, this has been the primary reason for the relatively low implementation rate of ERP systems in the construction industry.

Table 2-1 Comparing Construction and Manufacturing Industries (Chao 2001)

Views	Construction Industry		Manufacturing Industry
	Public Construction	**Private Construction**	
Initiator	Federal/state/local government	Individuals/ Corporations	Individuals
Client	General Public	Private group	General public
Planning/ Design	In-house engineering, A/E		In-house R&D
Bid/ Contracting	General procurement laws	Owner-contractor negotiations	Sale price based on market
Type of production	Unique, one at a time		Mass production
Location	Uncertain site conditions, affected to adjacent environment		In-house factory, lab
Supervisor	Owner, owner's representative		Production line manager
Finance	Auditory agencies	Self management	Self management
Scale	Large	Large	Small to large
Product life time	Usually long		Usually Short
Defect corrections	Hard to replace, correction measures, punch list during finishing stage		Replace, refund

In order to address the idiosyncratic needs of the construction industry, an ERP system intended for construction related applications should mainly be based on the life cycle of the project (Tatari et al. 2004b). In addition, it should be compatible with the way construction firms are conducting their businesses. Industry specific processes and accounting standards should be re-designed and embedded in the system comprehensively. Furthermore, the system should possess the necessary interfaces with standard engineering, scheduling, and office software. Access to information from worldwide sources should be facilitated through the use of the Internet.

The disparities between the distinct needs of the construction applications of ERP systems and the extant standard features of ERP has left a gap between solutions offered by ERP systems vendors and the needs of the construction industry for decades. In the meantime, with the saturation of the market in other industries, ERP vendors began to explore other industries to expand their existing services (Piturro 1999). As a result, with the advent of the new millennium, major ERP vendors such as SAP™ and Oracle™ have attempted to tailor their standard systems software to the needs of the construction market. Construction industry-specific solutions, such as C-ERP, conform to a set of criteria that set them apart from the generic ERP applications. Shi and Halpin (2003) developed standards for construction specific ERP. For instance, among other features, C-ERP systems are project-oriented, integrated toward the project life cycle, and accessible to distant parties:

- ***Project-oriented:*** C-ERP systems currently offered by major vendors are project-oriented. Integration of project finances with corporate finances has been addressed. Also, with portfolio view to all projects, visibility of financial, resource and workforce needs of all projects are more apparent; and necessary actions can be taken in a more optimal fashion.

- ***Integrated:*** The most important promise of C-ERP solutions catering to the unique needs of the construction industry is process and data integration of the construction project life cycle.
- ***Paralleled and distributed:*** ERP vendors have utilized parallel and distributed technology for their C-ERP solutions. With these technologies, hundreds of users that are geographically distributed can use C-ERP systems and find, revise or enter new data.
- ***Open and expandable:*** Although some C-ERP solutions also present alternatives, all of them offer integration with the most used construction software, such as *Timberline*™ for quantity take-offs, and estimating or *Primavera*™ for project scheduling and resource management. Additionally, *SAP*™'s C-ERP solution offers CAD integration as well. Also, the modular design of C-ERP allows new modules or software to be integrated without a need to change the whole system.
- ***Scalable:*** ERP vendors proffer scalability for their C-ERP solutions. Although they offer similar functionalities to small, medium, or large companies, their solutions for each differ in scalability. It is important to note that a C-ERP system installed for use by thousands of employees of a large company would cost significantly more than a C-ERP system used by only a hundred employees.
- ***Remotely accessible:*** C-ERP solutions offered by *SAP, Oracle,* and *PeopleSoft* are Internet and web-enabled. A company employee can access the various features of the system by connecting to the Internet.

- ***Transparent:*** Transparency in C-ERP is realized through the visibility of data and ability to trace all activities in the system.
- ***Reliable and robust:*** Criteria related to reliability and robustness have been the decisive force in the success of ERP systems in the manufacturing industry. Similarly, with the emerging C-ERP solutions, ERP vendors promise reliability and robustness for the construction industry.

Incorporating these standards, C-ERP solutions are expected to provide the following benefits (Ahmed et al. 2003; ML Payton Consultants 2002; Piturro 1999): real-time visibility of the finances of projects and enterprise; managing projects on time and within budget; enhanced decision making capabilities; strengthened client, supplier, and subcontractor relationships; eliminating data re-entry; and increasing management efficiency.

As ERP systems become more widely implemented, software applications are developed to help business managers implement ERP in diverse business activities such as project planning and management, subcontracting, material tracking, service, finance and human resources. Currently, SAP™ and Oracle™ offer C-ERP solutions. The functionality of C-ERP covers the entire construction project lifecycle. The scope of C-ERP systems is depicted in Figure 2.2, and the implications for the project life cycle are described below.

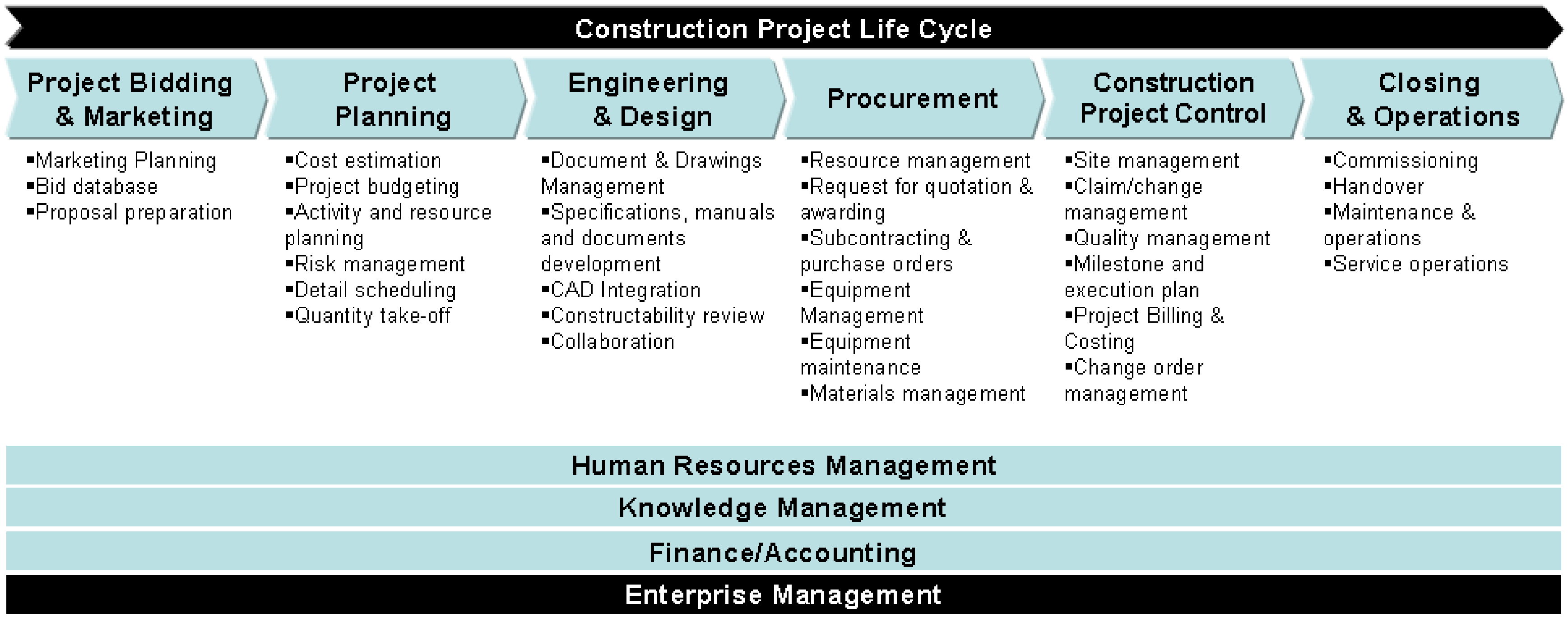

Figure 2.2 Scope of C-ERP system

- **Project bidding and marketing:** C-ERP automates the procedure of proposal preparation, bidding and reviewing bids, marketing campaign management, customer databases and competitor analysis.
- **Project planning:** C-ERP automates activities related to cost estimation, project budgeting, activity and resource planning, and detailed scheduling. All of these are realized in single software, which eliminates duplicate data entrance, especially between preliminary estimation and detailed planning.
- **Design and engineering:** With C-ERP, preparation of detailed specifications and requirements are automated. C-ERP maintains all specifications and drawings with the aid of its document management system. CAD integration is realized to avoid duplicate generation of drawings and specifications during the project life cycle; and collaboration tools are used to facilitate the communication needs of project participants.
- **Procurement:** C-ERP streamlines procurement of required materials, equipment and services. It automates the processes of identifying potential suppliers, supplier evaluation, price negotiation, contract management, awarding purchase orders to the supplier, and supplier billing. Supply chain management of materials is managed through this function. It also automates maintenance scheduling and service operations data for more efficient equipment management.
- **Construction project control:** Through integrated information visibility from other functions, many challenges of project execution are eliminated for the project manager. Also, project billing and project costing is integrated in real-

time, which allow the main office to keep track of projects. C-ERP also automates the change order management which is a seriously time consuming activity during project execution.

- **Workforce management:** C-ERP handles employee and payroll related activities of the construction firm. Complete employee database is maintained including contact information, salary details, attendance, performance evaluation and promotion of all employees. Also, this function is integrated with the knowledge management system to optimally utilize the expertise of all employees within the firm.
- **Finance and accounting:** As one of its core functions, C-ERP streamlines financial operations of the enterprise as well as the projects, collects financial data from all departments, and generates all financial reports, such as balance sheets, general ledger, accounts payable, accounts receivable, and quarterly financial statements.

With C-ERP, it is possible to share and exchange information in digital format throughout the project life cycle. Thus, information is stored only once and all project participants are able to access this information in real-time. Figure 2.3 shows the potential effects of streamlining communication between participants by C-ERP applications.

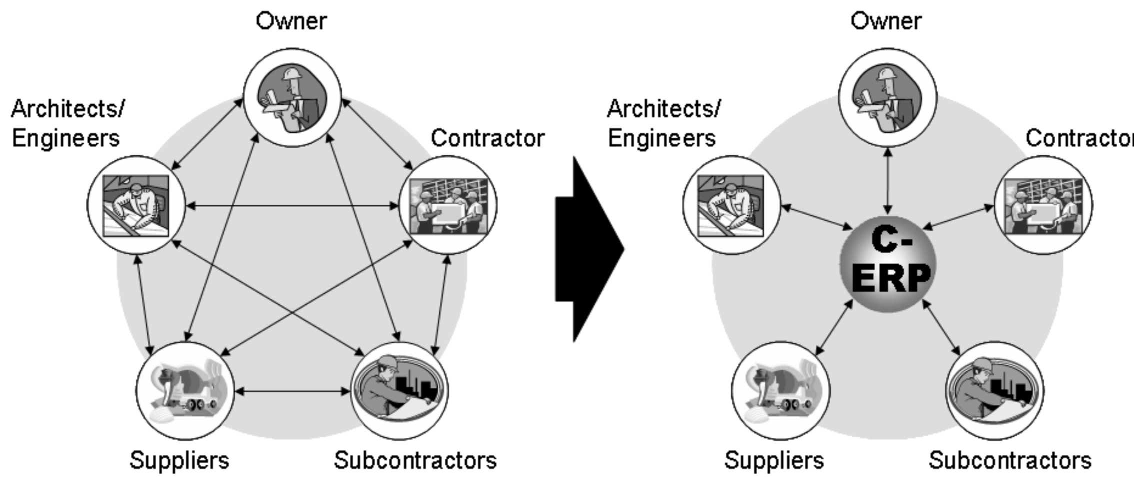

Figure 2.3 Streamlining Corporate and Project Communications with C-ERP

Data integration can be realized through a centralized database system in the core of C-ERP. All data is entered only once, and is visible throughout the entire project life cycle. Process integration is realized by utilizing a single integrated information system for the whole project life cycle, instead of using several stand-alone applications. By streamlining and connecting all business functions, business processes can be executed without interruption. Lastly, linking project participants is made possible by online access to project information by all participants. Participants can view project information with varying levels of access authorization, and enter or revise information related to the functions they are responsible from. As illustrated in Figure 2.4, the vision of computer integrated construction (CIC) is to integrate data, information, and project participants. C-ERP is also intended for this particular purpose.

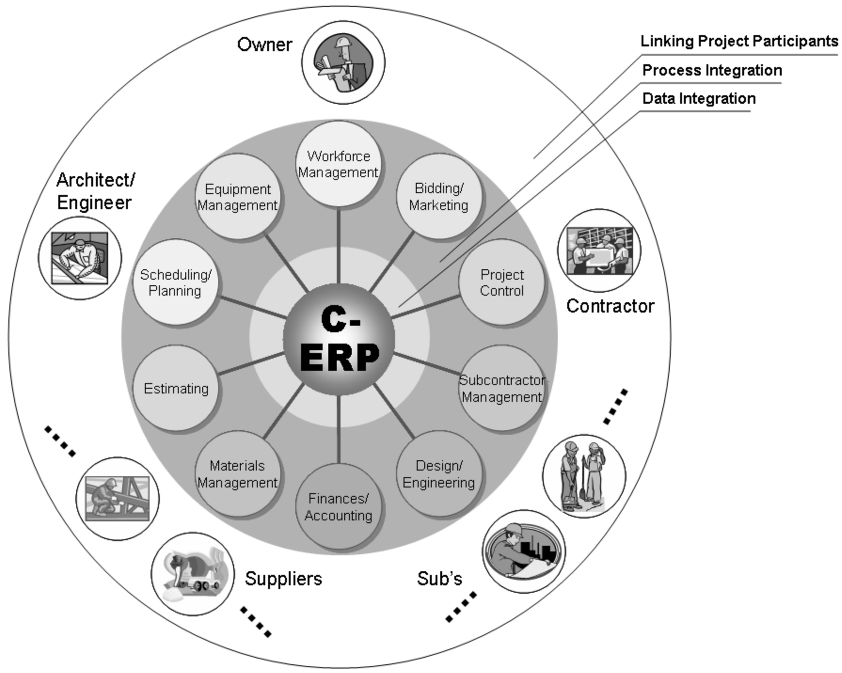

Figure 2.4 C-ERP Contributions toward the Objectives of CIC

2.4 Integration in Construction Research

Several researchers have identified the effects of integration in construction. Fischer *et al.* (1998) studied IT support for integration in three levels; project, multi-project and industry-wide. Single-project integration is related to communication between project participants from different phases and disciplines within the project. Multi-project integration adds a longitudinal aspect to the former, by incorporating historical data throughout projects. Industry-wide integration brings this learned experience to the industry through formal training and standards. According to Fischer *et al.* (1998), most extant IT systems automate specific aspects without integrating them. This results in largely paper-based paradigms. IT is seen as a vehicle that can overcome these aspects and help the firms achieve the three levels of integration mentioned above; project, multi-project and industry-wide. The authors proposed frameworks for IT utilization to achieve integration in all these dimensions of integration.

Fergusson and Teicholz (1996) defined integration as the flow of knowledge and information that occur in three dimensions; vertically between industry function, horizontally between disciplines and/or trades, and longitudinally through time. According to them, this happens in two modes of coordination; organizational and through information technology. Figure 2.5 summarizes their integration framework. The authors constructed and verified a regression model to determine whether the three-dimensional integration framework could predict facility quality. The study is significant since it shows that information integration is key in achieving facility quality.

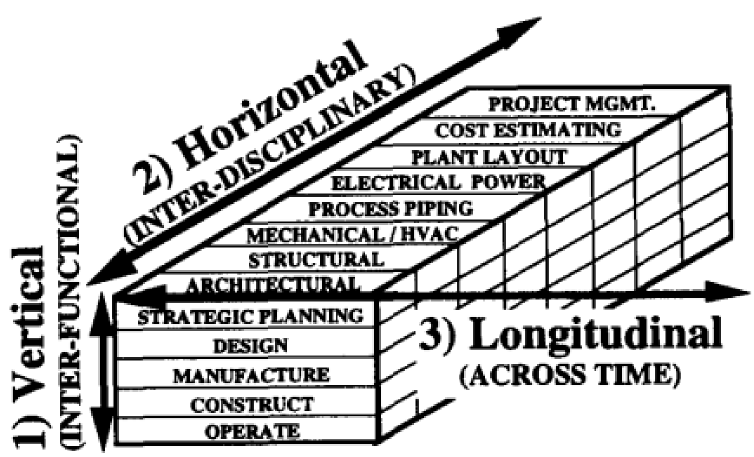

Figure 2.5 Three - Dimensional Integration Framework (Fergusson and Teicholz 1996)

Mitropoulos and Tatum (2000) developed a model of factors affecting the need for integration, mechnisms, and benefits in the constructoin industry (see Figure 2.6). They utilized a broader definition of integration which encapsulated organizational, behavioral, contractual and technical ascpects. By interviewing several firm managers they saught to validate their framework. They pointed out the necessity of evaluating the benefits of integration. As part of their integration framework, they emphasized the importance of IT in achiveing higher integration and observed a need for research in two different areas. First, they reported a need for developing software that can translate between different systems, helping to bridge the technical gap. Second, they reported a need for evaluating the benefits steming out of IT integration. Their study is significant since it is one of the first attempts to identify critical factors that affect the level of integration in construction.

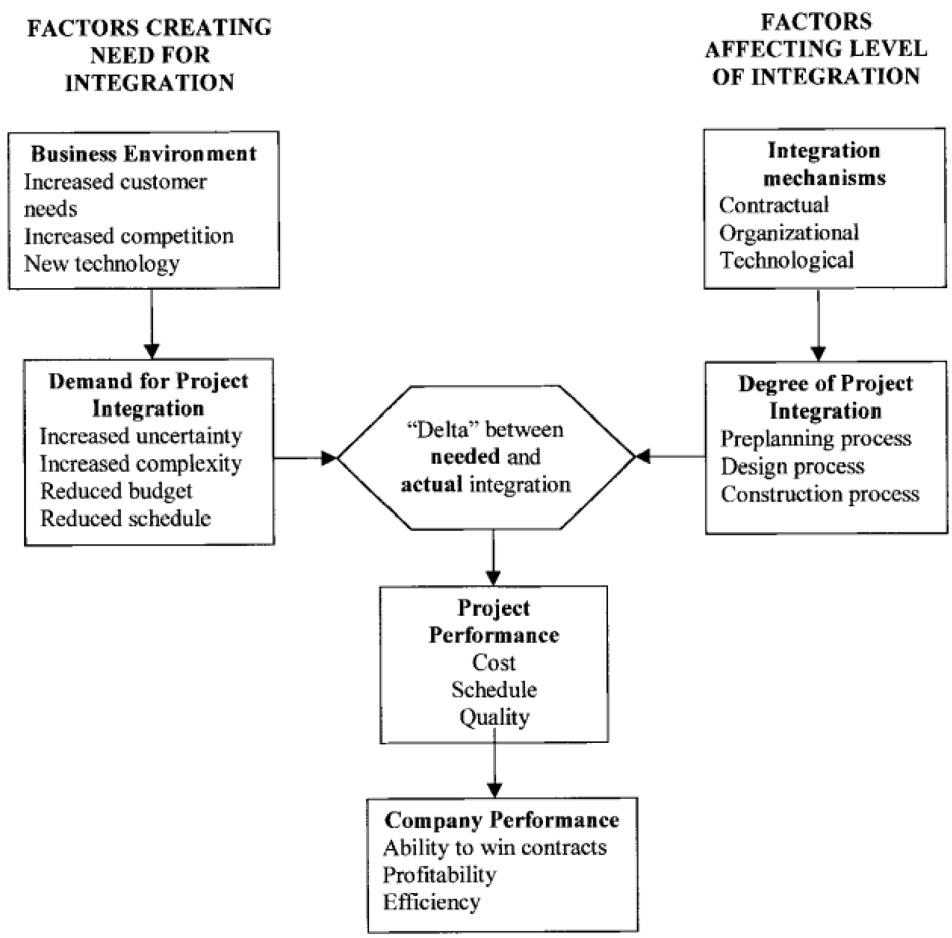

Figure 2.6 Factors Affecting Integration (Mitropoulos and Tatum 2000)

Back and Moreau (2000) developed a methodology to quantify the cost and schedule benefits of information management in an Engineer-Procure-Construct project. They showed that benefits of information management in such projects are significant. They concluded that project information needs to be integrated, preserved, and leveraged throughout the infrastructure of the project team. According to Back and Moreau (2000), internal and external information integration is a must to maximize the potential benefits of information management.

Yang et al. (2007b) defined integration as "the sharing of information between project participants or melding of information sourced from separate systems." Their main objective was to determine the extent to which integration/automation (IA) technologies contribute to project stakeholder success. Utilizing survey research and statistical analysis, they found significant benefits correlated with higher levels of technology implementation. The results of this study indicated the significance of technology in project work functions and its significant contribution to project performance.

These studies discussed above constitute the key research conducted regarding integration in construction. Most of the scholars define integration rather generally and include organizational aspects of it. Although there have been some empirical studies on integration, there is need for robust research on CEIS integration, critical factors that affect it, and its perceived benefits.

2.5 Enterprise Information Systems in Construction Research

There are relatively few journal articles that specifically anlayzes enterprise information systems in the construction industry. In this section, a summary of the literature on enterprise information systems in construction is presented first. The section concludes with situating the current research within the existent literature.

O'Connor and Dodd (2000) conducted a study on the use of ERP to execute capital projects. Their research draws upon the answers of 38 participants gathered in an SAP owner's forum. They summarized the concerns of the owners in their paper. According to their study, there are several gaps in SAP's capital projects solution (as of 1999) such as missing functionality to handle earned value, work breakdown structures, scheduling, and budgeting. The owners see a need in an improved integration between SAP and other systems. They also propose through their functional gap analysis that many project functions could be handled more efficiently by utilizing specialized systems that would lead into a *best-of-breed* strategy.

Shi and Halpin (2003) proposed conceptual framework for and ERP system that would target construction operations. They presented the uniqueness of construction enterprise operations and pointed out their differences from manufacturing enterprise operations (see Figure 2.7). They argued that an ERP suited for construction enterprises need to be developed with these differences in mind. Consequently, ERP systems that are developed primarily of the manufacturing industry could hardly meet the needs of construction firms. They postulated that construction industry specific ERP systems could result in the following benefits: improved information sharing, improved transparency of management responsibilities, and improved management efficiency.

Voordijk et al. (2003) conducted empirical research on three Dutch-based construction firms to study the fit between IT strategy, maturity of the IT infrastructure and the strategic role of IT, and the implementation method and organizational change. Based on the case study findings, they argued that the success of ERP implementations depended on the consistent patterns between the aforementioned elements. For them, the differentiation strategy of construction firms would stimulate the use of ERP.

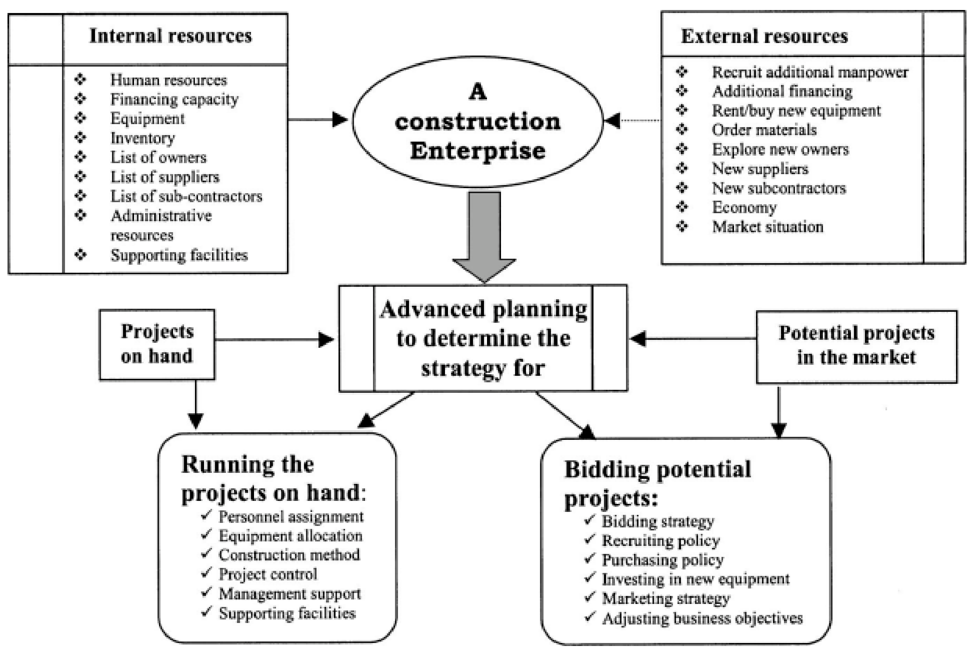

Figure 2.7 Construction Enterprise Operations (Shi and Halpin 2003)

Lee et al. (2004) utilized simulation to quantify the benefits of ERP system in the construction materials procurement process. They focused on the efficiency that could be achieved by automating the business processes related to material procurement. They simulated the transformation that is achieved through ERP by application integration, internal integration, external integration, and automation. According to their simulation results, ERP system could lower material management cycle and increase productivity immensely.

Bergstrom and Stehn (2005) analyzed the use of ERP in the 48 small or medium sized Swedish industrialized timber frame housing companies. Through descriptive analysis, they found that ERP use is fairly low in the companies analyzed. Operational and managerial benefits are ranked higher than strategic benefits in these firms. Potential improvements in material management processes were found to be the key driver force in the firms' decision to implement ERP. Other potential improvements were expected in purchasing processes and improved business process overview.

Yang et al. (2007a) developed an ERP selection model and provided a case study on a firm that implemented the selection model developed. They argued that seven issues are critical in ERP selection: coding system, working process reengineering, priority of ERP functionality implementation, customization, participant roles, consultant role, and performance level of subcontractor. According to them, the main difficulty to adopt ERP in construction lies in the inherent complexity of the industry's working processes and habits.

Tatari et al. (2008) utilized causal loop diagramming to depict the qualitative system dynamics model for the study of the dynamics of construction ERP. They argued that with better information capabilities, project management functions would be more efficient and less time consuming. This is turn would lead to an increase in the progress rate, which would successfully affect the project performance. Increased project performance would increase the rate of C-ERP satisfaction which would result in the continuation to invest in C-ERP.

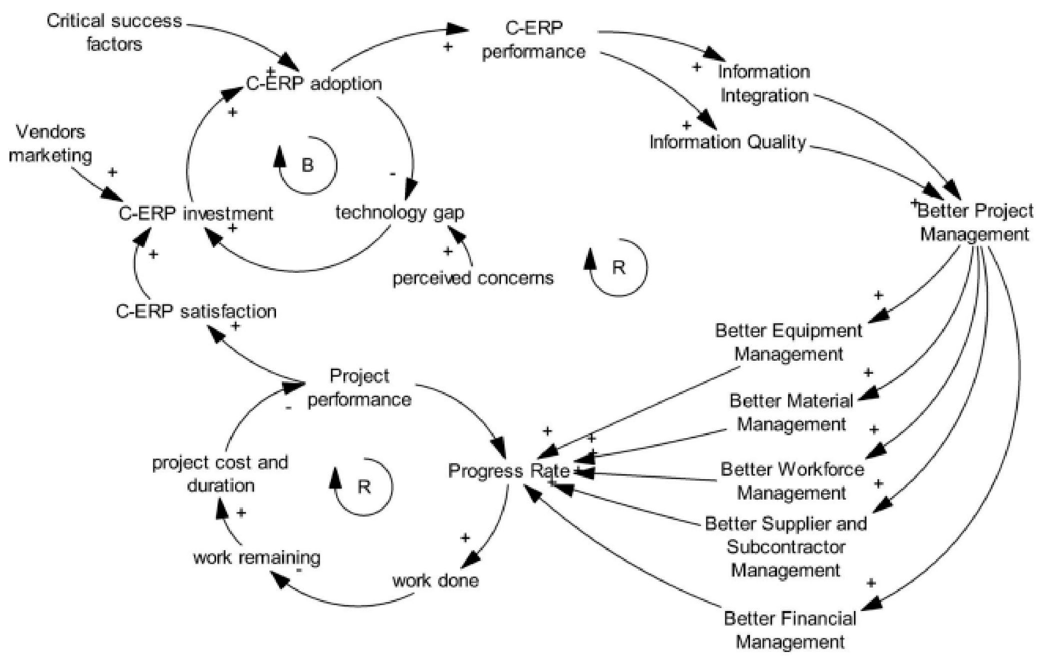

Figure 2.8 Qualitative system dynamics simulation model for C-ERP evaluation (Tatari et al. 2008)

Chung et al. (Chung et al. 2009; Chung et al. 2008) developed an ERP success model for construction firms based on the technology acceptance model and DeLone and McLean's information systems success model. Utilizing regression analysis, they tested the relationships concerning ERP implementation and user adoption. They found that ERP use and quality were associated with ERP benefits. Also, they discovered that function, subjective norm, output, perceived ease of use, and result of demonstrability had a significant impact on perceived usefulness. The summary of all their findings can be seen in Figure 2.9. Based on their findings, they recommended that ERP systems should be well defined and all users should be encouraged to use the ERP system. They also recommended that the construction firms should focus more on increasing the quality during implementation and that ERP system should be easy to use.

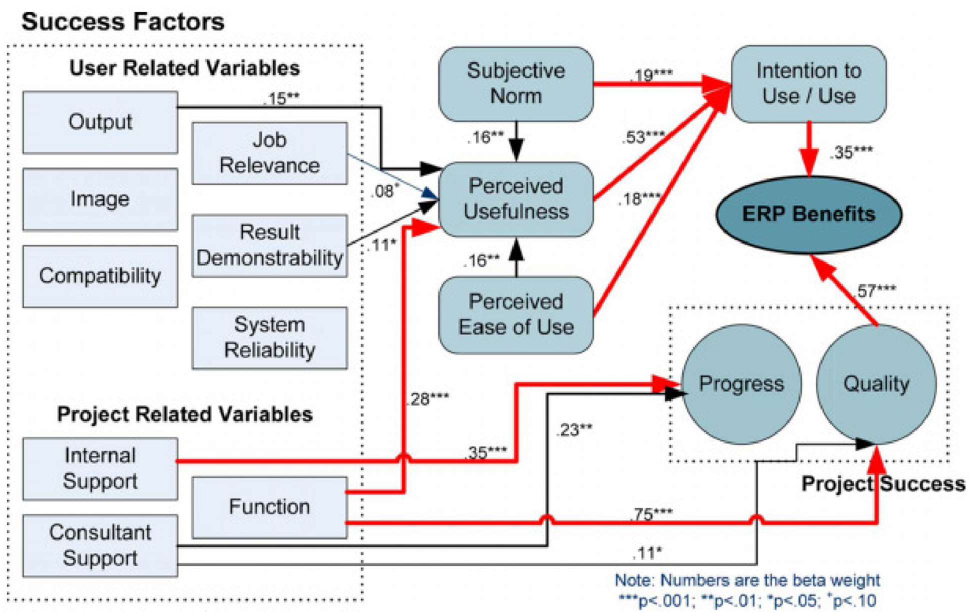

Figure 2.9 ERP success model with results of regressions (Chung et al. 2008)

The current research builds on previous findings and offer new incites to enterprise information systems in construction. It focuses on system integration and its dynamic relationship with the EIS strategy. It investigates the critical success factors not only related to user satisfaction but to the whole EIS implementation and quantifies their impacts on perceived benefits from EIS systems. Benefit dimensions include operational, strategic, organizational and IT infrastructure benefits. Chapters 6 and 7 provide a more comprehensive analysis of the contributions this research makes to the body of knowledge.

2.6 Relevant Research on Computer Integrated Construction

Over the years, researchers developed various models of information integration and collaborative work among parties in construction projects. Computer Integrated Construction (CIC) has evolved as a further step of IT integration in the construction industry, with the aim of better managing construction information. With CIC, the integration of the construction project life cycle information is sought. This term was coined in 1990 by a CIC research team at Penn State University (Sanvido 1990). By benchmarking with computer integrated manufacturing (CIM), the team drew attention to potential benefits of using computer technology in the construction project life cycle. Since that time, CIC research made considerable progress. Projects were undertaken to develop product and process models that would integrate construction information (Bjork 1994; Faraj et al. 2000; Froese 1996; Sanvido 1990; Teicholz and Fischer 1994; Yu et al. 2000).

Scholars have offered similar yet distinct definitions for CIC. For instance, Sanvido (1990) defined CIC as the "application of computers for better management of information and knowledge with the aim of total integration of the management, planning, design, construction and operation of facilities." On the other hand, Miyatake and Kangari (1993) defined CIC as "Linking existing ad emerging technologies and people in order to optimize marketing, sales, accounting, planning, management, engineering, design, procurement and contracting, construction, operation and maintenance, and support functions."

Teicholz and Fischer (1994) defined CIC as a business process that links all project participants through all phases of a project, and stated that, through CIC technology, project participants would be able to share information on a real-time basis. To achieve this integration, the researchers noted three requirements: internal and external business cooperation, integrated computer applications, sharing more information; and they proposed a CIC framework to accomplish this vision (see Figure 2.10).

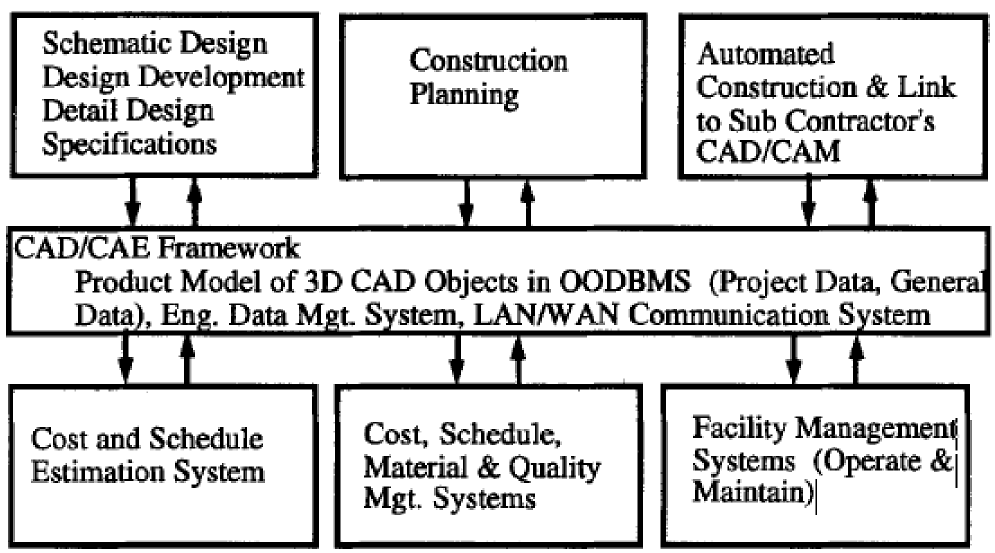

Figure 2.10 CIC Technology Framework (Teicholz and Fischer 1994)

Similarly, Jung and Gibson (1999) defined CIC as the "integration of corporate strategy, management, computer systems, and IT throughout the project's entire life cycle and across different business functions of a construction company."

Table 2-2 Summary of CIC Definitions in Literature

Definition	Source
Application of computers for better management of information and knowledge with the aim of total integration of the management, planning, design, construction and operation of facilities	Sanvido (1990) [1]
Linking existing ad emerging technologies and people in order to optimize marketing, sales, accounting, planning, management, engineering, design, procurement and contracting, construction, operation and maintenance, and support functions	Miyatake and Kangari (1993) [6]
Business process which links the project participants in a facility project into a collaborative team through all phases of a project	Teicholz and Fischer (1994) [7]
Integration of corporate strategy, management, computer systems, and IT throughout the project's entire life cycle and across different business functions of a construction company	Jung and Gibson (1999) [8]

Table 2-2 shows the definitions of CIC that are seen in construction literature. Based on these definitions, this research proposes that the definition of Jung and Gibson (1999) be detailed by adding the concept of a business process. Thus, we define CIC as the integration of all processes and data of the construction company and project related businesses, including engineering/design, planning, procurement, construction and maintenance/operations.

System and data integration has been the focal point in CIC research (Forbes and Ahmed 2003). Forbes et al. (2003) summarize the emphasis of integration in CIC research in four ways: integration at data-application level, integration at application-semantic level, integration at data-process level, and integration at process-semantic level. Works that are categorized under the integration at data-application level focus mainly on defining and explanation of product data models for the construction industry. Studies that are categorized under the integration at application-semantic level include systems and resources that aim to improve primarily communication that would increase the level of integration within construction computing. The third quadrant, integration at data-process level, refer to applications, such as the SABLE project, that function at higher levels of abstraction, and have “discipline specific interfaces to server based IFC building models. These interfaces including client briefing/space planning, architecture, HVAC design, cost/quantity takeoff, and scheduling move closer to the process oriented view of the project.” Finally, studies on construction industry focusing on integration at the process-semantic level are relatively scarce. Figure 2.11 depicts these four components of system and data integration in CIC research.

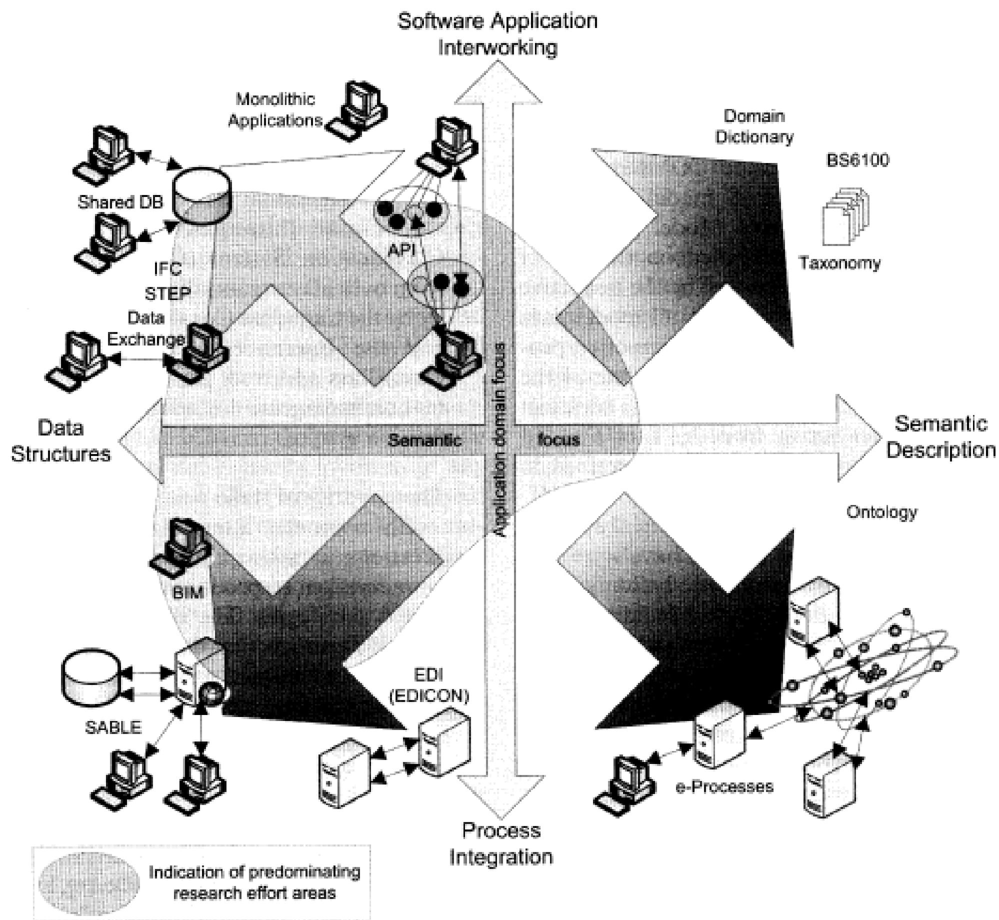

Figure 2.11 CIC Research Landscape

Chapter 3: Research Framework and Design

3.1 Introduction

A conceptual framework is vital to understand the complex dynamics of CEIS. The conceptual framework discussed below enables predictions to be made about CEIS related critical factors and benefits, and is subsequently used to test the hypotheses. In this chapter, the research classification is presented, followed by the conceptual framework and the main hypotheses. Next, the operationalizations of variables are explained and justified drawing on the existing literature. Lastly, the hypotheses and the underlying arguments are summarized and situated vis-à-vis extant research.

3.2 Research Classification

Engineering is an applied field and the primary research type in construction engineering and management field is "applied research" (Levitt 2007), which aims to advance the practice of the industry (Becker 1999). Applied research is directed towards solving practical problems and benefit the practitioners (Fellows and Liu 1997). By the same token, this dissertation research is based on a project funded by a major ERP software company and is also classified as applied research (Tatari et al. 2004a). Utilization of applied research, as opposed to "pure research", was selected for this project since this study was focused on a specific request from the client to analyze the dynamics of enterprise information system in the construction industry.

3.3 Conceptual Framework

In order to understand the effect of CEIS integration on firm benefits and the critical factors that impact CEIS integration, a framework was developed. The conceptual framework describes the relationship between critical factors, CEIS satisfaction, EIS type, firm benefits, and CEIS integration level. The rationale underlying the this conceptual framework can be summarized as follows. CEIS critical factors impact CIES level of integration; certain firm characteristics require and facilitate attaining higher levels of CEIS integration; CEIS integration level impacts the benefits acquired by the firm; and ERP/PMIS type affects both CEIS integration level and firm benefits. Figure 3.1 illustrates the six hypotheses that were developed from this conceptual framework. In the following sections, these hypotheses and the underlying arguments will be explained further.

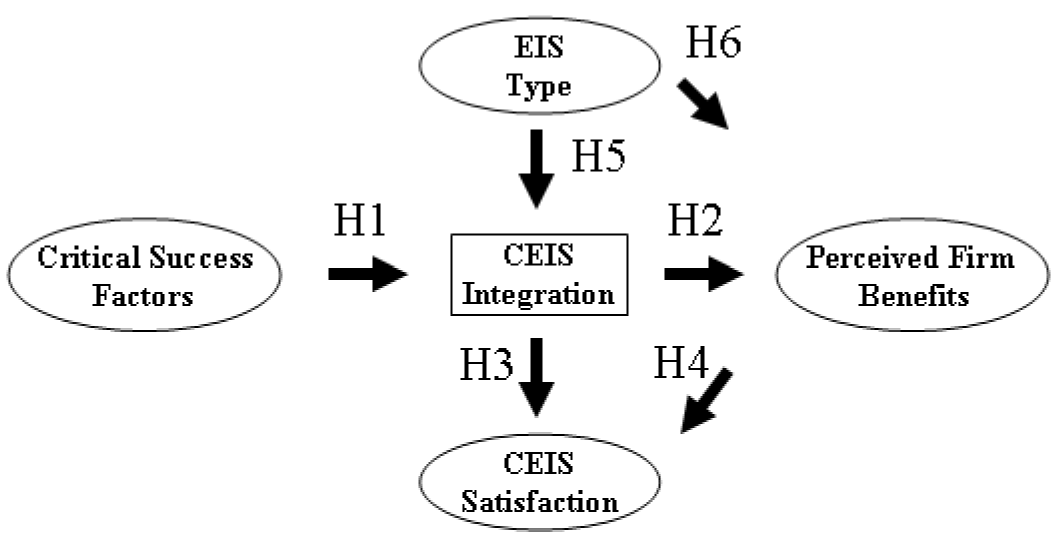

Figure 3.1 Conceptual Framework

3.4 Perceived Benefits of System Integration in Construction

CEIS integration level constitutes the focal point of this research, and Bhatt's (1995) definition of enterprise system (ES) integration is utilized for CEIS integration. Bhatt (1995) defines ES integration as "the extent various information systems are formally linked for sharing of consistent information within an enterprise." Many conceptual frameworks and arguments regarding the value of integration and benefits it would yield in construction firms have been developed by scholars. Some works have concentrated on technical prototypes of integrated systems, yet few of these studies involved systematic empirical analysis. This section concentrates on the perceived benefits expected from system integration as cited in the construction literature.

While fragmented construction firms look for innovative solutions to increase their integration, both inter and intra-organizationally, IT is seen as a catalyst to achieve this goal (Ahmad et al. 1995). According to Ahmad et al. (1995), "Information availability, accuracy, and timeliness are crucial factors in the decision making process", which will result in better decision making, increase managerial benefits, minimize errors and increase productivity. Moreover, Björk (1999) states that enhanced productivity results from integration of islands of information systems. Likewise, Betts et al. (1991) argue that IT induced integration between planning, design, and construction will result in increased productivity and quality of production. With having a single source of data, integration of operations and business functions within the organization will be possible (Ahmad et al. 1995). Finally, sharing the same site data by multiple contractors due to an integrated source of information would greatly increase the effectiveness of communication among project participants (Ahmad et al. 1995).

Many powerful software systems are being utilized during the project life cycle in the construction environment. Yet, since insufficient attention has been given to the integration of these systems, an ‘islands of automation’ problem has emerged. System integration, which enhances “the value added in whole network of shareholders throughout the building lifecycle” (Succar 2009), is necessary to avoid this problem. By integrating these disparate systems, cost reduction, quality and productivity increase is expected (Alshawi and Faraj 2002), which is anticipated to also augment profits, market share, market size and entrance to or creation of new markets (Betts et al. 1995).

Yang et al. (2007b) brought empirical evidence to confirm that integration and automation impacted project performance positively. Moreover, an important study in information systems research on the relationship between integration and perceived benefits was carried out by Singletary and Watson (2003). In this study, the theory of IT integration infrastructures was postulated and tested by empirical analysis. In their path analysis, Singletary and Watson (2003) validated their model which empirically confirmed that integration impacts firms’ perceived benefits.

3.5 Theory of IT Integration Infrastructures

There are many studies that analyze information systems in general, and ERP and integration in particular. However, because engineering as well as construction management fields are applied sciences, most of these works are applied research and thus are not based on vigorous theories verified by empirical studies. In IT integration research, the theory of IT integration infrastructures developed by Singletary (2003) is the only comprehensive theory and thus forms the basis of this study. In this section, this theory and the conceptual framework presented above is discussed, followed by a thorough explanation of the hypotheses.

This study is primarily based on IT integration infrastructures theory developed and tested by Singletary and Watson (2003) and Singletary (2003). The theory of IT integration infrastructures posits that certain characteristics of IT integration impact the degree of integration obtained and eventually the benefits attained from integration. This theory encompasses technical attributes related to the IT infrastructure of the firm, which define the technical properties of integration such as data-sharing, seamless integration, coordination, and real-time processing. The theory also accounts for the impact of stakeholder groups on the degree of integration and the benefits incurred from thereof. Stakeholder groups are defined as management, end-users, and IT professionals; and the effects of the level of their training and management objectives are modeled. Furthermore, the theory of IT integration infrastructures assesses the outcome of integration through a set of benefits, such as lower cost, customer service, competitive advantage, expanded capacity, and operational improvements.

The conceptual framework in this study draws heavily upon this theory of IT integration infrastructures, while also modifying and expanding it. First, in this study, the level of CEIS integration is constructed and operationalized according to Chang (2000)'s study, where different levels of system integration are coded as: no integration, partial relayed integration, partial seamless integration, full integration, full integration with other parties based on observable phenomena. No integration means that each department has a distinct IT system that is not related to other departments' IT systems. As the level of CEIS integration increases, the coding includes observable phenomena that is readily available and can be identified by the respondents. Whereas in Singletary's theory of IT integration infrastructures, level of integration is a latent variable calculated by certain technical attributes. The reason Chang (2000)'s codification of integration was selected for this study is because it was based on empirical research conducted for a highly similar project in the manufacturing industry.

Second, Singletary's theory assesses attitudes of different stakeholder groups towards IT integration, whereas the current study focuses only on the managers and management decisions related to integration, such as their support for integration, their attitudes towards possible business process changes due to integration, their commitment for financing the integration project and user-training. The significance of these critical factors for achieving higher levels of integration and benefits is assessed. This study uses the CSF approach to analyze the managerial factors vital for CEIS integration. CSF model was first developed by Rockart (1979) in order to help executives identify the critical areas that need further attention to ensure successful performance of their firms. CSF approach is seen as particularly valuable for firms considering more investment in IT (Boynton and Zmud 1984). It has also been adopted widely in the IS research (Soliman et al. 2001), and applied successfully to empirically analyze the CSF related to software integration and identify several factors that are critical to software integration (Soliman et al. 2001). Based on these arguments that are replete in literature and the above-mentioned theory, the following hypotheses are postulated:

> H1: Certain critical success factors are positively associated with higher levels of CEIS integration
>
> H2: CEIS integration level is positively associated with higher levels of perceived firm benefits
>
> H3: CEIS integration level is positively associated with CEIS satisfaction
>
> H4: Perceived firm benefits are positively associated with CEIS satisfaction
>
> H5: EIS type is positively associated with CEIS integration level
>
> H6: EIS type is positively associated with perceived firm benefits

3.6 Operationalization of Variables

The variables are operationalized by using measures already tested in the scientific literature. Following is a discussion of the variables selected in the framework based on the literature review and validation from ERP experts.

3.6.1 Operationalization of CEIS Integration Level

The measurement of CEIS integration level has been adopted from an integration model of computer aided production management (Chang 2000). In Chang (2000)'s research, a measurement scale to evaluate the level of integration in manufacturing related information systems was devised. The measurements which are adopted in this study were revised to fit the construction industry. These measures assign a level for the current state of CEIS applications. At the lowest level, the firm does not use any information system. Cases that have this level will not be included in the data analysis, since the unit of analysis in this research is a firm that has some form of CEIS. Table 3-1 details the explanations of the measures that are used to depict different levels of CEIS integration.

Table 3-1 Levels of CEIS Integration

Scale	Level of Integration	Explanation
0	No information system	Manual business processes and operation
1	No integration	Several stand-alone computer applications with no integration
2	Partial relayed integration	Several functions computerized and consolidated in certain periods (e.g. daily, weekly, monthly)
3	Partial seamless integration	Several functions integrated with seamless real-time integration
4	Full integration	All functions integrated with seamless real-time integration
5	Full Integration with other parties	All functions and many different business entities are integrated with seamless real-time integration

3.6.2 Operationalization of Critical Success Factors

A thorough literature review was conducted to identify the potential CSF for the integration of CEIS. The literature review included CSF related to IS success in general, and IS integration in particular (Barki and Pinsonneault 2002; Login and Areas 2005; Soliman et al. 2001). Within IS success, specific importance was given to studies related to ERP success (Akkermans and van Helden 2002; Al-Mashari et al. 2003; Holland and Light 1999; Hong and Kim 2002; Nah et al. 2001; Nah et al. 2003; Somers and Nelson 2004; Umble et al. 2003). This was coupled by CSF identified for IS in the construction industry (Love et al. 2001; Nitithamyong and Skibniewski 2004; Stewart et al. 2004; Tatari et al. 2004b; Voordijk et al. 2003). Many factors that are critical for enterprise information systems have been investigated in the cited literature. Based on prior research findings in the field and expert opinions, the following factors were identified as relevant to CEIS and thus were included in this study:

***1. Top management support and commitment*:** Commitment and support of top management is a crucial factor for the resulting level of CEIS integration for several reasons. First, without top management commitment, CEIS projects will never be realized. Second, employees will believe in the change only if their managers do. Third, CEIS often requires substantial effort of strategic planning by top managers. Finally, top management conviction that CEIS integration will yield critical benefits is vital for decisions to increase CEIS level of integration and implementing these decisions. Hence, top management support and commitment is a critical success factor impacting the level of CEIS integration and ensuing benefits.

2. Availability of financial investment in CEIS: Any plan to increase CEIS integration level might require significant financial investment. Even if top management commits to CEIS, if the firm does not possess the necessary funds, CEIS integration projects might not be initiated or carried out successfully. Moreover, any disruption of financial flow while CEIS integration project is undergoing might be detrimental to the general morale of the firm and might result in significant loss of investment. Therefore, the availability of financial investment in CEIS is identified as a critical success factor.

3. Clear CEIS strategy, goals and vision: A clear vision is needed for a successful CEIS implementation. This vision should be translated into a strategy, and goals to be realized in a specified period of time. The expectations from CEIS integration need to be analyzed and documented. Expectations of employees should be set clearly as CEIS integration might result in job re-definition and change in organizational structure. For these reasons, having a clear CEIS strategy, goals and vision is a critical success factor for level of CEIS integration and proceeding benefits.

4. Business process change to fit CEIS: While updating the information system or installing a new one, adjusting the business processes to fit the new information system becomes vital for success (Holland and Light 1999). Business process change may become particularly critical when the information systems of different departments are integrated. Before integration takes place, many departments may have been working with minimal interaction with other departments. CEIS integration forces departments to cooperate in order to integrate the information flow and business processes. Therefore, business process change to fit CEIS is a critical success factor impacting the level of CEIS integration and critical benefits resulting from thereof.

5. Minimum customization of CEIS to fit business processes: While business process adjustment is undertaken, minimizing the customization of CEIS should be sought. This is especially important to lower the cost of implementation and to standardize the business processes. The more CEIS is customized, the higher are the maintenance costs. Hence, having minimum levels of CEIS customization to fit business processes of the firm is a critical success factor affecting the level of CEIS integration and the critical benefits to be obtained.

6. Adequate vendor support from application suppliers: Technical assistance, update and emergency maintenance are important vendor support criteria for successful implementation and integration, as cited in the literature. Without proper support, the benefits sought from CEIS might not be realized due to system related issues. For this reason, adequate vendor support from application suppliers is a critical success factor for level of CEIS integration and resulting benefits.

7. MIS department competence in implementing CEIS: Competence of the MIS department is also important in order to realize the intended goals of the CEIS vision and strategies. MIS department that is not adequately qualified to maintain and support the new integration level might put the whole system in jeopardy. This becomes especially critical in construction firms where timely information is critical. Thus, competence of the MIS department in implementing CEIS is a critical factor for the success of CEIS integration and the consequential firm benefits.

8. Clear allocation of responsibilities for CEIS: Since many departments are engaged in CEIS implementation and work in collaboration, it is important to define the responsibilities clearly and allocate them prudently beforehand in order to prevent any problems that might occur during the implementation phase and thereafter. If departments and individuals are not clear about their new role as integration increases, this ambiguity might adversely affect the benefits of CEIS.

9. User training for CEIS: User training is an important factor for the success of the CEIS. Users not properly trained in the new CEIS might cause suboptimal levels of benefits or put the whole operation in jeopardy. Insufficient user training may also affect the user motivation regarding CEIS and might bring about user aversion. This aversion might result in less system use and prompt them to do their work out of the system as much as possible. Therefore, sufficient user training for CEIS is a critical success factor affecting the level of CEIS integration and the ensuing benefits.

3.6.3 Operationalization of Firm Characteristics

Based on the extant literature and empirical findings, several firm characteristics that may impact the level of CEIS integration and the resulting benefits has been identified. First, firm size can be critical in implementing EIS (Karim et al. 2007). Larger firms might implement more sophisticated CEIS because of their larger operations and availability of funds. Second, geographical dispersion might be a decision factor for increasing the level of CEIS integration. Local firms might not need the level of integration that a global firm might necessitate.

Third, it might be the case that certain types of construction firms are more CEIS integration friendly than others. For instance, firms specializing in residential construction might not need the level of CEIS integration that a commercial firm might need. Fourth, the same question can be asked for firms specializing in heavy construction, industrial construction, and specialty construction. It might be the case that firms specializing in a certain area are more CEIS friendly than others. Finally, it is worthwhile to analyze whether certain firm strategies have an impact on CEIS level of integration and CEIS benefits. Hence, these firm characteristics are included in the conceptual framework and the existence of relationships between these characteristics and the nature of these relationships will be tested.

3.6.4 Operationalization of EIS Type

Firms have different strategies when it comes to their EIS (see Table 3-2). Some firms use legacy systems that generally reside in main-frame computers, and are custom designed. These kinds of systems are mostly outdated and require continuous maintenance by IT departments. ERP is another type of EIS where users purchase some of the applications or the entire system from the vendor. As is discussed in the previous chapter, currently major ERP vendors provide modules that encompass the entire operations. Some firms choose to use collection of systems and create custom integration mechanisms to connect them. Such a strategy is commonly chosen in order to obtain the maximum benefit from the best software in their respective fields. This research investigates whether there is a significant relationship between any particular EIS type and CEIS level of integration. It also analyzes the CEIS benefits that pertain to these different EIS types.

Table 3-2 EIS Types

EIS Type	Explanation
Legacy system	Information system previously designed specifically for the firm's needs
Enterprise Resource Planning (ERP)	Off-the-shelf, commercially available enterprise information system
Best-of-breed	Collection of standalone applications connected to each other
Stand-alone	Collection of individual applications NOT connected to each other

3.6.5 Operationalization of Perceived Firm Benefits

The potential impacts of EIS on the firm has strategic, organizational, technological and behavioral dimensions, which necessitates a broader perspective of EIS evaluation (Stefanou 2002). Stefanou (2002) contended that since ERP systems are strategic and operational in nature, the evaluation has to be made from these main perspectives (see Table 3-3). From strategic aspect, it is imperative to identify the degree EIS contributes to business strategy of the firm (Fitzgerald 1998). From the operational aspect, it is critical to evaluate the aspects that contribute to cost reduction and operational efficiency.

Irani and Love (2002) classified the EIS benefits in three categories; strategic, tactical, and operational. They argued that the level of EIS planning will yield these benefits. The firms develop strategies for their investments, especially a large investment such as EIS. Once these strategic goals are set, they devise tactical plans on how to accomplish these goals. Consequently, operational benefits emerge as a result of strategies developed and tactics utilized.

Table 3-3 ERP Evaluation Factors identified by Stefanou (2002)

Strategic Level Factors	**Operational level factors**
• Contribution to business vision and strategy • Alignment of business and technology strategy • Flexibility and scalability of IT architecture • Flexibility and adaptability of ERP solution to changing conditions • Integration of business information and processes • Identification of the various components and magnitude of the project's risk • Impact of ERP on the decision making process • Competitors' adoption of ERP • Impact of ERP on cooperative business networks • Estimation of future intensity of competition and markets' deregulation • Impact of the decision to implement or not an ERP system on the competitive position and market share • Estimation of the total cost of ERP ownership and impact on organizations' resources • Analysis and ranking of alternative options in terms of the competitive position of the organization	• Impact of ERP on transaction costs • Impact of ERP on time to complete transactions • Impact of ERP on degree of business process integration • Impact of ERP on intra- and inter-organizational information sharing • Impact of ERP on business networks • Impact of ERP on reporting • Impact of ERP on customer satisfaction • Estimation of costs due to user resistance • Estimation of costs due to personnel training • Estimation of costs due to external consultants • Estimation of costs due to additional applications

On the other hand, the Shang and Seddon benefit framework classifies potential EIS benefits into 21 lower level measures grouped in five main dimensions; operational, managerial, strategic, IT infrastructure, and organizational benefits (Shang and Seddon 2002). Shang and Seddon (2002) constructed their framework based on a review of 233 success stories presented by EIS vendors. Shang and Seddon benefit framework for EIS benefits was adopted in this study due to its comprehensiveness. The five dimensions included in the following analysis are based on Shang and Seddon's benefit framework and are discussed in greater detail below.

1) Operational benefits: Operational activities include daily activities that constitute the major part of business. In the construction context, they involve daily operations of construction projects, including receiving construction supplies to the site, using equipment in the project site, and labor work. These processes are generally sought to be optimized by using maximum levels of automation. With the increase of IT use, it is expected to lower the cost of day-to-day operations. Since one of the CEIS goals is to streamline the business processes, firms expect to receive operational benefits by utilizing them. These benefits include cost reduction, cycle time reduction, productivity improvement, quality improvement, and improved customer service.

2) Managerial benefits: Managers base their decisions on whether or not to bid on new projects, increase labor, or lease new equipment, on managerial reports. Managerial reports are generally characterized as a bird's eye view of operations and exceptions. It is expected that by integrating the information systems of the firm, access to this data will be more efficient. Also, the accuracy of the data is expected to increase by eliminating the need of double entry resulting from disparate information systems. Seddon and Shang (2002) summarize these managerial benefits as achieving better resource management, improved decision making and planning and improved performance in different operating divisions of the organization.

3) Strategic benefits: With the promise of gaining more accurate information on a timely basis, competitive advantage may be gained. Getting accurate and timely information about their assets, their current strength and weakness, would enable the firms to act quickly and pursue their strategic goals. Also, the use of EIS might give firms more competitive advantage when compared to their rivals. These strategic benefits are summarized as support for business growth, support for business alliance, building business innovations, building cost leadership, generating product differentiation, and building external linkages.

4) IT infrastructure benefits: IT infrastructure includes sharable and reusable IT resources which provide the basis for the business applications of the firm (Earl 1989). Through CEIS implementation, the firm might benefit from a scalable IT infrastructure that can support the further growth of business. A durable and flexible IT infrastructure is needed for CEIS to run in the whole enterprise. Main-frame computers would need to be retired and new state-of-the-art servers need to be purchased. Also, by using vendor provided EIS, the firm might decrease the number of IT resources significantly. Since custom applications would be retired, it might not be necessary to keep a large number of developers. As a result, IT infrastructure benefits for a firm can be summarized as building business flexibility for current and future changes, IT cost reduction, and increased IT infrastructure capability.

5) Organizational benefits: Since CEIS requires rethinking the business processes, it might lead the firm to adopt a new vision within the firm. CEIS requires extensive training of employees throughout the firm, which can potentially increase learning the best practices and applying them in the firm as a whole. The organizational benefits that may result from CEIS integration are summarized in the framework as changing work patterns, facilitating organizational learning, empowerment, and building a common vision.

Table 3-4 Shang and Seddon Benefit Framework (2002)

Dimensions	**Sub-dimensions**
Operational	Cost reduction
	Cycle time reduction
	Productivity improvement
	Quality improvement
	Customer service improvement
Managerial	Better resource management
	Improved decision making and planning
	Performance improvement
Strategic	Support for business growth
	Support for business alliance
	Building business innovations
	Building cost leadership
	Generating product differentiation
	Building external linkages
IT infrastructure	Building business flexibility for current and future changes
	IT cost reduction
	Increased IT infrastructure capability
Organizational	Changing work patterns
	Facilitating organizational learning
	Empowerment
	Building common vision

Chapter 4: Survey Design and Data Collection

4.1 Introduction

In this chapter, the survey design and data collection methods are explained in detail, followed by presentation of the descriptive summary of collected data.

4.2 Survey Design and Data Collection

Survey research provides the ability to establish relationships and to make generalizations about given populations. The specification of industry needs through questionnaires filled by active users has been identified as a successful method for ensuring that the user requirements are met by the system under development (Thiels et al. 2002). Identifying the needs and problems of the potential users helps the problems to be addressed correctly. Hence, a survey was conducted to quantify the current state of CEIS and to test the aforementioned hypotheses. The objective of this questionnaire was to obtain information from selected construction related firms about their existing business solutions and to determine the emerging trends and the potential needs of the construction industry related to CEIS.

The survey, depicted in Appendix A, included questions that seek to gather information about the respondents' experience in construction, location, business classification, specialty, annual revenues, and geographical dispersion. Other questions were intended to elicit information about the use of PMIS and ERP, as well as the perceived level of integration achieved by the implementation of these systems.

The Likert scale is most appropriate for measuring attitude patterns or exploring theories of attitudes (Oppenheim 1992), and have been the most popular scale for obtaining opinions from respondents (Fellows and Liu 1997). Accordingly, the Likert scale was chosen for the survey for this research, since this project sought to measure the attitudes of the respondents. Some of the advantages of the Likert scale are the ease in usability and precision of information obtained about the degree of the attitudes towards a given statement (Oppenheim 1992). When measuring attitudes using a Likert scale, respondents were asked to position their attitudes towards a statement on a scale from strong agreement to strong disagreement. Depending on the content of the question, in this survey, attitudes were scored 5 for "very high" or "significant improvement", 4 for "high" or "some improvement", 3 for "neutral" or "no change", 2 for "low" or "some detriment", 1 for "very low" or "significant detriment". The Likert scale also helped in the subsequent statistical analysis of the attitudes.

The population to be investigated consisted of firms that utilize CEIS. Data was gathered from stakeholders with reliable working knowledge of their firms' information systems. The respondents included construction industry executives, operation managers, project managers, and IT managers. The survey was publicized to Engineering New Record's top 400 contractors, and to other construction related firms in the United States. More than 1000 e-mail addresses were utilized for the survey. Also, several related e-groups and newsletters were notified. The Internet was used to administer the survey. The advantages of using web-based survey include easy, instant and costless access, instant real-time feedback from respondents, responses being organized in a single database file, and simplifying the analysis and decreasing the risk of errors. Moreover, response rates are expected to be higher than paper-based surveys that take considerably more time and effort to fill out and return to the survey distributor. The survey web page was designed in the Zope™ environment in the School of Engineering at Purdue University. Data from the completed questionnaire were analyzed using SPSS™. 114 respondents submitted valid answers unto the survey web page. The rate of response to the survey was 11%. It has been acknowledged in construction literature that surveys that target construction firm managers generally result in low response rates due to the chaotic nature of managing projects and inability to allocate sufficient time to answering survey questions (Kartam et al. 2000; Vee and Skitmore 2003). Another reason for this low rate may have been the unavailability of an enterprise information system in all the firms that were contacted. As an example, some respondents asked in their email responses about the meaning of ERP, which demonstrated a widespread inexperience with integrated management information systems. In order to validate this assertion, the firm size proportion in this study was compared to the construction industry. While about 80 % of construction firms have 10 employees or less (U.S. Department of Labor 2009), the smallest firm size in revenue ($200 million) in the survey results constituted around 50 % of the respondents' firms. This finding confirms that the population selected is not all construction firms, but construction firms that have enterprise information systems, which would more likely be firms that have more than 5 employees. Since the survey was sent to email addresses of construction firm managers without taking into account their size, population average would confirm the low response rate. The number of responses was statistically valid (n=114) to test the hypotheses and to infer population tendencies.

4.3 Reliability and Validity of the Survey

The reliability of the questionnaire ensures that it will give similar results if it is performed by homogeneous group of respondents with similar values, attitudes, and experiences. In this study, Cronbach's alpha coefficient of reliability was used to assess the reliability of the survey instrument. Values over .70 are considered reliable for the survey instrument (Field 2009). Table 4-1 shows the values of Cronbach's alpha that were computed using SPSS for related measures. The measures were constructed using multi items and grouped based on factor analysis (see sections 5.2 and 5.3). The instruments show high internal consistency: operational benefits, α=.932; strategic benefits, α=.894; IT infrastructure benefits, α=.0.782; organizational benefits, α=.859; firm readiness, α=.844; firm commitment, α=.748. This indicates the high reliability of the survey instrument utilized in this study.

Content validity of the survey instrument was examined by an extensive inspection of the literature for all related items to be included (see section 3.6.2). Also, a group of academics, ERP experts, and construction firm managers were asked to validate the content and clarity of the questions. The survey instrument was revised based on these reviews before it took its final form.

Table 4-1 Internal Reliability of the Survey Instrument

Variable	**Cronbach's Alpha**
Operational Benefits	.932
Strategic Benefits	.894
IT Infrastructure Benefits	.782
Organizational Benefits	.859
Firm Readiness	.844
Firm Commitment	.748

Construct validity was assessed by employing factor analysis (see sections 5.2 and 5.3). In the factor analyses, the benefit dimensions were reduced to four and the items were grouped accordingly. Factor analysis regarding CSF was conducted as well and the CSF were grouped into two dimensions and these constructs were validated.

Also, since a single survey instrument was used, we assessed whether or not common method bias exists in the survey (see Appendix B 7). We conducted factor analysis of all items and confirmed that the items load on several components rather than one (Woszczynski and Whitman 2004). This test strengthened the view that common method bias does not exist in the survey.

4.4 Descriptive Summary

4.4.1 Experience of Respondents

Figure 4.1 illustrates the respondents' number of years of experience in the construction industry. Approximately 80 % of the respondents stated that they have over 10 years of experience. Also, it was found that the mean of their experience is 21.7 years. A large percentage (80.4 per cent) stated that they have over ten years of experience.

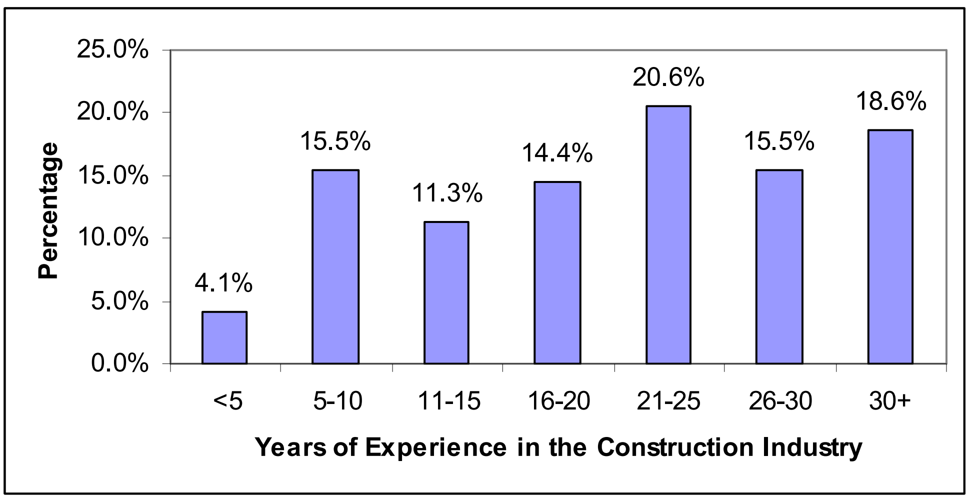

Figure 4.1 Years of experience of respondents

4.4.2 CEIS Integration Level

The CEIS level of integration in the firms of the respondents is shown in Table 4-2. Only one respondent stated that their firm had full seamless integration internally and externally. 3 firms (2.78%) had no information system, 22 firms had no integration (20.37%), 35 firms (32.41%) had partial relayed integration, 34 firms (31.48%) had partial seamless integration, 13 firms (12.04%) had full integration, and 1 firm (.93%) had full integration with other parties.

Table 4-2 Descriptive Summary of CEIS Integration Level

CEIS Integration Level	**Frequency**	**Percent**
No information system (manual business processes and operation)	3	2.78
No integration (several stand-alone computer applications with no integration)	22	20.37
Partial relayed integration (several functions computerized and consolidated in certain periods	35	32.41
Partial seamless integration (several functions integrated with seamless real-time integration)	34	31.48
Full integration (all functions integrated with seamless real-time integration)	13	12.04
Full integration with other parties (all functions and many different business entities are integrated with seamless real-time integration)	1	0.93
Total	108	100

Regarding the overall satisfaction with the level of CEIS integration, 11.4% had very low satisfaction, 26.7% had low satisfaction, 42.9% were neutral, 18.1% had high satisfaction, and only 1% had very high satisfaction. On a related question, whether the firms were increasing or planning to increase their CEIS, 16.5% stated that they were satisfied with their current level of integration, 48.5% stated that they were in the process of increasing their level of integration, and 35% stated that their firm was planning to increase their CEIS level of integration.

Table 4-3 Descriptive Summary of CEIS Integration Satisfaction and Plan

		Frequency	Percent
CEIS Integration Satisfaction	Very Low	12	11.4
	Low	28	26.7
	Neutral	45	42.9
	High	19	18.1
	Very High	1	1.0
Plan to Increase CEIS Integration	Satisfied	17	16.5
	Currently Increasing	50	48.5
	Plans to increase	36	35.0

4.4.3 Descriptive Summary of Firm related Characteristics

Table 4-4 summarizes the descriptive summary of firm characteristics. In the collected data, 83 firms (80.6%) were from the United States of America, and 20 firms (19.4%) were from other parts of the world. 3 firms (2.94%) were architectural, 42 firms (41.18%) were general contractors, 12 firms (11.76%) were specialty, 25 firms (24.51%) were engineering, and 20 firms (19.61%) were construction management firms. The specialties of the firms, according to the standard industrial code (SIC), were primarily commercial construction (64.4%), followed by industrial construction (51%) and heavy construction (50%). Residential construction was represented by 18.3% and specialty construction was represented by 26%.

Table 4-4 Descriptive Summary of Firm Characteristics

Firm Characteristics		**Frequency**	**Percent**
Firm Base	USA	83	80.6
	Non USA	20	19.4
Firm Role	Architectural firm	3	2.94
	General contractor	42	41.2
	Specialty contractor	12	11.8
	Engineering firm	25	24.5
	Construction Management	20	19.6
Firm Specialty	Residential	19	18.3
	Commercial	67	64.4
	Heavy	52	50.0
	Industrial	53	51.0
	Specialty	27	26.0
Firm Size	Less than $200 million	50	46.7
	Between $200 million and $750 million	24	22.4
	Between $750 million and $1.5 billion	9	8.4
	More than $1.5 billion	24	22.4
Firm Geographical Dispersion	Local market	13	12.3
	Multiple market areas in one region	22	20.8
	Multiple market areas across the nation	33	31.1
	Multiple market areas across the continent	6	5.7
	Multiple market areas across the world	32	30.2
Firm Strategy	Partnering	95	93.1
	TQM	63	61.8
	SCM	20	19.6
	Lean	28	27.5

Regarding the annual revenues of firms, 46.7 % had less than US$200 million, 22.4% had between $200 million and $750 million, 8.4% had between $750 million and $1.5 billion, and 26% had more than $1.5 billion yearly revenue. 12.3% of the firms operate in their local market only, 20.8% operate in multiple market areas in one region, 31.1% operate in multiple market areas across the nation, 5.7% operate in multiple market areas across the continent, and 30.2% operate in multiple market areas across the world. Lastly, 93.1% of the firms utilize partnering, 61.8% of the firms utilize TQM, 19.6% of the firms utilize SCM, and 27.5% of the firms utilize lean construction.

4.4.4 Descriptive Summary of EIS/PMIS related Characteristics

Table 4-5 summarizes the descriptive summary of EIS/PMIS types and satisfaction levels. 19.2 % of the firms use legacy system, 51.9% use ERP, 14.4% use best-of-breed, and 14.4% use stand-alone systems. 4.8% had very low satisfaction regarding their EIS, 18.1% had low satisfaction, 46.7% were neutral, 26.7% had high satisfaction, and 3.8% had very high satisfaction. Regarding the use of PMIS, 71.2% use windows-based PMIS, 9.6% use Web-enabled PMIS, 4.8% use Web-based subscription, 11.5% use Web-based solution package, and only 2.9% use an ERP project management module. Only 1% had very low satisfaction regarding their EIS, 16.3% had low satisfaction, 42.3% were neutral, 31.7% had high satisfaction, and 8.7% had very high satisfaction.

Table 4-5 Descriptive Summary of EIS/PMIS

		Frequency	Percent
PMIS Type	Windows-based	74	71.2
	Web-enabled	10	9.6
	Web-based subscription	5	4.8
	Web-based solution package	12	11.5
	ERP project management module	3	2.9
PMIS Satisfaction	Very low	1	1.0
	Low	17	16.3
	Neutral	44	42.3
	High	33	31.7
	Very high	9	8.7
EIS Type	Legacy system	20	19.2
	Enterprise Resource Planning (ERP)	54	51.9
	Best-of-breed	15	14.4
	Stand-alone	15	14.4
EIS Satisfaction	Very low	5	4.8
	Low	19	18.1
	Neutral	49	46.7
	High	28	26.7
	Very high	4	3.8

4.4.5 Scale Ranking of CEIS Integration Critical Success Factors

Table 4-6 illustrates the ranking by mean values of the critical factors identified by the respondents. As can be seen from the table, "top management support" scored the highest among the critical factors related to CEIS. Other highest average scores were "continuous interdepartmental cooperation", "availability of financial investment", "continuous interdepartmental communication", and "clear allocation of responsibilities for CEIS implementation" respectively. Finally, "poorly defined construction business processes", "user training for CEIS", "business process change to fit CEIS", and "minimum customization of CEIS to fit business processes" scored lowest among the critical factors.

Table 4-6 CSF Ranking by Mean Values

Critical Factors	**Mean**	**SD**	**Overall Rank**
Top management support and commitment	3.83	0.995	1
Clear allocation of responsibilities for CEIS	3.37	0.967	2
MIS department competence	3.34	1.055	3
Availability of financial investment in CEIS	3.32	0.991	4
Adequate vendor support	3.24	0.838	5
Clear CEIS strategy, goals and vision	3.11	1.073	6
User training for CEIS	3.07	1.018	7
Minimum customization of CEIS	3.02	1.015	8
Business process change	2.97	0.979	9

4.4.6 Scale Ranking of Perceived CEIS Benefits

CEIS benefits were ranked on categorical and overall basis by the respondents. According to Table 4-7, the top five measures with top mean value scores were "improved efficiency", "cycle time reduction", "improved decision making and planning", "productivity improvement" and "better resource management" respectively. Among operational benefits, “cycle time reduction” was ranked top, whereas among managerial benefits “improved efficiency” was ranked first. Among strategic benefits, “support for business growth” was ranked highest, and among IT infrastructure related benefits “increased business flexibility” was ranked first. Also, among organizational benefits “building common vision for the firm” was ranked highest. Furthermore, “IT cost reduction” was ranked lowest among overall benefit measures. Next lowest measures were three strategic benefits; “build better external linkage with suppliers, distributors and related business parties”, “enable expansion to new markets” and “building business innovations.”

After categorizing the data, managerial benefits were ranked highest amongst other categories (see Table 4-8.) This was followed by operational, organizational, strategic and IT infrastructure benefits respectively. On the other hand, benefits related to IT infrastructure were ranked lowest among other categories.

Table 4-7 Ranking by Mean Values of the Responses on CEIS Benefits

Benefits	Measures	Mean	SD	Var	Category Rank	Overall Rank
Operational	Cycle time reduction	3.67	0.98	0.95	1	2
	Productivity improvement	3.62	0.95	0.91	2	4
	Quality improvement	3.59	0.97	0.94	3	8
	Cost Reduction	3.49	0.90	0.81	4	12
Managerial	Improved efficiency	3.68	0.97	0.94	1	1
	Improved decision making and planning	3.67	0.89	0.79	2	3
	Better resource management	3.62	0.86	0.74	3	5
Strategic	Support for business growth	3.57	0.96	0.91	1	9
	Generating or sustaining competitiveness	3.52	0.98	0.97	2	11
	Building business innovations	3.42	0.92	0.84	3	16
	Enable expansion to new markets	3.23	0.98	0.96	4	17
	Build better external linkage with suppliers, distributors and related business parties	3.23	1.02	1.04	5	18
IT Infrastructure	Increased business flexibility	3.48	0.90	0.81	1	13
	Increased IT infrastructure capability (flexibility, adaptability, etc.)	3.42	0.88	0.77	2	15
	IT costs reduction	2.97	0.99	0.99	3	19
Organizational	Building common vision for the firm	3.60	0.98	0.96	1	6
	Facilitate business learning and broaden employee skills	3.60	0.91	0.84	2	7
	Support business organizational changes in structure & processes	3.54	0.76	0.58	3	10
	Empowerment of employees	3.48	0.92	0.85	4	14

Table 4-8 Ranking by Mean Values of the Responses on CEIS Benefits

Benefits	Mean
Managerial	3.66
Operational	3.59
Organizational	3.56
Strategic	3.39
IT Infrastructure	3.29

4.5 Data Screening

Before proceeding with the data analysis, all variables were screened for possible code, statistical assumption violations, missing values, and outliers. SPSS

Frequencies, Explore, and Plot procedures were used in this screening. During the initial screening, three cases (67, 82, and 88) had integration level as ‘0’; no information system, and subsequently were removed from further data analysis (see Chapter 3 for further discussion).

4.5.1 Missing Values

The 114 cases were screened for missing values on 33 continuous variables (see Appendix B 1). Four cases (27, 49, 56, and 66) were found to be submitted almost without responses and were dropped. After removing these cases, the missing data percentage ranged from 0% to 6.80%. The relative frequency of cases with missing data was small enough to be ignored and the remaining cases were included in the subsequent tests. Based on Myers et al (2006), list-wise deletion method was chosen in factor analysis, ANOVA, and regression analysis. Pair-wise deletion method was chosen for descriptive correlation analysis.

4.5.2 Outliers

Box-Plots were used to identify potential outliers. Grubbs’ test for detecting outliers was conducted on variables to verify if these cases were outliers. Grubbs’ test which is sometimes called *extreme studentized deviate* detects one outlier at a time. Once an outlier is found it is removed from the dataset and the test is repeated until no outliers are detected (Barnett and Lewis 1994). Based on the Grubbs’ test no univariate outliers were detected.

4.5.3 Normality of Scale Variables

To ensure normality of the variables, frequency distributions were plotted for each of the variables. Likert scales are considered approximately normal if the frequency distribution is close to normal (Morgan 2004). Additionally, the skewness and kurtosis values of each distribution were calculated (see Appendix B 1). In a normal distribution, the values of skewness and kurtosis should be zero. Since all the values of skewness and kurtosis for all scale variables were in the range of +1.0 to -1.0, they were found adequate to include in subsequent tests.

4.5.4 Multicollinearity

In order to assess whether any variable should be excluded from the statistical analysis due to multicollinearity, correlation matrix was produced between all variables in the final conceptual framework (see Appendix B 6). Based on this analysis, all measures regarding firm benefits were found to correlate fairly well ($p < .05$) and none of the correlation coefficients were particularly large ($R < .55$). From this assessment, all variables were found to be adequate for subsequent analysis and no variables were eliminated.

Chapter 5: Data Analysis and Results

5.1 Introduction

This chapter presents the results of the analyses conducted based on the survey data. First, the principal component factor analysis was performed for perceived firm benefits, CSF, and CEIS satisfaction. Second, comparison of samples related to firm characteristics was analyzed. Third, the conceptual framework was analyzed utilizigin several regression models. Last, the relationship between CEIS integration and perceived firm benefits was analyzed separately.

5.2 Principal Component Factor Analysis of Perceived Firm Benefits

An exploratory factor analysis using a principal component extraction method and a varimax rotation of 19 benefit measures was conducted. The purpose of factor analysis is to identify a small number of dimensions underlying a relatively large set of variables. These small numbers of variables are able to account for most of the variability in the original measures (Sheskin 2007). Since there were a large number of critical factors and firm benefits, using factor analysis was chosen as an appropriate tool to possibly reduce the data to a small number of factors. Also, it was to ensure that our benefit related measures were grouped correctly; operational, managerial, IT infrastructure, strategic, and to observe if a better grouping was to be found. Further analysis such as regression and ANOVA can then be conducted on the newly formed components rather than individual measures. Moreover, confirmatory factor analysis ensures the reliability of the scale (Meyers et al. 2006).

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were applied. KMO measures over .70 are considered above sufficient (Meyers et al. 2006). The KMO measure of sampling adequacy was .915, indicating that the present data were suitable for principal component factor analysis. Similarly, Bartlett's test of sphericity was 1279.79 with significance level of $p < .001$. This test indicated that the R-matrix is not identity matrix and that there is sufficient correlation between variables that are necessary for analysis; therefore, factor analysis was verified to be appropriate (see Table 5-1).

Table 5-1 KMO and Bartlett's Test for Firm Benefits

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.915
Bartlett's Test of Sphericity	Approx. Chi-Square	1279.793
	df	171.000
	Sig.	.000

Based on the factor analysis, SPSS extracted four factors out of the 19 measures which had eigenvalues greater than 1.0. The four dimensions cumulatively explained 73.37% of the total variance (see Appendix B 4). The set of measures were regrouped based on the factor analysis and five dimensions were reduced to four. As a result, operational and managerial benefits were regrouped as operational benefits, since that was the dominant factor.

As can be seen in Appendix B 4, Factor 1: Operational Benefits (eigenvalue = 4.91) accounted for 25.86% of the variance and had six items; Factor 2: Strategic Benefits (eigenvalue = 3.54) and accounted for 18.64% of the variance and had six items; Factor 3: Organizational Benefits (eigenvalue = 2.96) accounted for 15.57% of the variance and had three items; and Factor 4: IT Benefits (eigenvalue = 2.53) accounted for 13.31% of the variance and had two items.

Table 5-2 Rotated Component Matrix for Firm Benefits

Variables	**Component**			
	1	**2**	**3**	**4**
Improved efficiency	**.799**	.295	.202	.085
Cost Reduction	**.799**	.127	.137	.265
Productivity improvement	**.784**	.425	.104	.170
Cycle time reduction	**.767**	.154	.330	.166
Improved decision making and planning	**.703**	.333	.180	.213
Quality improvement	**.698**	.252	.283	.272
Better resource management	**.562**	.527	.263	-.031
Building business innovations	.283	**.782**	.306	.064
Enable expansion to new markets	.145	**.730**	.215	.345
Support for business growth	.362	**.722**	.304	.004
Build better external linkage with suppliers and distributors	.409	**.663**	-.078	.350
Generating or sustaining competitiveness	.360	**.508**	.393	.443
Support business organizational changes in structure & processes	.092	.148	**.728**	.416
Empowerment of employees	.508	.105	**.710**	.165
Facilitate business learning and broaden employee skills	.178	.353	**.690**	.133
Building common vision for the firm	.315	.226	**.669**	.216
Increased IT infrastructure capability	.123	.114	.319	**.785**
IT costs reduction	.409	.076	.116	**.733**
Increased business flexibility	.163	.437	.362	**.645**
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				
a. Rotation converged in 7 iterations.				

Table 5-2 summarizes the respective factor loadings for the four components and are sorted by size. According to Hair et al. (1998), the factor loadings will have practical significance according to the following guidelines; ±0.3 minimal, ±0.4 more Important, ±0.5 practically significant. Factor loadings were fairly high with a range of .80 to .65. Cronbach's coefficient alpha for the five dimensions are higher from the acceptable limit; .50, and indicates good subscale reliability.

Table 5-3 summarizes the factor loadings and their respective dimensions. Principal analysis factor analysis scores were saved using the regression method as variables *OB*, *SB*, *OB*, and *IB* denoting the first initials of the four components. These set of measures are used in subsequent tests. Utilizing factor scores in this way is deemed analytically more appropriate than computing a mean by simply assigning equal weights to items (Lastovicka and Thamodaran 1991).

Table 5-3 Four Firm Benefit Components and their Associated Measures

Component	**Measures**	**Factor Loading**
Operational Benefits α = .932	Improved efficiency	.799
	Cost Reduction	.799
	Productivity improvement	.784
	Cycle time reduction	.767
	Improved decision making and planning	.703
	Quality improvement	.698
	Better resource management	.562
Strategic Benefits α = .894	Building business innovations	.782
	Enable expansion to new markets	.730
	Support for business growth	.722
	Build better external linkage with suppliers and distributors	.663
	Generating or sustaining competitiveness	.508
Organizational Benefits α = .859	Support business organizational changes in structure & processes	.728
	Empowerment of employees	.710
	Facilitate business learning and broaden employee skills	.690
	Building common vision for the firm	.669
IT Benefits α = .782	Increased IT infrastructure capability	.785
	IT costs reduction	.733
	Increased business flexibility	.645

5.3 Principal Component Factor Analysis of Critical Success Factors

Principal component analysis was conducted on CSF to create more reliable constructs for the SEM model. An exploratory factor analysis using principal component extraction method and varimax rotation of 9 CSF measures was conducted (see Appendix B 5). The KMO measure of sampling adequacy was .869, indicating that the present data was suitable for principal component factor analysis. Similarly, Bartlett's test of sphericity was 336.832 with significance level of $p < .001$. This test indicated that the R-matrix is not identity matrix and that there is sufficient correlation between variables that are necessary for analysis; therefore, factor analysis was verified to be appropriate.

Table 5-4 Two Firm Critical Success Dimensions and their Associated Measures

Component	Measures	Factor Loading
Firm Commitment	Minimum customization of CEIS	.777
	Availability of financial investment in CEIS	.698
α = .748	Business process change	.615
	Top management support and commitment	.596
	Adequate vendor support	.483
Firm Readiness	User training for CEIS	.832
	Clear CEIS strategy, goals and vision	.774
α = .844	Clear allocation of responsibilities for CEIS	.755
	MIS department competence	.729

Based on the factor analysis, SPSS extracted two factors out of the 9 measures which had eigenvalues greater than 1.0. The four dimensions cumulatively explained 60.03% of the total variance. The set of measures were regrouped based on the factor analysis. As a result, two dimensions, firm readiness and firm commitment were created based on the general direction of the variables. Table 5-4 summarizes the factor loadings and their respective dimensions. Cronbach's coefficient alpha for the two dimensions are higher than the acceptable limit; .50, and indicates strong subscale reliability. Principal analysis factor analysis scores were saved using the regression method as variables *RDNS* and *COMMT* denoting firm readiness and firm commitment, respectively. These set of measures are used in subsequent tests. Utilizing factor scores in this way is deemed analytically more appropriate than computing a mean by simply assigning equal weights to items (Lastovicka and Thamodaran 1991).

5.4 Principal Component Factor Analysis of CEIS Satisfaction

Principal component analysis was conducted on CEIS satisfaction to create more reliable constructs for the SEM model. An exploratory factor analysis using principal component extraction method of 2 CEIS satisfaction measures was conducted (see Appendix B 5). The KMO measure of sampling adequacy was .5, indicating an acceptable value for principal component factor analysis (Field 2009). Bartlett's test of sphericity was 21.356 with significance level of $p < .001$. This test indicated that the R-matrix is not identity matrix and that there is sufficient correlation between variables that are necessary for analysis; therefore, factor analysis was verified to be appropriate. Based on the factor analysis, SPSS extracted one factor out of the two measures which had eigenvalues greater than 1.0, explaining 71.78% of the total variance. Principal analysis factor analysis score was saved using the regression method as variable SAT denoting CEIS satisfaction.

5.5 Final Conceptual Framework of CEIS Integration

Based on the factor analyses, the final conceptual framework is depicted below (see Figure 5.1). CSF are categorized into two constructs; firm readiness and firm commitment. Perceived firm benefits are categorized into four constructs; operational benefits, strategic benefits, organizational benefits, and IT infrastructure benefits. The details of the hypotheses are presented in Table 5-5.

Table 5-5 Detailed Hypotheses

Hypotheses	**Predictor Variables**	**Dependent Variable**
H1: Certain critical success factors are positively associated with higher levels of CEIS integration	a) Firm readiness; b) firm commitment	CEIS integration
H2: CEIS integration level is positively associated with higher levels of perceived firm benefits	CEIS integration	a) Operation benefits; b) strategic benefits; c) organizational benefits; d) IT infrastructure benefits
H3: CEIS integration level is positively associated with CEIS satisfaction	CEIS integration	CEIS satisfaction
H4: Perceived firm benefits are positively associated with CEIS satisfaction	a) Operation benefits; b) strategic benefits; c) organizational benefits; d) IT infrastructure benefits	CEIS satisfaction
H5: EIS type is positively associated with CEIS integration level	a) Legacy; b) ERP; c) BOB; d) stand-alone	CEIS integration
H6: EIS type is positively associated with perceived firm benefits	a) Legacy; b) ERP; c) BOB; d) stand-alone	a) Operation benefits; b) strategic benefits; c) organizational benefits; d) IT infrastructure benefits
H7: Certain critical success factors are positively associated with perceived firm benefits	a) Firm readiness; b) firm commitment	a) Operation benefits; b) strategic benefits; c) organizational benefits; d) IT infrastructure benefits

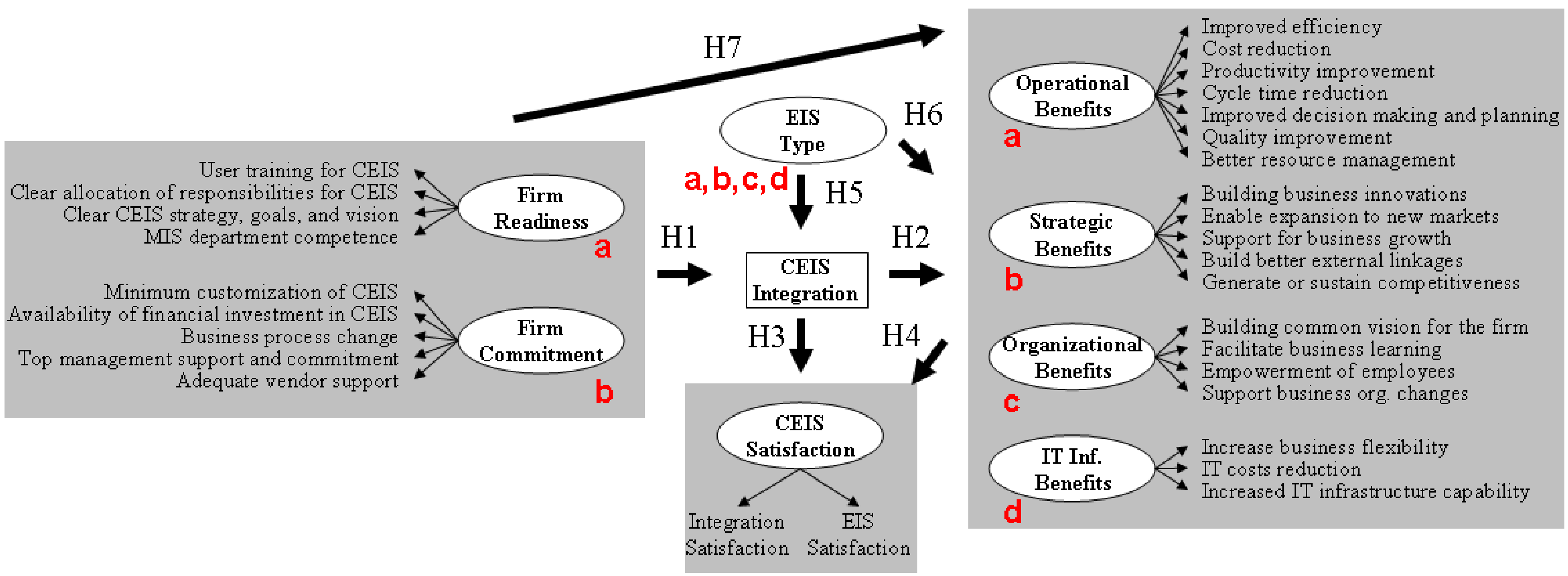

Figure 5.1 Final Conceptual Framework

5.6 Comparison of Samples

In this section, differences between samples were examined using analysis of variance (ANOVA). This analysis was conducted to analyze whether certain firm characteristics could be statistically differentiated in the study.

5.6.1 Country

A one-way between-groups ANOVA was utilized to determine the effect of firm base on CEIS benefits. ANOVA is utilized to test if there is a difference between at least two means in a set of data where two or more means are calculated (Sheskin 2007). The effect of firm base on operational benefits, $F(1, 87) = .339$, $p > .05$; strategic benefits, $F(1, 87) = .330$, $p > .05$; organizational benefits, $F(1, 87) = .022$, $p > .05$; and IT infrastructure benefits, $F(1, 87) = .857$, $p > .05$, was not significant (see Table 5-6).

Table 5-6 ANOVA Results for Firm Base by CEIS Benefits

	Sum of Squares	Df	Mean Square	F	Sig.
Operational Benefits	.337	1	.337	.339	.562
Strategic Benefits	.333	1	.333	.330	.567
Organizational Benefits	.023	1	.023	.022	.883
IT Infrastructure Benefits	.874	1	.874	.857	.357

5.6.2 Firm Role

A one-way between-groups ANOVA was utilized to determine the effect of firm role on CEIS benefits. The effect of firm role on operational benefits, $F(4, 89) = .212$, $p > .05$; strategic benefits, $F(4, 89) = .477$, $p > .05$; organizational benefits, $F(4, 89) =$

.132, $p > .05$; and IT infrastructure benefits, $F(4, 89) = .644$, $p > .05$, was not significant (see Table 5-7).

Table 5-7 ANOVA Results for Firm Role by CEIS Benefits

	Sum of Squares	Df	Mean Square	F	Sig.
Operational Benefits	5.756	4	1.439	1.492	.212
Strategic Benefits	3.594	4	.899	.884	.477
Organizational Benefits	7.095	4	1.774	1.824	.132
IT Infrastructure Benefits	2.581	4	.645	.627	.644

5.6.3 Firm Specialization

A one-way between-groups ANOVA was utilized to determine the effect of firm specialization on CEIS benefits. The effect of firm specialization on operational benefits, strategic benefits, organizational benefits, and IT infrastructure benefits were not significant (see Table 5-8).

Table 5-8 ANOVA Results for Firm Specialty by CEIS Benefits

		Sum of Squares	Df	Mean Square	F	Sig.
Residential	Operational Benefits	.443	1	.443	.426	.516
	Strategic Benefits	.113	1	.113	.107	.745
	Organizational Benefits	2.037	1	2.037	1.902	.172
	IT Infrastructure Benefits	.390	1	.390	.407	.525
Commercial	Operational Benefits	.955	1	.955	.917	.341
	Strategic Benefits	.219	1	.219	.207	.650
	Organizational Benefits	.002	1	.002	.002	.968
	IT Infrastructure Benefits	.476	1	.476	.497	.483
Heavy	Operational Benefits	.085	1	.085	.082	.776
	Strategic Benefits	.022	1	.022	.021	.886
	Organizational Benefits	.007	1	.007	.006	.937
	IT Infrastructure Benefits	2.570	1	2.570	2.687	.105
Industrial	Operational Benefits	.039	1	.039	.038	.846
	Strategic Benefits	.181	1	.181	.171	.680
	Organizational Benefits	.533	1	.533	.497	.483
	IT Infrastructure Benefits	.192	1	.192	.200	.656

5.6.4 Firm Size

A one-way between-groups ANOVA was utilized to determine the effect of firm role on CEIS benefits. The effect of firm role on operational benefits, $F(3, 89) = 1.897$, $p > .05$; strategic benefits, $F(3, 89) = .115$, $p > .05$; organizational benefits, $F(3, 89) = .724$, $p > .05$; and IT infrastructure benefits, $F(3, 89) = .152$, $p > .05$, was not significant (see Table 5-9).

Table 5-9 ANOVA Results for Firm Role by CEIS Benefits

	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Operational Benefits	5.446	3	1.815	1.897	.136
Strategic Benefits	.358	3	.119	.115	.951
Organizational Benefits	2.210	3	.737	.724	.541
IT Infrastructure Benefits	.476	3	.159	.152	.928

5.6.5 Geographic Dispersion

A one-way between-groups ANOVA was utilized to determine the effect of firm role on CEIS benefits. The effect of firm role on operational benefits, $F(4, 89) = 3.543$, $p > .05$; strategic benefits, $F(4, 89) = .436$, $p > .05$; organizational benefits, $F(4, 89) = 2.174$, $p > .05$; and IT infrastructure benefits, $F(4, 89) = .770$, $p > .05$, was not significant (see Table 5-10).

Table 5-10 ANOVA Results for Firm Role by CEIS Benefits

	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Operational Benefits	12.536	4	3.134	3.543	.010
Strategic Benefits	1.810	4	.452	.436	.782
Organizational Benefits	8.330	4	2.082	2.174	.079
IT Infrastructure Benefits	3.145	4	.786	.770	.548

5.6.6 Firm Characteristics and PMIS Type by CEIS Integration Level

A one-way between-groups ANOVA was utilized to determine the effect of firm characteristics on CEIS integration. The effect of industrial construction on CEIS integration level, $F(1, 95) = 22.53$, $p < .05$ was significant. All other firm characteristics did not have a significant effect on CEIS integration (see Table 5-11).

Table 5-11 ANOVA Results for Firm Characteristics by CEIS Integration

Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Base	1.377	1	1.377	1.825	.181
Role	4.190	4	1.047	1.388	.246
Res	.014	1	.014	.019	.890
Com	.051	1	.051	.068	.795
Hev	2.065	1	2.065	2.737	.102
Ind	16.998	1	16.998	22.527	**.000**
Spc	.450	1	.450	.596	.442
Size	.735	3	.245	.325	.807
Geo	2.037	4	.509	.675	.611
ptype	4.111	4	1.028	1.143	.341

5.7 Regression Analysis

Standard multiple regression was conducted to test the overall conceptual framework using ‘enter’ method (where all variables are entered at once.) Multiple regression is used to derive a linear equation that would best describe the relationship between several independent variables and a dependant scale variable (Sheskin 2007). Following are several multiple regression models that test the conceptual framework.

1. INTGR = fn (RDNS, COMM, LGC, ERP, BOB, STND)

First, we run regression for dependent variable INTGR on independent variables RDNS and COMM along with four dummy variables; LGC, ERP, BOB, and STND. The regression model is presented as follows:

$$INTGR = \beta_0 + \beta_1\ RDNS + \beta_2\ COMM + \beta_3\ LGC + \beta_4\ ERP + \beta_5\ BOB + \beta_6\ STND + e$$

where INTGR: Level of CEIS Integration

RDNS: Firm Readiness

COMM: Firm Commitment

LGC: Legacy System (dummy variable)

ERP: Enterprise Resource Planning (dummy variable)

BOB: Best-of-Breed (dummy variable)

STND: Stand-alone System (dummy variable)

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$: coefficients of the independent variables

e: error item

Regression results of the impact of RDNS, COMM, LGC, ERP, BOB and STND on INTGR are summarized in Table 5-12. Multiple *R* for regression was statistically significant, $F(3, 91) = 10.429$, $p < .01$, adjusted $R^2 = .231$. COMM and RDNS contributed significantly to the prediction of INTGR ($p < .01$). STND was found to be negatively associated with INTGR ($p < .05$). Other predictor variables did not make a statistically significant contribution ($p > .05$) to the prediction of INTGR. Based on the data analysis, the following sub-hypotheses are supported:

> H1a: Firm readiness is positively associated with higher levels of CEIS integration

H1b: Firm commitment is positively associated with higher levels of CEIS integration

H5d: Stand-alone EIS type is negatively associated with CEIS integration level

Table 5-12 Multiple Linear Regression Results of Regression Equation 1

Multiple *R*	.527				
Adjusted R^2	.277				
	Sum of Squares	*Df*	Mean Square	*F*	Significance of *F*
Regression	23.951	5	4.790	6.832	.000a
Residual	62.407	94	.701		
Model					
Variable	*B*	S.E. of *B*	*B*	*T*	Sig. of *t*
(Constant)	2.340	.118		19.800	.000
RDNS	.262	.088	.277	2.966	**.004**
COMM	.296	.089	.308	3.325	**.001**
LGC	.354	.237	.143	1.497	.138
BOB	.244	.253	.091	.966	.337

2. OB = fn (INTGR, RDNS, COMM, LGC, ERP, BOB, STND)

Second, we run regression for dependent variable OB on independent variables INTGR, RDNS and COMM along with four dummy variables; LGC, ERP, BOB, and STND. The regression model is presented as follows:

$$OB = \beta_0 + \beta_1 \text{ INTGR} + \beta_2 \text{ RDNS} + \beta_3 \text{ COMM} + \beta_4 \text{ LGC} + \beta_5 \text{ ERP} + \beta_6 \text{ BOB}$$
$$+ \beta_7 \text{ STND} + e$$

where OB: Operational Benefits

INTGR: Level of CEIS Integration

RDNS: Firm Readiness

COMM: Firm Commitment

LGC: Legacy System (dummy variable)

ERP: Enterprise Resource Planning (dummy variable)

BOB: Best-of-Breed (dummy variable)

STND: Stand-alone System (dummy variable)

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_6$: coefficients of the independent variables

e: error item

Regression results of the impact of INTGR, RDNS, COMM, LGC, ERP, BOB, STND on OB are summarized in Table 5-13. Multiple *R* for regression was statistically significant, $F(2, 79) = 4.967$, $p < .01$, adjusted $R^2 = .089$. STND and LGC were found to be negatively associated with OB ($p < .05$). Other predictor variables did not make a statistically significant contribution ($p > .05$) to the prediction of OB. Based on the data analysis, the following sub-hypotheses are supported:

H6aa: Legacy EIS type is negatively associated with operational benefits

Table 5-13 Multiple Linear Regression Results of Regression Equation 2

Multiple *R*	.410				
Adjusted R^2	.101				
	Sum of Squares	*Df*	Mean Square	*F*	Significance of *F*
Regression	12.328	6	2.055	2.523	.028[a]
Residual	61.068	75	.814		
Model					
Variable	*B*	S.E. of *B*	*B*	*T*	Sig. of *t*
(Constant)	-.080	.316		-.253	.801
INTGR	.077	.121	.078	.634	.528
RDNS	.129	.104	.141	1.245	.217
COMM	.102	.110	.108	.930	.355
LGC	-.645	.289	-.256	-2.229	**.029**
BOB	.317	.287	.122	1.105	.273
STND	-.457	.322	-.165	-1.420	.160

3. SB = fn (INTGR, RDNS, COMM, LGC, ERP, BOB, STND)

Third, we run regression for dependent variable SB on independent variables INTGR, RDNS and COMM along with four dummy variables; LGC, ERP, BOB, and STND. The regression model is presented as follows:

$$SB = \beta_0 + \beta_1 \text{ INTGR} + \beta_2 \text{ RDNS} + \beta_3 \text{ COMM} + \beta_4 \text{ LGC} + \beta_5 \text{ ERP} + \beta_6 \text{ BOB} + \beta_7 \text{ STND} + e$$

where SB: Strategic Benefits

INTGR: Level of CEIS Integration

RDNS: Firm Readiness

COMM: Firm Commitment

LGC: Legacy System (dummy variable)

ERP: Enterprise Resource Planning (dummy variable)

BOB: Best-of-Breed (dummy variable)

STND: Stand-alone System (dummy variable)

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_6$: coefficients of the independent variables

e: error item

Multiple regression did not find any significant results related to the impact of INTGR, RDNS, COMM, LGC, ERP, BOB, STND on SB.

Table 5-14 Multiple Linear Regression Results of Regression Equation 3

Multiple *R*	.237				
Adjusted R^2	.056				
	Sum of Squares	*Df*	Mean Square	*F*	Significance of *F*
Regression	4.410	6	.735	.746	.614[a]
Residual	73.879	75	.985		
Model					
Variable	*B*	S.E. of *B*	*B*	*T*	Sig. of *t*
(Constant)	-.233	.348		-.670	.505
INTGR	.067	.133	.066	.503	.616
RDNS	.156	.114	.164	1.366	.176
COMM	.037	.121	.038	.307	.760
LGC	.303	.318	.117	.953	.344
BOB	-.125	.316	-.047	-.396	.694
STND	.188	.354	.066	.532	.596

4. GB = fn (INTGR, RDNS, COMM, LGC, ERP, BOB, STND)

Fourth, we run regression for dependent variable GB on independent variables INTGR, RDNS and COMM along with four dummy variables; LGC, ERP, BOB, and STND. The regression model is presented as follows:

GB = $\beta_0 + \beta_1$ INTGR + β_2 RDNS + β_3 COMM+ β_4 LGC + β_5 ERP+ β_6 BOB

+ β_7 STND+ e

where GB: Organizational Benefits

INTGR: Level of CEIS Integration

RDNS: Firm Readiness

COMM: Firm Commitment

LGC: Legacy System (dummy variable)

ERP: Enterprise Resource Planning (dummy variable)

BOB: Best-of-Breed (dummy variable)

STND: Stand-alone System (dummy variable)

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_6$: coefficients of the independent variables

e: error item

Regression results of the impact of INTGR, RDNS, COMM, LGC, ERP, BOB, STND on GB are summarized in Table 5-15. Multiple R for regression was statistically significant, $F(1, 80) = 10.832$, $p < .01$, adjusted $R^2 = .108$. COMM contributed significantly to the prediction of GB ($p < .01$). Other predictor variables did not make a statistically significant contribution ($p > .05$) to the prediction of GB. Based on the data analysis, the following sub-hypothesis is supported:

H7bc: Firm commitment is positively associated with organizational benefits

Table 5-15 Multiple Linear Regression Results of Regression Equation 4

Multiple R	.397				
Adjusted R^2	.091				
	Sum of Squares	*Df*	Mean Square	*F*	Significance of *F*
Regression	11.986	6	1.998	2.345	.039[a]
Residual	63.882	75	.852		
Model					
Variable	*B*	S.E. of *B*	*Β*	*T*	Sig. of *t*
(Constant)	-.208	.323		-.645	.521
INTGR	.146	.124	.146	1.176	.243
RDNS	.052	.106	.055	.488	.627
COMM	.281	.112	.292	2.506	**.014**
LGC	-.100	.296	-.039	-.337	.737
BOB	-.273	.293	-.104	-.932	.354
STND	-.165	.329	-.059	-.502	.617

5. IB = fn (INTGR, RDNS, COMM, LGC, ERP, BOB, STND)

Fifth, we run regression for dependent variable IB on independent variables INTGR, RDNS and COMM along with four dummy variables; LGC, ERP, BOB, and STND. The regression model is presented as follows:

$IB = \beta_0 + \beta_1$ INTGR + β_2 RDNS + β_3 COMM+ β_4 LGC + β_5 ERP+ β_6 BOB

+ β_7 STND+ e

where IB: IT infrastructure Benefits

INTGR: Level of CEIS Integration

RDNS: Firm Readiness

COMM: Firm Commitment

LGC: Legacy System (dummy variable)

ERP: Enterprise Resource Planning (dummy variable)

BOB: Best-of-Breed (dummy variable)

STND: Stand-alone System (dummy variable)

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_6$: coefficients of the independent variables

e: error item

Regression results of the impact of INTGR, RDNS, COMM, LGC, ERP, BOB, STND on IB are summarized in Table 5-16. Multiple R for regression was statistically significant, $F(1, 80) = 16.271$, $p < .01$, adjusted $R^2 = .159$. RDNS contributed significantly to the prediction of GB ($p < .01$). Other predictor variables did not make a statistically significant contribution ($p > .05$) to the prediction of IB. Based on the data analysis, the following sub-hypothesis is supported:

H7ad: Firm readiness is positively associated with organizational benefits

Table 5-16 Multiple Linear Regression Results of Regression Equation 5

Multiple R	.470				
Adjusted R^2	.158				
	Sum of Squares	*Df*	Mean Square	F	Significance of F
Regression	14.069	6	2.345	3.540	.004[a]
Residual	49.684	75	.662		
Model					
Variable	B	S.E. of B	B	T	Sig. of t
(Constant)	.202	.285		.709	.480
INTGR	-.059	.109	-.064	-.539	.592
RDNS	.339	.093	.397	3.631	**.001**
COMM	.089	.099	.101	.901	.371
LGC	.177	.261	.076	.679	.500
BOB	-.032	.259	-.013	-.124	.902
STND	-.449	.290	-.173	-1.544	.127

6. SAT = fn (INTGR, OB, SB, GB, IB)

Last, we run regression for dependent variable SAT on independent variables INTGR, OB, SB, GB, and IB. The regression model is presented as follows:

SAT = $\beta_0 + \beta_1$ INTGR + β_2 OB + β_3 SB+ β_4 GB + β_5 IB+ e

where SAT: CEIS satisfaction

INTGR: Level of CEIS Integration

OB: Operational Benefits

SB: Strategic Benefits

GB: Organizational Benefits

IB: IT infrastructure Benefits

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5$: coefficients of the independent variables

e: error item

Table 5-17 Multiple Linear Regression Results of Regression Equation 5

Multiple *R*	.662				
Adjusted R^2	.404				
	Sum of Squares	*Df*	Mean Square	*F*	Significance of *F*
Regression	37.706	5	7.541	12.514	.000[a]
Residual	48.209	80	.603		
Model					
Variable	*B*	S.E. of *B*	*B*	*T*	Sig. of *t*
(Constant)	-.831	.237		-3.501	**.001**
INTGR	.360	.093	.348	3.866	**.000**
OB	.327	.084	.328	3.879	**.000**
SB	.165	.083	.168	1.982	.051
GB	.150	.087	.151	1.729	.088
IB	.234	.084	.237	2.781	**.007**

Regression results of the impact of INTGR, OB, SB, GB, IB on SAT are summarized in Table 5-17. Multiple *R* for regression was statistically significant, $F(3, 82) = 17.649$, $p < .01$, adjusted $R^2 = .159$. INTGR, OB, and IB contributed significantly to the prediction of SAT ($p < .01$). Other predictor variables did not make a statistically significant contribution ($p > .05$) to the prediction of SAT. Based on the data analysis, the following sub-hypotheses are supported:

H3: CEIS integration level is positively associated with CEIS satisfaction

H4a: Operational benefits are positively associated with CEIS satisfaction

H4d: IT infrastructure benefits are positively associated with CEIS satisfaction

Through several regression models we analyzed the conceptual framework. The following figure summarizes the results of the regression analysis (see Figure 5.2). The regression equations are as follows:

1) INTGR = 2.46 + .248 RDNS + .307 COMM - .534 STND

2) OB = .202 - .732 LGC - .648 BOB

3) GB = .065 + .332 COMM

4) IB = .024 + .352 RDNS

5) SAT = -.988 + .427 INTGR + .320 OB + .228 IB

One of the reasons for a lower R-squared may be related to the variable INTGR reflecting actual integration level rather that integration probability of each firm. Since integration level can be only an integer from 1 to 5, and the probability model would have produced many values between 1 and 5 that are not necessarily integer, the model would be expected to have low R-squared values. Another explanation might be related to including some other variables which might have results in an increased R-squared value.

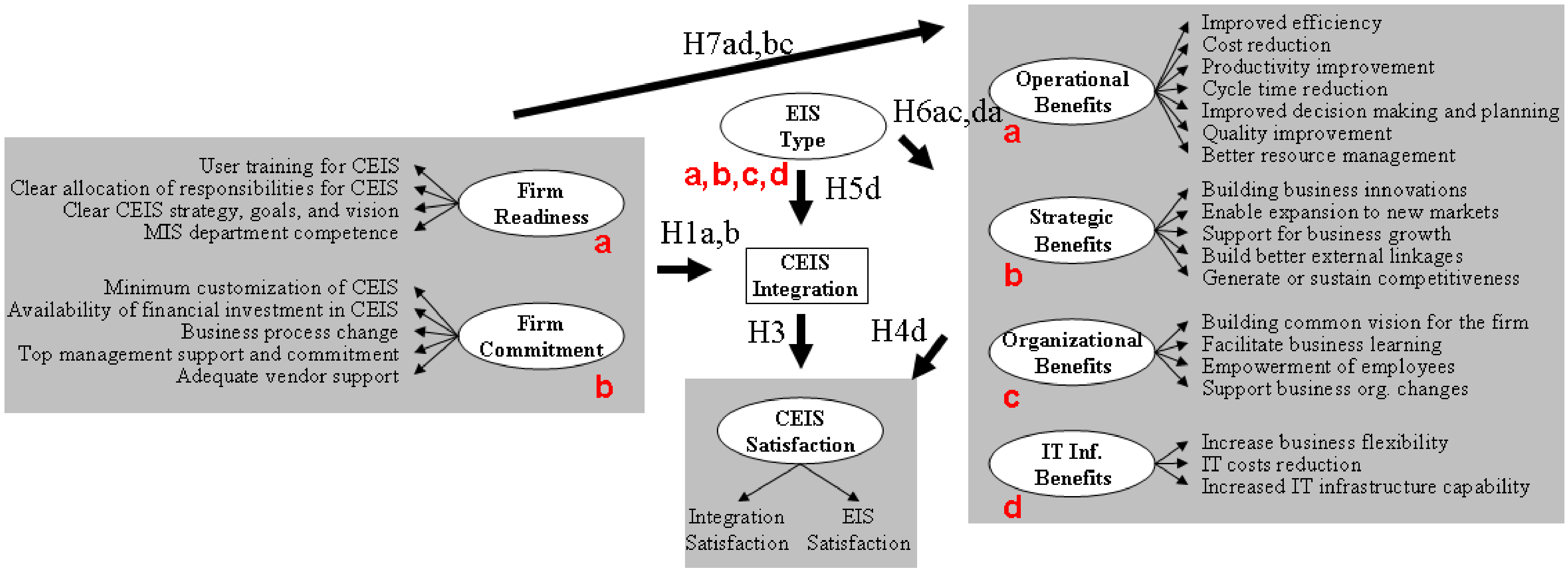

Figure 5.2 Summary of the Regression Analysis

5.8 Additional Analyses to enhance Findings

5.8.1 Effect of CEIS Integration Level on CEIS Benefits

Although CEIS integration did not have any impact on the perceived benefits when CSF were present, we run an ANOVA to analyze if CEIS integration levels differ without the effect of CSF. A one-way between-groups ANOVA was utilized to determine the effect of CEIS integration level on CEIS benefits. The effect of CEIS integration level on organizational benefits was significant, $F(3, 89) = 2.998$, $p < .05$. However, the effect of CEIS integration level on operational benefits, $F(3, 89) = .884$, $p > .05$; strategic benefits, $F(3, 89) = .642$, $p > .05$; and IT infrastructure benefits, $F(3, 89) = 1.082$, $p > .05$, was not significant (see Table 5-18).

Table 5-18 ANOVA Results for CEIS Benefit Dimensions by CEIS Integration Level

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Operational Benefits	2.204	3	.735	.739	.532
Strategic Benefits	2.313	3	.771	.756	.522
Organizational Benefits	8.879	3	2.960	3.148	**.029**
IT Infrastructure Benefits	2.544	3	.848	.834	.479

The ANOVA analysis was followed by Tukey method of pairwise comparison to determine which CEIS integration level differs significantly from others in its effect on organizational benefits (see Table 5-19). The Tukey HSD test ($p < .05$) indicated that *full integration* ($M = 2.25$, $SD = .967$) was significantly higher than *no integration* ($M = 1.60$, $SD = .894$).

Table 5-19 Tukey Post Hoc Multiple Comparisons for Organizational Benefits

Dependent Variable	(I) intgra	(J) intgra	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Organizational Benefits	1	2	-.290	.291	.751	-1.052	.472
		3	-.282	.287	.761	-1.034	.471
		4	-1.083*	.361	**.018**	-2.028	-.1361
	2	1	.290	.291	.751	-.472	1.052
		3	.009	.251	1.000	-.648	.665
		4	-.793	.333	.088	-1.665	.079
	3	1	.282	.287	.761	-.471	1.034
		2	-.009	.251	1.000	-.665	.648
		4	-.801	.330	.079	-1.665	.0624
	4	1	1.083*	.361	**.018**	.1361	2.030
		2	.793	.333	.088	-.0793	1.665
		3	.801	.330	.079	-.0624	1.665

*. The mean difference is significant at the 0.05 level.

Further analysis on each benefit was conducted using one-way between-groups ANOVA to determine the effect of CEIS integration level. The effects of CEIS integration level on cost reduction; $F(3, 89) = 2.703$, $p < .05$, building business innovations; $F(3, 89) = 3.166$, $p < .05$, generating or sustaining competitiveness; $F(3, 89) = 3.428$, $p < .05$, increased business flexibility; $F(3, 89) = 2.750$, $p < .05$, facilitate business learning and broaden employee skills; $F(3, 89) = 3.657$, $p < .05$, empowerment of employees; $F(3, 89) = 3.958$, $p < .05$, and building common vision for the firm; $F(3, 89) = 4.422$, $p < .01$ were significant. The effect of CEIS integration level on other benefits was not significant (see Table 5-20). Therefore, the following hypothesis is supported:

> H2c: CEIS integration level is positively associated with higher levels of organizational benefits

Table 5-20 ANOVA Results for CEIS Benefit variables by CEIS integration level

Dimension	**Variable**	**Mean** 1	2	3	4	***F***	**Sig.**
Operational (1)	Cost Reduction	3.22	3.45	3.48	4.08	2.703	**.050**
	Cycle time reduction	3.44	3.66	3.58	4.25	1.995	.121
	Productivity improvement	3.39	3.52	3.68	4.08	1.504	.219
	Quality improvement	3.50	3.41	3.52	4.17	2.208	.093
	Better resource management	3.44	3.48	3.71	4.08	1.900	.136
	Improved decision making and planning	3.50	3.48	3.65	4.25	2.515	.064
	Improved efficiency	3.61	3.62	3.68	4.08	0.765	.517
Strategic (2)	Support for business growth	3.61	3.45	3.61	4.17	1.752	.163
	Building business innovations	3.11	3.52	3.52	4.08	3.166	**.029**
	Build better external linkage with suppliers and distributors	3.22	3.28	3.29	3.83	1.359	.261
	Enable expansion to new markets	3.17	3.03	3.48	3.75	2.478	.067
	Generating or sustaining competitiveness	3.17	3.45	3.55	4.25	3.428	**.021**
IT Infrastructure (3)	Increased business flexibility	3.28	3.34	3.68	4.00	2.750	**.048**
	IT costs reduction	2.67	2.83	3.23	3.33	2.064	.111
	Increased IT infrastructure capability	3.22	3.45	3.45	3.92	1.606	.194
Organizational (4)	Support business organizational changes in structure & processes	3.44	3.41	3.55	4.08	2.582	.059
	Facilitate business learning and broaden employee skills	3.28	3.62	3.58	4.25	3.657	**.016**
	Empowerment of employees	3.17	3.45	3.52	4.25	3.958	**.011**
	Building common vision for the firm	3.22	3.48	3.68	4.42	4.422	**.006**

5.8.2 Analysis of CSF as Mediating Variables

CEIS Integration was found to be not significantly associated with the perceived firm benefits when CSF were taken into effect. In the prior analysis between CEIS integration and perceived benefits without taking CSF into account, CEIS integration was found to be significantly associated with organizational benefits. In this section, we analyze whether firm commitment is mediating factor between CEIS integration and organizational benefits (see Figure 5.3.)

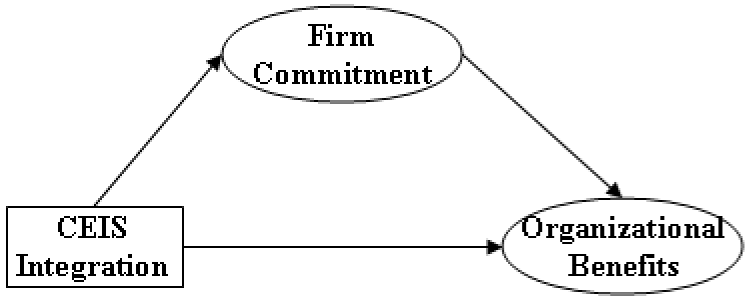

Figure 5.3 Firm Commitment as the Mediating Variable

In order to conduct the Sobel test for mediation, the raw regression coefficient and the standard error for this regression coefficient for the association between the independent variable, organizational benefits, and the mediator, firm commitment, and the association between the mediator and the dependent variable, CEIS integration, was computed (see Appendix C.)

	Input:		Test statistic:	*p*-value:
a	2.39	Sobel test:	3.56736899	0.00036058
b	.36	Aroian test:	3.56488789	0.00036401
s_a	.09	Goodman test:	3.56985528	0.00035718
s_b	.10	Reset all	Calculate	

Figure 5.4 Results of Sobel Test

Sobel Test was calculated using an interactive calculation tool for mediation tests (Preacher and Leonardelli 2003). The test statistic for the Sobel test was found to be 3.57, with an associated p-value of .0004 ($p < .001$). Since the observed p-value falls below the established alpha level of .05, this indicates that the association between the IV and the DV is reduced significantly by the inclusion of the mediator in the model, which confirms the existence of mediation.

5.8.3 Effect of EIS Type on CEIS Benefits

A one-way between-groups ANOVA was utilized to determine the effect of EIS type on CEIS benefits. The effect of EIS type on operational benefits was significant, $F(3, 87) = 3.287$, $p < .05$. However, the effect of EIS type on strategic benefits, $F(3, 87) = .148$, $p > .05$; organizational benefits, $F(3, 87) = 1.233$, $p > .05$; and IT infrastructure benefits, $F(3, 87) = 1.340$, $p > .05$, was not significant (see Table 5-21).

Table 5-21 ANOVA Results for CEIS Benefit Dimensions by EIS Type

	Sum of Squares	df	Mean Square	F	Sig.
Operational Benefits	9.095	3	3.032	3.287	**.025**
Strategic Benefits	.444	3	.148	.140	.936
Organizational Benefits	3.606	3	1.202	1.233	.303
IT Infrastructure Benefits	4.083	3	1.361	1.340	.267

Table 5-22 Tukey Post Hoc Multiple Comparisons for Organizational Benefits

Dependent Variable	(I) etyp	(J) etyp	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Operational Benefits	1	2	-0.411	0.279	.458	-1.142	0.320
		3	-0.846	0.351	.084	-1.767	0.076
		4	0.197	0.367	.950	-0.764	1.158
	2	1	0.411	0.279	.458	-0.320	1.142
		3	-0.435	0.293	.452	-1.203	0.334
		4	0.608	0.311	.214	-0.208	1.424
	3	1	0.846	0.351	.084	-0.076	1.767
		2	0.435	0.293	.452	-0.334	1.203
		4	1.043*	0.378	.035	0.052	2.033
	4	1	-0.197	0.367	.950	-1.158	0.764
		2	-0.608	0.311	.214	-1.424	0.208
		3	-1.043*	0.378	.035	-2.033	-0.052

*. The mean difference is significant at the 0.05 level. (1) Legacy system. (2) ERP. (3) Best-of-Breed. (4) Stand-alone.

The ANOVA analysis was followed by Tukey method of pairwise comparison to determine which EIS type differs significantly from others in its effect on operational benefits (see Table 5-22). The Tukey HSD test ($p < .05$) indicated that *best-of-breed* ($M = .536$, $SD = .746$) was significantly higher than *stand-alone* ($M = -.507$, $SD = 1.074$).

Table 5-23 ANOVA Results for CEIS Benefit variables by EIS Type

		Mean					
Dimension	**Variable**	**1**	**2**	**3**	**4**	***F***	**Sig.**
Operational	Cost Reduction	3.31	3.63	3.71	2.92	2.929	**.038**
	Cycle time reduction	3.56	3.80	3.79	3.17	1.668	.180
	Productivity improvement	3.44	3.72	3.93	3.00	2.747	**.048**
	Quality improvement	3.25	3.76	3.64	3.17	2.402	.073
	Better resource management	3.69	3.61	3.79	3.42	0.449	.719
	Improved decision making and planning	3.50	3.67	3.86	3.33	0.927	.431
	Improved efficiency	3.69	3.72	4.07	3.25	1.703	.173
Strategic	Support for business growth	3.50	3.65	3.71	3.58	0.157	.925
	Building business innovations	3.50	3.52	3.50	3.42	0.045	.987
	Build better external linkage with suppliers and distributors	3.31	3.35	3.57	3.00	0.841	.475
	Enable expansion to new markets	3.50	3.30	3.29	3.17	0.330	.804
	Generating or sustaining competitiveness	3.69	3.63	3.43	2.92	2.063	.111
IT Infrastructure	Increased business flexibility	3.56	3.74	3.14	3.08	3.414	**.021**
	IT costs reduction	3.00	3.02	3.14	2.67	0.547	.651
	Increased IT infrastructure capability	3.56	3.57	3.29	3.08	1.286	.285
Organizational	Support business organizational changes in structure & processes	3.75	3.63	3.36	3.25	1.504	.219
	Facilitate business learning and broaden employee skills	3.63	3.70	3.50	3.33	0.691	.560
	Empowerment of employees	3.44	3.63	3.71	3.00	1.959	.126
	Building common vision for the firm	4.06	3.61	3.64	3.08	2.566	.060

Further analysis on each benefit was conducted using one-way between-groups ANOVA to determine the effect of CEIS integration level. The effects of CEIS integration level on cost reduction; $F(3, 89) = 2.929$, $p < .05$, productivity improvement; $F(3, 89) = 2.747$, $p < .05$, and increased business flexibility; $F(3, 89) = 3.414$, $p < .05$, were significant. The effect of CEIS integration level on other benefits was not significant (see Table 5-23).

5.8.4 Relationship between CSF individual variables and CEIS Benefits

In this section, the relationship between CSF individual variables and CEIS benefit dimensions is examined to enhance the findings of the regression analyses of CSF dimensions. Standard multiple regression was conducted with each CEIS benefit as the dependant variable. Nine of the CSF were hypothesized as predictors of each CEIS benefit dimension; operational benfits (OB), strategic benefits (SB), organizational benefits (GB), and IT infrastructure benefits (IB). In total, four regressions were executed. The independent variables refer to top management support and commitment (topmgm), clear CEIS strategy, goals and vision (clestrat), business process change (bpr), minimum customization of CEIS (mincus), availability of financial investment in CEIS (fininv), adequate vendor support (vensup), MIS department competence (misdep), clear allocation of responsibilities for CEIS (cleresp), and user training for CEIS (utrain).

1. Impact of CSF on Operational Benefits

Regression results of the impact of CSF on operational benefits are summarized in Table 5-24. Multiple R for regression was statistically significant, $F(1, 81) = 9.813$, $p < .01$, $R^2 = .108$. One of the nine CSF, user training for CEIS, contributed significantly to the prediction of CEIS operational benefits dimension ($p < .01$). Other

CSF did not make a statistically significant contribution ($p > .05$) to the prediction of CEIS integration level.

Table 5-24 Multiple Linear Regression Results of Operational Benefits based on CSF

Multiple *R*	.329				
R^2	.108				
	Sum of Squares	*Df*	Mean Square	*F*	Significance of *F*
Regression	7.960	1	7.960	9.813	.002
Residual	65.700	81	.811		
Model					
Variable	*B*	S.E. of *B*	*β*	*t*	Sig. of *t*
(Constant)	-.937	.311		-3.012	.003
utrain	.297	.095	.329	3.133	.002

2. Impact of CSF on Strategic Benefits

Regression results of the impact of CSF on strategic benefits are summarized in Table 5-25. The model with the highest *R* was chosen. Multiple *R* for regression was statistically significant, $F(2, 80) = 7.887$, $p < .001$, $R^2 = .165$. Two of the nine CSF; clear CEIS strategy, goals and vision (clestrat) and clear allocation of responsibilities for CEIS (cleresp) contributed significantly to the prediction of CEIS operational benefits dimension ($p < .05$). Other CSF did not make a statistically significant contribution ($p > .05$) to the prediction of CEIS integration level.

Table 5-25 Multiple Linear Regression Results of Strategic Benefits based on CSF

Multiple R	.416				
R^2	.144				
	Sum of Squares	Df	Mean Square	F	Significance of F
Regression	12.899	2	6.450	7.887	.001
Residual	65.424	80	.818		
Model					
Variable	B	S.E. of B	B	t	Sig. of t
(Constant)	-.438	.371		-1.180	.242
clestrat	.468	.118	.506	3.969	.000
cleresp	-.308	.123	-.318	-2.498	.015

3. Impact of CSF on Organizational Benefits

Regression results of the impact of CSF on organizational benefits are summarized in Table 5-26. The model with the highest R was chosen. Multiple R for regression was statistically significant, $F(2, 80) = 6.941$, $p < .001$, $R^2 = .176$. Two of the nine CSF; minimum customization of CEIS (mincus) and availability of financial investment in CEIS (fininv) contributed significantly to the prediction of CEIS operational benefits dimension ($p < .05$). Other CSF did not make a statistically significant contribution ($p > .05$) to the prediction of CEIS integration level.

Table 5-26 Multiple Regression Results of Organizational Benefits based on CSF

Multiple R	.420				
R^2	.176				
	Sum of Squares	df	Mean Square	F	Significance of F
Regression	Regression	13.883	2	6.941	8.567
Residual	Residual	64.818	80	.810	
Model					
Variable	B	S.E. of B	β	t	Sig. of t
(Constant)	-1.581	.405		-3.899	.000
fininv	.288	.107	.287	2.683	.009
mincus	.218	.101	.230	2.158	.034

4. Impact of CSF on IT Infrastructure Benefits

Regression results of the impact of CSF on organizational benefits are summarized in Table 5-25. The model with the highest *R* was chosen. Multiple *R* for regression was statistically significant, $F(2, 80) = 6.360$, $p < .001$, $R^2 = .199$. Two of the nine CSF; MIS department competence (misdep) and clear allocation of responsibilities for CEIS (cleresp) contributed significantly to the prediction of CEIS operational benefits dimension ($p < .05$). Other CSF did not make a statistically significant contribution ($p > .05$) to the prediction of CEIS integration level.

Table 5-27 Multiple Regression Results of IT Infrastructure Benefits based on CSF

Multiple *R*	.446				
R^2	.199				
	Sum of Squares	*df*	Mean Square	*F*	Significance of *F*
Regression	Regression	12.719	2	6.360	9.937
Residual	Residual	51.196	80	.640	
Model					
Variable	*B*	S.E. of *B*	*β*	*T*	Sig. of *t*
(Constant)	-1.405	.339		-4.139	.000
misdep	.215	.097	.264	2.212	.030
cleresp	.212	.104	.243	2.034	.045

Chapter 6: Research Findings and Discussions

6.1 Introduction

This chapter discusses the research findings and the implications of these findings for the construction industry and CEIS. It first addresses what components of the CEIS benefits and critical success factors were confirmed by the statistical analyses. Then, it discusses the research findings on the significance of firm characteristics, the relationship between CSF and CEIS integration, the relationship between CSF and CEIS induced perceived firm benefits, the relationship between CEIS integration level and CEIS benefit, the relationship between EIS type and CEIS benefits, the relationship between EIS Type and CEIS integration level, the effect of CEIS Integration level on satisfaction, and the effect of CEIS benefits on satisfaction.

6.2 Dimensions of CEIS Benefits

By utilizing principal component factor analysis, four distinct CEIS benefit dimensions were established; operational, strategic, organizational, and IT infrastructure. Based on this analysis, operational and managerial benefits were combined into one. This is particularly suitable since in the project management environment it is difficult to differentiate between these dimensions. Managers are frequently aware of the day-to-day operations, since any disruption to these activities may lead to managerial problems, and vice versa. By assessing the impact of CEIS, EIS type, and CSF on these dimensions it will be possible to establish the key benefit areas in the firm. Also, through this research, the Shang and Seddon benefit framework (2002) has been implemented in construction research for the first time and its applicability has been established with a slight modification, reducing from five dimensions to four dimensions.

6.3 Dimensions of Critical Success Factors

By utilizing principal component factor analysis, two distinct CSF dimensions were constructed. Firm readiness included variables that were related to the readiness of the firm to implement CEIS and increase its integration. The most important aspect was found to be user training for CEIS. When we assess whether a firm is ready to go live, the thing that matter most is whether the users will be able to perform their daily operations and the only way to make this happen is when there is adequate training for them. Also, a clear CEIS strategy, goals and vision set out by firm managers is vital to the readiness of the firm. Goals prepare all individuals within the firm to accomplish the target in hand; successful use of CEIS. Clear allocation of responsibilities is critical as well. Users aware of their new roles ahead of time are likely to be more ready to use CEIS. MIS department competence is crucial as well for the firm to be ready for a new CIES. Another dimension was constructed and named firm commitment. Minimum customization of CEIS shows the firm's commitment to change and embrace new business processes that are enabled through CEIS. This commitment entails changing of business processes and requires immense collaboration and commitment from all impacted employees, especially management.

Also, availability of financial investment is critical and is an important sign that the top management is committed to embracing the new system.

6.4 Impact of Firm Characteristics

One other research question was related to the relationship of firm characteristics to CEIS integration and benefits. More specifically, it was postulated whether we can predict the benefits and level of integration based on certain firm characteristics. Only industrial construction specialty area was found to be significantly negatively related to CEIS integration level. In other words, this finding suggests that firms that specialize in industrial construction have lower levels of CEIS integration. This might be related to the fact that industrial projects are generally located in areas where Internet networks are not available. This can lead to dependence on paper-based processes.

6.5 Relationship between CSF and CEIS Integration Level

It was found that both firm readiness and firm commitment were positively associated with CEIS integration level. In other words, whenever CSF dimensions increase, CEIS integration level increases as well. This is expected, since without a sound firm commitment and readiness, system integration may not be realized. System integration requires detailed knowledge of the current information systems and how they could be integrated technically. It requires commitment to business process change and availability of financial funds. It also entails user training, competent MIS team, and clear strategies and goal set forth by the top management. Thus, ensuring firm readiness and commitment are a prerequisite for a successful CEIS integration.

6.6 Relationship between CSF and CEIS Benefits

The regression results between CSF and CEIS operational benefit dimension showed that firm readiness and commitment are not related to higher levels of operational benefits. When looked at a more detailed level through bivariate relationships between CSF variables and operational benefits, it was found that higher levels of user training might yield higher operational benefits. Especially in daily operations of construction projects, such as receiving construction supplies to the site, using equipment in the project site, and labor work, keying the necessary data to the system is critical. For this reason, as the level and quality of user training to use CEIS increases, users perform their duties better and faster, and will enter the necessary data more rapidly. This may also lead to possible cost reductions due to streamlined processes, cycle time reductions due to faster single entry, and quality improvement due to consistent system usage. As a result, better managerial decisions would be possible because of the accurate and timely data entry. This may lead to better allocation of resources and thus results in performance improvements. On the other hand, untrained users may discard the CEIS due to their lack of training. This may lead to less usage of it and might result in having more manual processes instead of utilizing the functionalities of CEIS. Thus, to achieve a higher operational benefit, adequate user training is a necessary condition.

On the other hand, results of regression analysis between CSF constructs and strategic benefits did not reveal a critical impact of the constructs on strategic benefits. A detailed level of analysis might suggest that clearer strategies, goals, and vision regarding CEIS and clear allocation of responsibilities are two critical factors that lead to higher strategic benefits. It is vital to think thoroughly and set clear goals regarding how CEIS would assist the firm in their business growth, as well as building business alliances and external linkages. Also, it is imperative to set clear responsibilities and goals for firm divisions, so that they can form internal teams that would assist in utilizing CEIS to achieve the strategic benefits sought.

Firm commitment was found to be significantly impacting organizational benefits. A more detailed analysis suggests that two of these success factors might be best predictors of organizational benefits; minimum customization of CEIS to fit business processes and availability of financial investment. Minimum customization would allow the firm to rethink their business processes and might lead to adopting more efficient best practices. This in turn might empower the employees, since during adopting more efficient business processes, they will get the opportunity to learn and contribute to the improvement of these processes. Also, shifts in work patterns may lead to consolidating idle and unproductive business processes and redefine responsibilities of the employees. For these strategic benefits to be actualized, availability of financial investment is another critical factor, since dedicating teams from each department to analyze future business processes would require significant financial resources.

Lastly, results of regression analysis between CSF and IT infrastructure suggest that firm readiness is positively associated with IT infrastructure benefits. Within the firm readiness dimension, MIS department competence and clear allocation of responsibilities might be the two critical factors that lead to higher IT infrastructure benefits. It is expected that the more competent an MIS department is, the more benefits the firm would attain regarding its IT infrastructure. Through a competent MIS department, the firm might benefit from a scalable IT infrastructure that can support the further growth of business. A durable and flexible IT infrastructure would be put in place and managed successfully. Also, this would lead to possible IT cost reductions, since custom in-house developed ad-hoc computer software would be retired and thus less technical team would be needed for support and maintenance. Clear allocation of responsibilities is also critical to achieve IT infrastructure benefits. For instance, the firm can allocate a dedicated team to serve as a centralized helpdesk to support a standardized information system.

6.7 Relationship between CEIS Integration Level and CEIS Benefits

It is important to note that when CEIS integration and CSF dimensions were tested as predictor variable of CEIS benefits, CEIS integration was not found to impact the perceived firm benefits. In other words, it was found that CEIS integration cannot provide benefits to the firm unless certain critical success factors exist. CSF act as mediating factor between CEIS integration and CEIS benefits. This finding is vital to understanding the limitation of studying CEIS integration alone and provides a guideline to the firms that integration should be sought as the sole solution that will bring benefits to the firm.

CEIS integration's relationship with perceived firm benefits was analyzed by not taking CSF into account to provide more insight into the effect of CEIS integration by itself, assuming that CSF effect is constant. Results of ANOVA regarding the effect of CEIS integration level on CEIS benefits indicates that as integration level increases only organizational benefits increase. In other words, CEIS integration level has a significant impact on organizational benefits. CEIS integration level was not found to be critical in achieving higher levels of operational, strategic, and IT infrastructure benefits. This finding suggests that CEIS integration may be critical in changing work patterns and facilitating organizational learning. CEIS integration might lead to more integrated business processes, and this might lead to a new vision within the firm. The fact that CEIS integration does not impact other benefit dimensions is surprising, yet it constitutes an important finding. For instance, this finding confirms that system integration cannot be seen as a factor for increased operational, strategic, and IT benefits by itself. In other words, system integration can be a useful tool, but only if used in conjunction with other variables.

It was decided to study the impact of CEIS integration on benefits not only at the dimensional level, but at the variable level as well. Since, although it was confirmed that dimension-wise CEIS integration only impacted organizational benefits, its interaction at the variable level would constitute important information as well. Based on the ANOVA, several key variables were found to be impacted significantly by CEIS integration level; cost reduction, building business innovations, generating or sustaining competitiveness, facilitate business learning, empowerment of employees, and building common vision for the firm.

CEIS integration may result in less time and resource in data entry, since the data is entered to the system only once, avoiding double entry. This may yield to cost reduction, since the firms might not need as many resources for data entry. Cost reduction was the only variable within the operational benefits dimensions that was found to be impacted by the level of CEIS integration.

Two strategic factors that were found to be impacted by the level of CEIS integration are building business innovations and generating or sustaining competitiveness. This finding suggests that CEIS integration helps the firms to improve their way of doing business and provides a venue for it. Through CEIS integration the firms can become more innovative in their businesses. Also, CEIS integration may lead to getting more accurate and timely information about their assets, their current strengths and weaknesses, and would put firms in more competitive advantage with respect to their rivals.

Only one IT infrastructure factor was found to be impacted by the level of CEIS integration; increased business flexibility. This finding suggests that as the level of CEIS integration increases, the firm increases its flexibility in adapting to modern technology, extending to external parties and expanding to a range of applications as suggested by Shang and Seddon (2002).

Most organizational factors were significantly impacted by CEIS integration level and the findings were discussed earlier. Assessing the benefits at the dimensional and variable levels proved beneficial for the purposes of this study. Through variable analysis, it was possible to get more detailed information regarding the impact of CEIS integration. On the other hand, through dimensional analysis it was possible to observe the main impact category.

Coupled with the earlier findings that suggest that CEIS integration can only be beneficial when certain CSF are present, this study shows that CEIS integration should only be seen as a tool and not a goal by itself. It was also shown that when certain CSF exists, CEIS integration can bring positive impact to the firm.

6.8 Relationship between EIS Type and CEIS Benefits

The regression model showed that legacy systems adversely affect the operational benefits. In other words, when legacy systems are used, the operational benefits are compromised. This result offers many important conclusions. Especially in the construction industry, where there are many software solutions particularly geared towards certain functions, issues like double entry and unavailability of data through the system is causing the firms to loose certain benefits in their operations.

Although it was confirmed that dimension-wise EIS type only impacted operational benefits, its interaction at the variable level would help to uncover important information as well. Hence, it was decided to study the impact of EIS type on benefits not only at the dimensional level, but at the variable level as well. Based on the ANOVA, several key variables were found to be impacted significantly by EIS type; cost reduction, productivity improvement, and increased business flexibility.

The type of EIS may result in a faster and more reliable system that would help to increase productivity and lessen costs. Some legacy systems take a very long time to process a simple command, whereas more recent EIS types are faster and more standardized. Confirming these postulates, cost reduction and productivity improvement were the only variables within the operational benefits dimensions that were found to be impacted by the level of CEIS integration.

Only one IT infrastructure factor was found to be impacted by the level of CEIS integration; increased business flexibility. This finding suggests that as the firm adopts more advanced EIS types, it increases its flexibility in adapting to modern technology that can be utilized to integrate stand-alone systems. No strategic or organizational benefits were found to be impacted by the selection of EIS type. This is somewhat surprising since the adoption of newer technologies is expected to yield particularly strategic benefits. Yet, it is also understandable since strategic and organizational benefits depend primarily on business decisions and cannot be based on the system alone.

6.9 Relationship between EIS Type and CEIS Integration Level

Another important research question was related to the impact of EIS type on CEIS integration level. In the regression models, it was found that stand-alone EIS type was a significant negative factor for an increased CEIS integration. This finding confirmed that stand-alone systems do decrease the system integration level in the construction industry. This suggests that commercially developed EIS systems can assist to achieve the goals of CIC. PMIS type was not found to be associated with CEIS integration level. Since it is a stand-alone tool, this finding was expected.

6.10 Effect of CEIS Integration Level on Satisfaction

Through regression analysis, it was found that as CEIS integration level increases, so does the level of satisfaction of CEIS integration and EIS. In other words, the increased level of system integration increases the satisfaction of the users. Also, as their EIS becomes more integrated with other stand-alone systems, they become more satisfied. Users become more satisfied and may become more productive when CEIS lessens the time and effort wasted by double entry.

6.11 Effect of CEIS Benefits on Satisfaction

Results of regression analysis revealed that only operational benefit dimension and IT infrastructure dimension had a significant impact on the users. Since users of CEIS are mostly involved in day to day operations, they will be more satisfied with the system integration when it facilitates their daily activities. Also, as their experience with IT infrastructure improves, so does their satisfaction with CEIS integration.

Chapter 7: Conclusions and Recommendations

Although the use of CEIS is rapidly increasing in the construction industry, there are few quantitative studies that assess their effectiveness. This research aimed to be exploratory in nature and assessed many facets of CEIS. In order to successfully implement CEIS and increase the integration level, the construction firms need to evaluate the critical factors associated with such endeavors carefully. Also, it is critical to know whether CEIS provides what it primarily promises; a more integrated enterprise. It is also vital to evaluate the key benefit areas CEIS and CEIS integration target. Based on the findings of the research, the following key contributions were made to the body of knowledge on construction research:

- **Identifying the key CEIS benefit areas:** Four distinct dimensions of firm benefits are impacted by CEIS; operational, strategic, organization, and IT infrastructure. Each of these dimension aid in explaining different effects of CEIS on construction firms.

- **Identifying the critical success factors that impact CEIS integration level:** Firm commitment and firm readiness dimensions were constructed out of nine CSF variables. Firm readiness, especially MIS competence and sufficient funding is critical for any attempt to increase CEIS integration level. Construction firms that are planning to increase their integration level should start their endeavor by ensuring that a qualified MIS team is present and an adequate budget is set.

- **Identifying the critical success factors that impact CEIS induced benefits:** Different critical success factors are required to achieve the desired benefits in each dimension. User training is critical to achieve higher operational benefits. Clear CEIS strategy and allocation of responsibilities are required to achieve higher levels of strategic benefits. Minimum customization and financial investment availability are necessary to maximize organizational benefits. Also, to achieve higher IT infrastructure benefits, MIS department competence and clear allocation of responsibilities are necessary.

- **Identifying the impact of system integration on CEIS induced benefits:** As CEIS integration increases the organizational benefit dimension of the firm increases. This dimensional impact is complemented by individual variable benefits such as cost reduction, building business innovations, generating competitiveness, increasing business flexibility, facilitating business learning and broadening employee skills, empowering employers, and building common vision for the firm. It was also found that CEIS integration would not yield any benefits unless certain critical success factors are present. This finding is critical in that it shows that ultimately CEIS integration is not the goal but only a tool that can be beneficial when other critical factors are present.

- **Identifying the impact of CEIS strategy on CEIS induced perceived firm benefits:** With the adoption of best-of-breed strategy and leaving stand-alone strategy, firms can maximize their operational benefits. Significant cost reduction, productivity improvement, and increased business flexibility are actualized through adoption of this strategy.

- **Identifying the relationship between CEIS and system integration:** Best-of-breed and ERP strategies increase the level of system integration. This has been verified empirically, and it guides the firms to adopt these strategies if they seek higher levels of system integration.

- **Identifying the impact of CEIS induced perceived firm benefits and CEIS integration on satisfaction:** The acquirement of both operational and organizational benefits and CEIS integration are necessary for an increased level of user satisfaction. Employees become more satisfied with their CEIS if they notice improvements in their daily activities and if it facilitates broadening of their skills.

This research elucidates and empirically tests many assumptions made about CEIS. Yet, this study has certain limitations. The major limitations of this study are as follows:

- A larger number of respondents may have strengthened the findings. Also, the data is mostly limited to firms based in the United States.
- The model could be enriched by extending it to other organizational and economic critical factors.

- Survey research assumes that the respondents are unbiased. Yet, there is always a possibility that some respondents might have been biased in their answers. Systematically biased responses have been minimized through statistical techniques (see Chapter 4).

The findings of this research invite new venues of research in CEIS. Some of the recommendations for future work are as follows:

- The primary focus of this research was system integration. The dimensionality of integration could be taken into account in future research, such as organizational and supply chain integration. The impact of all the components of the model introduced in this study could be tested vis-à-vis different dimensions of integration.
- Other organizational and economic factors could be introduced to the model that might supplement the findings and conclusions of this research.

Following these findings, it is possible to generate a guide map for the construction firms that are planning to increase the integration of their CEIS.

1. Hire a highly qualified MIS team and set aside an adequate budget before embarking on CEIS integration projects.
2. Select the best-of-breed strategy to maximize the level of integration and benefits.
3. Ensure that adequate user training is given to all CEIS users to maximize operational benefits.

4. Ensure a clear CEIS strategy is devised and clear allocation of responsibilities are communicated to all users in order to achieve maximum level of strategic benefits.
5. Minimize customization and maximize changing business processes to fit CEIS best practices. Also, ensure adequate funding is allocated. These conditions would increase organizational benefits.
6. Gauge the satisfaction of users by assessing the operational and organizational benefits CEIS is providing, on a regular basis.

Appendix A: Survey Instrument

Survey on the Construction Enterprise Information Systems

This survey is one part of a research project being conducted by the e-Construction Group at Purdue University, USA, headed by Prof. M.J. Skibniewski. We aim at identifying the factors that affect the adoption and integration of construction enterprise information systems (CEIS) in the construction industry.

The questionnaire is designed for CONSTRUCTION INDUSTRY FIRM EXECUTIVES (i.e., CEOs, CIOs, CTOs, VPs, OPERATIONS MANAGERS, PROJECT MANAGERS AND IT/IS MANAGERS) who have good working knowledge of the information systems in their firms.
The questionnaire should take about 15-20 minutes to complete. Your contribution towards this study is greatly appreciated, as it will add significantly to the value of the research. All information provided through this questionnaire will eventually be compiled and presented as part of a Purdue University report. YOUR RESPONSES WILL BE KEPT SECURELY AND WILL REMAIN CONFIDENTIAL.

If you have any questions or require further information, please e-mail Mr. Omer Tatari at otatari@purdue.edu.

Benefits of the Survey:
This survey is an opportunity to harness the collective experience of the user base, expand industry awareness, and contribute to further understanding and development of CEIS in the construction industry.

Construction Enterprise Information Systems (CEIS) include all computer based information systems solutions that are used to aid the management of the construction business.

A summary report and an analysis of the survey will be e-mailed to the participants.

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1) General Information

1.1. Your length of experience in construction (years):

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2) Firm-Related Factors

2.1. Firm Location (City, State, Country)

2.2. Select one of the following that describes your firm?s primary role (select one) :
 Architectural firm
 General contractor
 Specialty contractor
 Engineering firm
Other (Specify):

2.3. The nature of construction projects (select all that apply):
 Residential
 Commercial
 Heavy construction
 Industrial
 Specialty
Other (Specify):

2.4. Firm?s Size (Approximate range of Annual Revenue in US Dollars):
 Less than $200 million
 Between $200 million and $750 million
 Between $750 million and $1.5 billion
 More than $1.5 billion

2.5. Which of the following best describes your firm? My firm:
 serves only our local market area
 serves multiple market areas in our region of the country
 serves multiple market areas across the nation
 serves multiple market areas across the continent
 serves multiple market areas across the world
2.6. My firm uses these strategies in business (check all that apply):
 Partnering strategy with other parties
 Total Quality Management
 Supply Chain Management
 Lean construction

----
3) CEIS Related Factors

3.1. Rate the level of actual performance for the following factors regarding your firm's Construction Enterprise Information System.
1:Very low
2:low
3:Neutral
4:High
5:Very high

1) Top Management Support and Commitment for better CEIS
1 2 3 4 5

2) Continuous Interdepartmental Cooperation for better CEIS
1 2 3 4 5

3) Continuous Interdepartmental Communication for better CEIS
1 2 3 4 5

4) Clear CEIS Strategy, goals and vision
1 2 3 4 5

5) Business process change to fit CEIS
1 2 3 4 5

6) Minimum customization of CEIS to fit business processes
1 2 3 4 5

7) Difficulty to integrate different standalone applications into an integrated CEIS
1 2 3 4 5

8) Poorly defined construction business processes
1 2 3 4 5

9) Availability of financial investment in CEIS applications
1 2 3 4 5

10) Adequate vendor support from application suppliers
1 2 3 4 5

11) MIS department competence in implementing CEIS
1 2 3 4 5

12) Clear allocation responsibilities for CEIS
1 2 3 4 5

13) User training for CEIS
1 2 3 4 5

14) High CEIS operation and maintenance cost
1 2 3 4 5

----
4) PMIS Related Information

4.1. Which type of Project Management Information System (PMIS) does your firm use for its construction projects?
Windows-based (e.g. Prolog?, MS Project?, Primavera?)
Web-enabled
Web-based subscription (vendor providing PMIS hosts the system)
Web-based solution package (purchased and hosted internally)
ERP project management module
4.2. Which PMIS is used for your firm's construction projects? (Please state the name of the system)

4.3. How would you rate your overall satisfaction with the current PMIS in use?
Very low
Low
Neutral
High
Very high

----
5) EIS Related Information

5.1. What is your firm's strategy in terms of enterprise information system (EIS) (Finance, Accounting, and other needs)?
Legacy system (information system previously designed specifically for our firm's needs)
Enterprise Resource Planning (ERP) (off-the-shelf, commercially available enterprise information system)
Best-of-breed (collection of standalone applications connected to each other)
Stand-alone (collection of individual applications NOT connected to each other)

5.2. If you use an ERP system, which modules are already implemented or planned for implementation?
SAP
Oracle
J.D. Edwards
PeopleSoft
Baan
Deltek
Timberline
Other (Specify):

5.3. How would you rate the overall satisfaction with the current EIS in use?
Very low
Low
Neutral
High
Very high

----
6) ES/PMS Integration Success

6.1. How would you rate the level of your Construction Enterprise Information System's integration?
No information system (manual business processes and operation)
No integration (several stand-alone computer applications with no integration)
Partial relayed integration (several functions computerized and consolidated in certain periods (e.g. daily, weekly, monthly))
Partial seamless integration (several functions integrated with seamless real-time integration)
Full integration (all functions integrated with seamless real-time integration)
Full Integration with other parties (all functions and many different business entities are integrated with seamless real-time integration)

6.2. How would you rate the overall satisfaction with the current integration of CEIS?
Very low
Low
Neutral
High
Very high

6.3. Does your firm plan to increase the level of integration of your CEIS?
My firm is satisfied with current level of integration of CEIS.
My firm is in the process of increasing the level of integration of CEIS.
My firm plans to increase the level of integration of CEIS.

----
7) Benefits

7.1. From the experience your firm has had with your CEIS, to what extent has CEIS helped in the following?
1:Significant detriment
2:Some detriment
3:No change
4:Some Improvement
5:Significant Improvement

Operational Benefits
Cost Reduction
1 2 3 4 5

Cycle time reduction
1 2 3 4 5

Productivity improvement
1 2 3 4 5

Quality improvement
1 2 3 4 5

Managerial Benefits
Better resource management
1 2 3 4 5

Improved decision making and planning
1 2 3 4 5

Improved efficiency
1 2 3 4 5

Strategic Benefits
Support for business growth
1 2 3 4 5

Building business innovations
1 2 3 4 5

Build better external linkage with suppliers, distributors and related business parties
1 2 3 4 5

Enable expansion to new markets
1 2 3 4 5

Generating or sustaining competitiveness
1 2 3 4 5

IT Infrastructure Benefits
Increased business flexibility
1 2 3 4 5

IT costs reduction
1 2 3 4 5

Increased IT infrastructure capability (flexibility, adaptability, etc.)
1 2 3 4 5

Organizational Benefits
Support business organizational changes in structure & processes
1 2 3 4 5

Facilitate business learning and broaden employee skills
1 2 3 4 5

Empowerment of employees
1 2 3 4 5

Building common vision for the firm
1 2 3 4 5

---

8) Personal Information (Optional)

8.1. Your name:

8.2. Your title:

8.3. Firm Name:

8.4. E-mail address that we will send you the summary report of the questionnaire:

Provide any additional comments in the space below.

Thank you for your participation! The results of the survey will be e-mailed to you if you have provided us with your e-mail.

Appendix B: SPSS Output

Appendix B 1 Statistics on Central Tendency, Dispersion, and Distribution

		topmgm	clestrat	bpr	mincus	fininv	vensup	misdep	cleresp
N	Valid	110	110	108	109	106	109	109	109
	Missing			2	1	4	1	1	1
	Missing	0.00%	0.00%	1.85%	0.92%	3.77%	0.92%	0.92%	0.92%
	Mean	3.74	3.05	2.98	2.96	3.30	3.19	3.28	3.27
	Std. Error of Mean	.100	.106	.099	.099	.098	.085	.104	.099
	Median	4.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
	Std. Deviation	1.046	1.107	1.032	1.036	1.006	.887	1.089	1.033
	Skewness	-.625	-.151	.090	-.282	-.412	-.066	-.240	-.197
	Std. Error of Skewness	.230	.230	.233	.231	.235	.231	.231	.231
	Kurtosis	-.207	-.736	-.519	-.617	-.363	-.021	-.476	-.491
	Std. Error of Kurtosis	.457	.457	.461	.459	.465	.459	.459	.459

		utrain	psat	esat	topmgm	clestrat	bpr	mincus	fininv
N	Valid	109	107	108	110	110	108	109	106
	Missing	1	3	2			2	1	4
	Missing	0.92%	2.80%	1.85%	0.00%	0.00%	1.85%	0.92%	3.77%
	Mean	3.00	3.26	3.03	3.74	3.05	2.98	2.96	3.30
	Std. Error of Mean	.100	.089	.088	.100	.106	.099	.099	.098
	Median	3.00	3.00	3.00	4.00	3.00	3.00	3.00	3.00
	Std. Deviation	1.045	.925	.912	1.046	1.107	1.032	1.036	1.006
	Skewness	-.198	-.111	-.206	-.625	-.151	.090	-.282	-.412
	Std. Error of Skewness	.231	.234	.233	.230	.230	.233	.231	.235
	Kurtosis	-.543	-.170	-.074	-.207	-.736	-.519	-.617	-.363
	Std. Error of Kurtosis	.459	.463	.461	.457	.457	.461	.459	.465

		vensup	misdep	cleresp	utrain	psat	esat	isat	cosred
N	Valid	109	109	109	109	107	108	108	106
	Missing	1	1	1	1	3	2	2	4
	Missing	0.92%	0.92%	0.92%	0.92%	2.80%	1.85%	1.85%	3.77%
	Mean	3.19	3.28	3.27	3.00	3.26	3.03	2.66	3.47
	Std. Error of Mean	.085	.104	.099	.100	.089	.088	.092	.085
	Median	3.00	3.00	3.00	3.00	3.00	3.00	3.00	4.00
	Std. Deviation	.887	1.089	1.033	1.045	.925	.912	.959	.875
	Skewness	-.066	-.240	-.197	-.198	-.111	-.206	-.169	-.564
	Std. Error of Skewness	.231	.231	.231	.231	.234	.233	.233	.235
	Kurtosis	-.021	-.476	-.491	-.543	-.170	-.074	-.617	.503
	Std. Error of Kurtosis	.459	.459	.459	.459	.463	.461	.461	.465

		timred	prodimp	qualimp	resmgm	impdec	impeff	busgro	busino
N	Valid	106	105	105	105	105	104	103	104
	Missing	4	5	5	5	5	6	7	6
	Missing	3.77%	4.76%	4.76%	4.76%	4.76%	5.77%	6.80%	5.77%
	Mean	3.63	3.61	3.54	3.63	3.62	3.67	3.55	3.44
	Std. Error of Mean	.092	.091	.093	.084	.087	.094	.095	.088
	Median	4.00	4.00	4.00	4.00	4.00	4.00	4.00	3.00
	Std. Deviation	.949	.935	.951	.858	.892	.960	.967	.901
	Skewness	-.627	-.433	-.672	-.316	-.326	-.507	-.651	-.271
	Std. Error of Skewness	.235	.236	.236	.236	.236	.237	.238	.237
	Kurtosis	.299	-.043	.120	-.013	-.197	-.073	.334	.299
	Std. Error of Kurtosis	.465	.467	.467	.467	.467	.469	.472	.469

Appendix B 2 Pearson Correlation Coefficients for CSF

	topmgm	clestrat	Bpr	mincus	fininv	vensup	misdep	Cleresp	utrain
topmgm	1.000	.662**	.511**	.332**	.605**	.402**	.502**	.474**	.450**
clestrat		1.000	.605**	.251**	.485**	.430**	.625**	.595**	.598**
bpr			1.000	.334**	.449**	.319**	.444**	.349**	.338**
mincus				1.000	.320**	.243*	.354**	.304**	.214*
fininv					1.000	.402**	.431**	.337**	.407**
vensup						1.000	.484**	.308**	.346**
misdep							1.000	.533**	.576**
cleresp								1.000	.600**
utrain									1.000

Appendix B 3 Correlation Coefficients for CEIS Benefits

	cosred	timred	prodimp	qualimp	resmgm	impdec	impeff	busgro	busino	extlink
cosred	1.000	.738**	.685**	.650**	.526**	.671**	.674**	.516**	.438**	.471**
timred		1.000	.738**	.776**	.571**	.579**	.697**	.560**	.446**	.416**
prodimp			1.000	.743**	.627**	.716**	.774**	.604**	.521**	.587**
qualimp				1.000	.556**	.644**	.667**	.572**	.515**	.497**
resmgm					1.000	.718**	.673**	.583**	.579**	.457**
impdec						1.000	.745**	.554**	.489**	.498**
impeff							1.000	.576**	.483**	.502**
busgro								1.000	.741**	.529**
busino									1.000	.588**
extlink										1.000

	expnew	gencomp	busflex	Itcred	incinf	busch	buslearn	empemp	comvis
cosred	.394**	.576**	.419**	.476**	.368**	.367**	.394**	.542**	.463**
timred	.445**	.645**	.498**	.378**	.395**	.422**	.469**	.588**	.555**
prodimp	.519**	.636**	.478**	.435**	.344**	.254**	.477**	.513**	.479**
qualimp	.478**	.695**	.577**	.446**	.468**	.435**	.527**	.591**	.544**
resmgm	.510**	.506**	.437**	.256**	.343**	.324**	.459**	.542**	.458**
impdec	.473**	.547**	.533**	.465**	.418**	.380**	.503**	.561**	.506**
impeff	.481**	.553**	.468**	.420**	.320**	.381**	.407**	.609**	.500**
busgro	.623**	.670**	.534**	.327**	.349**	.454**	.513**	.451**	.561**
busino	.560**	.637**	.452**	.395**	.393**	.441**	.531**	.464**	.526**
extlink	.635**	.618**	.478**	.454**	.397**	.349**	.420**	.409**	.352**
expnew	1.000	.671**	.640**	.377**	.454**	.474**	.518**	.439**	.501**
gencomp		1.000	.688**	.469**	.571**	.563**	.570**	.600**	.676**
busflex			1.000	.468**	.636**	.551**	.559**	.468**	.551**
itcred				1.000	.563**	.465**	.392**	.459**	.433**
incinf					1.000	.569**	.425**	.428**	.530**
busch						1.000	.611**	.616**	.550**
buslearn							1.000	.658**	.565**
empemp								1.000	.670**
comvis									1.000

Appendix B 4 Total Variance Explained for Firm Benefits

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	10.010	52.683	52.683	10.010	52.683	52.683	4.913	25.856	25.856
2	1.655	8.709	61.391	1.655	8.709	61.391	3.541	18.635	44.491
3	1.257	6.614	68.006	1.257	6.614	68.006	2.958	15.570	60.061
4	1.019	5.361	73.367	1.019	5.361	73.367	2.528	13.306	73.367
5	.712	3.747	77.114						
6	.630	3.314	80.428						
7	.552	2.905	83.333						
8	.489	2.574	85.908						
9	.443	2.329	88.237						
10	.369	1.941	90.178						
11	.323	1.701	91.879						
12	.286	1.503	93.382						
13	.247	1.301	94.683						
14	.207	1.091	95.774						
15	.201	1.056	96.830						
16	.181	.954	97.784						
17	.162	.851	98.635						
18	.138	.728	99.362						
19	.121	.638	100.000						

Extraction Method: Principal Component Analysis.

Appendix B 5 Total Variance Explained for Critical Success Factors

Comp	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
onent	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	4.368	48.533	48.533	4.368	48.533	48.533	3.096	34.395	34.395
2	1.035	11.500	60.033	1.035	11.500	60.033	2.307	25.637	60.033
3	.821	9.121	69.154						
4	.732	8.137	77.291						
5	.550	6.108	83.399						
6	.463	5.142	88.541						
7	.422	4.691	93.232						
8	.329	3.654	96.885						
9	.280	3.115	100.000						
Extraction Method: Principal Component Analysis.									

Appendix B 6 Pearson Correlation Coefficients for Final Framework Variables

Correlations													
		INTGR	OB	SB	GB	IB	RDNS	COMM	LGC	ERP	BOB	STND	SAT
INTGR	Pearson Correlation	1.000	.114	.140	.261*	.161	.309**	.350**	.136	.073	.075	-.329**	.523**
	Sig. (2-tailed)		.287	.188	.013	.130	.002	.000	.171	.461	.449	.001	.000
	N	105.000	90	90	90	90	96	96	103	103	103	103	101
OB	Pearson Correlation	.114	1.000	.001	-.009	.000	.203	.109	-.153	.093	.229*	-.208	.370**
	Sig. (2-tailed)	.287		.995	.936	.999	.065	.327	.154	.387	.031	.052	.000
	N	90	90.000	90	90	90	83	83	88	88	88	88	86
SB	Pearson Correlation	.140	.001	1.000	.000	.000	.164	.071	.040	-.053	-.017	.049	.221*
	Sig. (2-tailed)	.188	.995		.998	1.000	.139	.525	.709	.626	.876	.649	.040
	N	90	90	90.000	90	90	83	83	88	88	88	88	86

GB	Pearson Correlation	.261*	-.009	.000	1.000	.000	.096	.353**	.125	.079	-.112	-.136	.245*
	Sig. (2-tailed)	.013	.936	.998		1.000	.387	.001	.248	.463	.300	.206	.023
	N	90	90	90	90.000	90	83	83	88	88	88	88	86
IB	Pearson Correlation	.161	.000	.000	.000	1.000	.412**	.121	.053	.150	-.111	-.160	.303**
	Sig. (2-tailed)	.130	.999	1.000	1.000		.000	.276	.622	.162	.303	.136	.005
	N	90	90	90	90	90.000	83	83	88	88	88	88	86
RDNS	Pearson Correlation	.309**	.203	.164	.096	.412**	1.000	.000	-.026	.179	.009	-.240*	.378**
	Sig. (2-tailed)	.002	.065	.139	.387	.000		1.000	.799	.081	.934	.019	.000
	N	96	83	83	83	83	98.000	98	96	96	96	96	92
COMM	Pearson Correlation	.350**	.109	.071	.353**	.121	.000	1.000	.180	.020	-.029	-.203*	.384**
	Sig. (2-tailed)	.000	.327	.525	.001	.276	1.000		.080	.850	.777	.047	.000
	N	96	83	83	83	83	98	98.000	96	96	96	96	92
LGC	Pearson Correlation	.136	-.153	.040	.125	.053	-.026	.180	1.000	-.507**	-.200*	-.200*	.089
	Sig. (2-tailed)	.171	.154	.709	.248	.622	.799	.080		.000	.041	.041	.378
	N	103	88	88	88	88	96	96	104.000	104	104	104	100
ERP	Pearson Correlation	.073	.093	-.053	.079	.150	.179	.020	-.507**	1.000	-.427**	-.427**	.112
	Sig. (2-tailed)	.461	.387	.626	.463	.162	.081	.850	.000		.000	.000	.267
	N	103	88	88	88	88	96	96	104	104.000	104	104	100
BOB	Pearson Correlation	.075	.229*	-.017	-.112	-.111	.009	-.029	-.200*	-.427**	1.000	-.169	.022
	Sig. (2-tailed)	.449	.031	.876	.300	.303	.934	.777	.041	.000		.087	.827
	N	103	88	88	88	88	96	96	104	104	104.000	104	100
STND	Pearson Correlation	-.329**	-.208	.049	-.136	-.160	-.240*	-.203*	-.200*	-.427**	-.169	1.000	-.275**
	Sig. (2-tailed)	.001	.052	.649	.206	.136	.019	.047	.041	.000	.087		.006
	N	103	88	88	88	88	96	96	104	104	104	104.000	100
SAT	Pearson Correlation	.523**	.370**	.221*	.245*	.303**	.378**	.384**	.089	.112	.022	-.275**	1.000
	Sig. (2-tailed)	.000	.000	.040	.023	.005	.000	.000	.378	.267	.827	.006	
	N	101	86	86	86	86	92	92	100	100	100	100	101.000

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix B 7 One-Factor Analysis for Common Method Bias

	Component				
	1	2	3	4	5
topmgm			.664		
clestrat			.773		
Bpr			.725		
mincus					.615
fininv			.611		.484
vensup		.426	.582		
misdep			.723		
cleresp			.552	.555	
utrain			.666		
cosred	.744				
timred	.791				
prodimp	.804				
qualimp	.770				
resmgm	.570	.486			
impdec	.688				
impeff	.808				
busgro		.719			
busino		.768			
extlink	.414	.633			
expnew		.782			
gencomp	.449	.618			
busflex		.528		.507	
itcred				.587	
incinf				.695	
busch		.436		.485	.542
buslearn		.477			.486
empemp	.501				.607
comvis					.511

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 20 iterations.

Appendix B 8 Factor Analysis for CEIS Satisfaction

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.500
Bartlett's Test of Sphericity	Approx. Chi-Square	21.356
	df	1.000
	Sig.	.000

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.436	71.780	71.780	1.436	71.780	71.780
2	.564	28.220	100.000			
Extraction Method: Principal Component Analysis.						

Component Matrix[a]	
	Component
	1
esat	.847
isat	.847
Extraction Method: Principal Component Analysis.	
a. 1 components extracted.	

Appendix C: SPSS Regression Output

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT INTGR
  /METHOD=ENTER RDNS COMM LGC ERP BOB STND.
```

Variables Entered/Removedb

Model	Variables Entered	Variables Removed	Method
1	STND, BOB, COMM, RDNS, LGCa	.	Enter

a. Tolerance = .000 limits reached.

b. Dependent Variable: INTGR

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.527a	.277	.237	.83738

a. Predictors: (Constant), STND, BOB, COMM, RDNS, LGC

ANOVAb

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	23.951	5	4.790	6.832	.000a
	Residual	62.407	89	.701		
	Total	86.358	94			

a. Predictors: (Constant), STND, BOB, COMM, RDNS, LGC

b. Dependent Variable: INTGR

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.340	.118		19.800	.000
	RDNS	.262	.088	.277	2.966	.004
	COMM	.296	.089	.308	3.325	.001
	LGC	.354	.237	.143	1.497	.138
	BOB	.244	.253	.091	.966	.337
	STND	-.416	.274	-.150	-1.518	.132

a. Dependent Variable: INTGR

Excluded Variablesb						
Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	ERP	.a	.	.	.	.000
a. Predictors in the Model: (Constant), STND, BOB, COMM, RDNS, LGC						
b. Dependent Variable: INTGR						

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT OB
  /METHOD=ENTER INTGR RDNS COMM LGC ERP BOB STND.
```

Variables Entered/Removedb			
Model	Variables Entered	Variables Removed	Method
1	STND, BOB, COMM, RDNS, LGC, INTGRa	.	Enter
a. Tolerance = .000 limits reached.			
b. Dependent Variable: OB			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.410a	.168	.101	.90235546
a. Predictors: (Constant), STND, BOB, COMM, RDNS, LGC, INTGR				

ANOVAb						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12.328	6	2.055	2.523	.028a
	Residual	61.068	75	.814		
	Total	73.396	81			
a. Predictors: (Constant), STND, BOB, COMM, RDNS, LGC, INTGR						
b. Dependent Variable: OB						

Coefficientsa						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.080	.316		-.253	.801
	INTGR	.077	.121	.078	.634	.528
	RDNS	.129	.104	.141	1.245	.217
	COMM	.102	.110	.108	.930	.355
	LGC	-.645	.289	-.256	-2.229	.029
	BOB	.317	.287	.122	1.105	.273
	STND	-.457	.322	-.165	-1.420	.160
a. Dependent Variable: OB						

Excluded Variablesb						
Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	ERP	.a	.	.	.	.000
a. Predictors in the Model: (Constant), STND, BOB, COMM, RDNS, LGC, INTGR						
b. Dependent Variable: OB						

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT SB
  /METHOD=ENTER INTGR RDNS COMM LGC ERP BOB STND.
```

Variables Entered/Removedb			
Model	Variables Entered	Variables Removed	Method
1	STND, BOB, COMM, RDNS, LGC, INTGRa	.	Enter
a. Tolerance = .000 limits reached.			
b. Dependent Variable: SB			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.237a	.056	-.019	.99249565
a. Predictors: (Constant), STND, BOB, COMM, RDNS, LGC, INTGR				

ANOVAb						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.410	6	.735	.746	.614a
	Residual	73.879	75	.985		
	Total	78.288	81			
a. Predictors: (Constant), STND, BOB, COMM, RDNS, LGC, INTGR						
b. Dependent Variable: SB						

Coefficientsa						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.233	.348		-.670	.505
	INTGR	.067	.133	.066	.503	.616
	RDNS	.156	.114	.164	1.366	.176
	COMM	.037	.121	.038	.307	.760
	LGC	.303	.318	.117	.953	.344
	BOB	-.125	.316	-.047	-.396	.694
	STND	.188	.354	.066	.532	.596
a. Dependent Variable: SB						

Excluded Variablesb						
Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	ERP	.a	.	.	.	.000
a. Predictors in the Model: (Constant), STND, BOB, COMM, RDNS, LGC, INTGR						
b. Dependent Variable: SB						

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT GB
  /METHOD=ENTER INTGR RDNS COMM LGC ERP BOB STND.
```

Variables Entered/Removedb			
Model	Variables Entered	Variables Removed	Method
1	STND, BOB, COMM, RDNS, LGC, INTGRa	.	Enter
a. Tolerance = .000 limits reached.			
b. Dependent Variable: GB			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.397a	.158	.091	.92290827
a. Predictors: (Constant), STND, BOB, COMM, RDNS, LGC, INTGR				

ANOVAb						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11.986	6	1.998	2.345	.039a
	Residual	63.882	75	.852		
	Total	75.868	81			
a. Predictors: (Constant), STND, BOB, COMM, RDNS, LGC, INTGR						
b. Dependent Variable: GB						

Coefficientsa						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.208	.323		-.645	.521
	INTGR	.146	.124	.146	1.176	.243
	RDNS	.052	.106	.055	.488	.627
	COMM	.281	.112	.292	2.506	.014
	LGC	-.100	.296	-.039	-.337	.737
	BOB	-.273	.293	-.104	-.932	.354
	STND	-.165	.329	-.059	-.502	.617
a. Dependent Variable: GB						

Excluded Variablesb						
Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	ERP	.a	.	.	.	.000
a. Predictors in the Model: (Constant), STND, BOB, COMM, RDNS, LGC, INTGR						
b. Dependent Variable: GB						

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT IB
  /METHOD=ENTER INTGR RDNS COMM LGC ERP BOB STND.
```

Variables Entered/Removedb			
Model	Variables Entered	Variables Removed	Method
1	STND, BOB, COMM, RDNS, LGC, INTGRa	.	Enter
a. Tolerance = .000 limits reached.			
b. Dependent Variable: IB			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.470a	.221	.158	.81391375
a. Predictors: (Constant), STND, BOB, COMM, RDNS, LGC, INTGR				

ANOVAb						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14.069	6	2.345	3.540	.004a
	Residual	49.684	75	.662		
	Total	63.753	81			
a. Predictors: (Constant), STND, BOB, COMM, RDNS, LGC, INTGR						
b. Dependent Variable: IB						

Coefficientsa						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.202	.285		.709	.480
	INTGR	-.059	.109	-.064	-.539	.592
	RDNS	.339	.093	.397	3.631	.001
	COMM	.089	.099	.101	.901	.371
	LGC	.177	.261	.076	.679	.500
	BOB	-.032	.259	-.013	-.124	.902
	STND	-.449	.290	-.173	-1.544	.127
a. Dependent Variable: IB						

Excluded Variablesb						
Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	ERP	.a	.	.	.	.000
a. Predictors in the Model: (Constant), STND, BOB, COMM, RDNS, LGC, INTGR						
b. Dependent Variable: IB						

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT SAT
  /METHOD=ENTER INTGR OB SB GB IB.
```

Variables Entered/Removedb

Model	Variables Entered	Variables Removed	Method
1	IB, OB, SB, GB, INTGRa	.	Enter

a. All requested variables entered.
b. Dependent Variable: SAT

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.662a	.439	.404	.77627747

a. Predictors: (Constant), IB, OB, SB, GB, INTGR

ANOVAb

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	37.706	5	7.541	12.514	.000a
	Residual	48.209	80	.603		
	Total	85.915	85			

a. Predictors: (Constant), IB, OB, SB, GB, INTGR
b. Dependent Variable: SAT

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.831	.237		-3.501	.001
	INTGR	.360	.093	.348	3.866	.000
	OB	.327	.084	.328	3.879	.000
	SB	.165	.083	.168	1.982	.051
	GB	.150	.087	.151	1.729	.088
	IB	.234	.084	.237	2.781	.007

a. Dependent Variable: SAT

Firm Commitment as the Mediating Variable

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT GB
  /METHOD=ENTER INTGR COMM.
```

Variables Entered/Removedb

Model	Variables Entered	Variables Removed	Method
1	COMM, INTGRa	.	Enter

a. All requested variables entered.
b. Dependent Variable: GB

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.377a	.142	.120	.91882169

a. Predictors: (Constant), COMM, INTGR

ANOVAb

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11.162	2	5.581	6.611	.002a
	Residual	67.539	80	.844		
	Total	78.701	82			

a. Predictors: (Constant), COMM, INTGR
b. Dependent Variable: GB

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.301	.290		-1.036	.303
	INTGR	.144	.112	.141	1.280	.204
	COMM	.296	.108	.303	2.747	.007

a. Dependent Variable: GB

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT COMM
  /METHOD=ENTER INTGR.
```

Variables Entered/Removedb			
Model	Variables Entered	Variables Removed	Method
1	INTGRa	.	Enter
a. All requested variables entered.			
b. Dependent Variable: COMM			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.350a	.123	.113	.93644694
a. Predictors: (Constant), INTGR				

ANOVAb						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11.515	1	11.515	13.131	.000a
	Residual	82.432	94	.877		
	Total	93.947	95			
a. Predictors: (Constant), INTGR						
b. Dependent Variable: COMM						

Coefficientsa						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.882	.258		-3.414	.001
	INTGR	.364	.101	.350	3.624	.000
a. Dependent Variable: COMM						

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