THE IMPACT OF IT USE AT THE FIRM LEVEL: AN EMPIRICAL STUDY OF CONTRACTOR PERFORMANCE

MOHAMMAD S. EL-MASHALEH, PH.D.

WILLIAM O'BRIEN, PH.D.

YOUNGCHEOL KANG

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by

MOHAMMAD S. EL-MASHALEH, PH.D.

WILLIAM O'BRIEN, PH.D.

YOUNGCHEOL KANG

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Executive Summary

This document presents findings from a survey of construction firms in the Southeastern United States. The purpose of this research is to investigate the relationship between firm performance and Information Technology (IT) use. Firm performance is measured from several standpoints: schedule performance, cost performance, safety performance, customer satisfaction, profit, and resource utilization. IT use, on the other hand, is studied in terms of how much technology is incorporated in the different tasks used to execute projects. Data was collected using a survey questionnaire. Eighty-eight respondents, representing seventy-four firms, participated in the survey. The participating firms are general contractors, construction management firms, subcontractors, and design/build firms. These firms represent the residential, commercial, industrial, and heavy and highway construction industry segments, although the majority of firms work solely or in part in the commercial sector.

Analysis was performed using statistical regression between IT use as an independent variable and performance, measured individually or as a composite metric, as the dependent variable. The results of the analysis show positive relationships between composite performance and IT use, schedule performance and IT use, and cost performance and IT use. No statistically significant relationship was found between IT use and the individual performance metrics for customer satisfaction, safety, or profitability. No significant differences were found between firms operating in different sectors.

In addition to quantitative data about performance and IT use, survey respondents were asked their opinions about the use and benefits of IT. The majority of the respondents believe that the industry is still learning to take advantage of IT and that IT has a positive impact on profitability of the firm, schedule performance, cost performance, and customer satisfaction. About half the respondents believe that the industry suffers from lack of investment in IT, that technology is immature to the needs of the industry, and that IT expands the scope of work offsetting specific productivity gains.

Overall, the research results show a positive relationship between IT use and performance. It is reasonable to conclude that IT use is a strong enough contributor to performance that further investment by firms is warranted.

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CHAPTER 1 INTRODUCTION

1.1 Purpose of the Study

This study examines the effect that information technologies (IT) have on construction firm performance and addresses the need for research that quantifies this impact. Mitropoulos and Tatum (2000) regard advances in technology as major sources of improvement for firms and industries. Hampson and Tatum (1997) argue that intense competitive pressures in construction require new ways to improve performance. According to these authors, advanced technology offers one possible way to differentiate a firm from its competitors. Unfortunately, construction firms are often slow to adopt new information technologies. Andresen et al. (2000) attribute this hesitancy to the industry-wide perception that the possible benefit would not justify large investments in IT. Mitropoulos and Tatum (2000) give two major reasons for reluctance to incorporate technology: uncertainty about the competitive advantage of using new technologies; and lack of information regarding technologies and benefits. Correspondingly, construction researchers have declined a need for improved tools to analyze how technology affects the performance of the firm. Hampson and Tatum (1997) argue that before managers can invest in IT, they need a way to measure its benefits. O'Connor and Yang (2003) call for quantitative analysis to guide IT implementations, arguing that firms would be better able to make technology decisions with the aid of such metrics.

This research responds to these calls by examining the relationship between firm performance and IT utilization. Based on empirical data collected from 74 construction firms, this study conducts regression analyses to test the relationship between firm performance and IT.

1.2 Structure of the Report

The report unfolds as follows: literature review, research methodology, data collection, results and analysis, and conclusions. The literature review chapter discusses the several extant construction studies on the impact of IT on performance. The research methodology chapter explains the methods used to quantify construction firm performance and level of IT utilized by the firms. The data collection chapter presents and elaborates on the survey questionnaire that was used to collect data for this research. The results and analysis chapter provides information on the participating firms and conducts regression analyses to test the impact of IT on their performance. The conclusion chapter draws conclusions based on the findings of the research.

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CHAPTER 2 LITERATURE REVIEW

There are relatively few studies of the impact of IT on performance, and the existing studies have focused on the project rather than on firm performance. Further, many of these studies have mainly considered the impact of specific technologies. Examples of these studies include Griffis et al. (1995), Koo and Fischer (2000), and Back and Bell (1995). Some studies review the current level of IT use (e.g., Rivard (2000), Kumar (2003)). The most detailed among them, O'Connor et al. (2000), evaluates the use of IT on specific project activities. O'Connor and Yang (2003) built on their initial evaluation to assess the impact of IT utilization on project cost and schedule success. The following discussion briefly reviews these studies.

Griffis et al. (1995) studied the impact of 3D CAD on project performance in terms of cost (actual cost/estimated cost), schedule (actual schedule/estimated schedule), and rework (additional labor expenditure due to rework/total labor expenditure of the project). Based on data from their 93 sample projects, Griffis et al. (1995) concluded that projects using 3D models experience a 5% reduction in cost growth, a 4% reduction in schedule slip, and a 65% reduction in rework. To validate their survey results for cost savings, they also conducted a case study of a project that used 3D CAD. The project staffs were asked to identify incidents of potential problems that were avoided as a result of using 3D CAD. By using conservative estimates the case study concluded a cost savings of 12%, validating the survey results.

Fischer and his colleagues (Fischer et al (2003) and Koo and Fischer (2000)) conducted a number of case studies on the impact of 4D CAD on project performance. Koo and Fischer (2000) investigated the feasibility of 4D CAD in commercial construction. Using the master CPM schedule of an already completed project, the research team sought to identify any potential problems. They found it difficult to conceptualize the construction process by viewing the CPM schedule alone. The researchers also had difficulty associating each component in the 2D drawing with its related activity or activities. After generating the 4D model for this project, they were able to predict several potential problems. Koo and Fischer (2000) argue that their case study proves the usefulness of 4D models in several categories: they help managers visualize and interpret construction sequences; they convey any special constraints of a project; they make it easier to formalize design and construction information; they help management anticipate safety hazard situations; they allow for better allocation of resources and equipment relative to site work place; and they aid constructability reviews. Such 4D visualizations, according to Fischer et al. (2003), allow more project stakeholders to understand the construction schedule more quickly and completely than do traditional construction management tools. Fischer et al (2003) report on several other projects using 4D models with similar benefits, and suggest how these benefits accrue to different stakeholders in construction projects.

Back and Bell (1995) examined the impact of Electronic Data Management (EDM) technologies on material management. The authors conducted their examination by simulating four materials management process models. The first model was nonintegrated and intended to represent the baseline condition prior to the implementation of electronic information technologies. The second process model assumed an internal integration of information in the form of a well-developed integrated database system. The third process model included EDI and bar coding technology. The fourth process model utilized the concept of reengineering. Back and Bell (1995) collected data from industry practitioners, including durations and personnel (cost) requirements for the tasks that comprised the material management processes. Based on their simulations, Back and Bell (1995) report significant time and cost savings when a firm moves to progressively more integrated processes. For example, the reengineered process model exhibits 85% time savings and 75% cost savings compared to the nonintegrated model.

The studies reviewed above are related to specific technologies rather than to benefits gleaned from adoption of a broader range of technologies. A related stream of research attempts to assess the level of IT utilization. For example, building on the IT-Barometer survey developed by Samuelson (2002), Rivard (2000) assessed the level of IT utilization among design and construction firms in Canada. He found the majority of firms were using computers heavily for administrative tasks such as book keeping, while fewer firms used IT tools for project management tasks or for electronic document exchange. A recent meta-study of related industry and academic studies by Kumar (2003) reports similar results, finding widespread use basic IT tools for accounting, word-processing, spreadsheets, and e-mail. A minority of firms were found to have used more advanced tools such as 3D models, although Kumar (2003) reports increasing utilization of tools such as project web-sites (particularly among larger firms).

Studies such as Kumar's (2003) provide a useful, albeit broad, snapshot of IT adoption in the construction industry. To gain a more detailed view, O'Connor et al. (2000) conducted a study of IT utilization for specific tasks on projects. The authors divided the project life cycle into six phases: front end, design, procurement, construction management, construction execution, and startup/operations/maintenance. Each phase is further broken down into work functions; there are 68 work functions in total. Examples of the procurement phase work functions include: determine the lead time required to order equipment and materials; conduct a quantity survey of drawings; and link quantity survey data to the cost estimating process.

The research team used a survey questionnaire to collect data. The survey was administered to owners, architects/engineers, contractors, design/build firms, engineering/procurement/construction firms, and construction management firms. Data was collected from 180 projects. For each subject project, the survey asked participants to assess the technology used in executing each work function for that project. To quantify this assessment, the survey offered the respondents a choice from among three levels of technology utilization (O'Connor et al. 2000, p. 15):

Level 1: no electronic tools or only the most common electronic tools were used in executing the work function. Information is conveyed verbally or on paper and transmitted via mail, fax, or courier.

Level 2: uncommon electronic tools played key roles in executing the work functions, but human workers still dominate the work process. Information was stored primarily in stand-alone electronic formats and was transmitted via isolated electronic media such as disks or as e-mail attachments, etc.

Level 3: while human workers still participate, fully- or nearly fully- automated systems dominated execution of the work function. Information is stored on a networked system accessible by all appropriate participants.

The study utilizes a scoring system to quantify the degree of technology use for the project at hand. The final score reflects the levels of technology use for all work functions. O'Connor et al. (2000) report that on a 0 to 10 scale, the US construction industry scored 3.85, indicating a relatively low level of overall usage of technology. The scores for front end, design, procurement, construction management, construction execution, maintenance and start-up are 4.94, 4.98, 3.50, 3.27, 3.04, and 3.94, respectively.

In a follow-up study, O'Connor and Yang (2003) quantified whether project success is associated with level of technology use. Project success was defined in terms of cost performance and schedule performance. The analyses in the study indicated that technology utilization may make a significant contribution to project cost and schedule performance.

This literature review reveals that extant construction studies do not offer quantitative findings on the impact of IT on firm-level performance. The present study, detailed in the following chapters, was tailored to satisfy the industry need for quantitative assessment.

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CHAPTER 3 RESEARCH METHODOLOGY

3.1 Measuring Firm Performance and IT Use

To measure the impact of IT on firm performance, the research team used a methodology based on quantifying firm performance and IT use of the construction firms that participated in the study. With the firm performance variable and IT variable at hand, it was possible to conduct statistical regression analysis to measure the impact of IT on firm performance.

The independent variable for regression is firm performance). A review of the related benchmarking literature (Fisher et al. (1995), CBPP (1998), Hudson (1997), CII (2000)) suggests the following metrics: schedule performance, cost performance, customer satisfaction, safety performance, and profit. Definitions for these measures are provided in Table 1. Respondents were asked to rate their firm performances for each metric. It was possible to run individual statistical regressions for each metric. It was also possible to determine a composite score of the metrics to establish an overall rating for firm performance.

This composite score was determined by the use of Data Envelopment Analysis (DEA) (Cooper et al. (2000)). DEA is based on mathematical linear programming. It enables firms to compare their performances to other firms in the industry. Using DEA terminology, the best performing firms form an efficient frontier. It is then possible to measure the performance of the remaining firms against this frontier. DEA analysis is based on each firm's performance scores on a (0-1) scale.

Table 1: Performance Metrics that Compose Firm Performances

Metric	Measurement Method
Schedule Performance	% of the time projects are delivered on/ahead of schedule
Cost Performance	% of the time projects are delivered on/under budget
Customer Satisfaction	% of repeat business customers
Safety Performance	Experience Modification Rating (EMR)
Profit	Net profit after tax as a % of total sales

The measurement of the IT variable is based on the study by O'Connor et al. (2000) in which 68 work functions were developed to study the impact of IT use in the construction industry. The six construction phases they considered were front-end, design, procurement, construction management, construction execution, and start up, operation and maintenance. This research excludes the first two phases, front end and design since the targeted participant of this research is limited to general contractors, construction management firms, design/build firms, and subcontractors. The total number of work functions for the remaining four phases is 48.

The level of technology utilized by construction firms is termed ITindex and is based on a (0-10) score. The ITindex is calculated as follows (O'Connor et al. 2000, p. 23):

*ITindex = [[Sum of work functions scores / (Total # of work functions - # of "N/A" responses - # of "Don't know" responses)] - 1] * 5*

3.2 Data Collection

Data for this research were collected through a five-part survey questionnaire (see Appendix). The first part, Respondent Information, collects general information about the respondents. The second part, Firm General Information, gathers data on five characteristics of each firm: firm type (e.g., general contractor, construction management firm, subcontractor, etc.); firm industry sector (e.g., commercial, industrial, etc.); percentage of firms' projects that are negotiated bid; typical range of project sizes that the firm executes; and the approximate revenues of the firm.

The third part of the survey questionnaire, Degree of Technology Use, collects information regarding the use of IT based on the work functions developed by O'Connor et al. (2000). The purpose of this part is to quantify the level of technology used by the participating firms.

The fourth part of the survey questionnaire, Firm Overall Performance, collects information about the performance of the firm. Firms are asked to supply their Schedule Performance, Cost Performance, Safety Performance (EMR), Customer Satisfaction, and Profit. This part includes directions to the respondents on how to calculate these performance measures.

In the fifth part of the questionnaire, Information Technology Impact and Payoffs, the researchers made several evaluative statements regarding the impact and payoffs of IT and asked the respondents to select one of four answers to these statements: "strongly agree," "slightly agree," "slightly disagree," or "strongly disagree." In the IT Impact section, respondents were asked whether IT affects their firm's competitive advantage, profitability, schedule performance, cost performance, customer satisfaction, and safety performance.

The payoffs section asked respondents to choose from among four reasons for the construction industry's resistance to using IT. The four choices were: lack of investment, the industry is still learning to take advantage of IT, technology is still immature with the respect to the needs of the industry, and IT expands scope of work offsetting specific productivity gains.

The survey questionnaire was posted on the University of Florida web site, and the survey link was e-mailed to 777 construction industry practitioners. 232 of the e-mails were returned as undeliverable, making the number of e-mails that reached potential respondents 545. Out of these 545 e-mails the researcher received 88 responses, which accounts for a 16.15% response rate. The 88 respondents represent 74 firms.

3.3 Research Question and Hypotheses

The basic research question addressed by this study is: “Does IT utilization affect firm performance?” The researchers address this question by statistical methods, obtaining data about IT utilization and firm performance and seeking to determine a relation between them, if any. Linear regression is used to investigate the relationship between the variables. The sample population is limited to construction firms.

Collection of multiple metrics for the independent variable enabled the researchers to test six hypotheses: that each of the five individual metrics and the composite firm performance is positively correlated with IT utilization. The null hypothesis is that there is no relationship. Each hypothesis is shown in Table 2.

Table 2: Research Hypotheses

No.	Hypothesis
1	ITindex and firm performance are positively correlated
2	ITindex and schedule performance are positively correlated
3	ITindex and cost performance are positively correlated
4	ITindex and customer satisfaction are positively correlated
5	ITindex and EMR are positively correlated
6	ITindex and profit are positively correlated

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CHAPTER 4 RESULTS AND ANALYSIS

This chapter is structured into four parts. The first part provides respondents' and firms' general information. The second part supplies respondents' perceptions about the impact and payoffs of IT. The third part provides the reported levels of IT utilized by each firm participating in the study. The fourth part shows the regression analysis conducted to investigate the relationship between firm performances and IT.

4.1 Respondents' and Firms' General Information

Figure 1 shows the managerial level of the 88 respondents. Among them, 52% are from top management (i.e., president, vice president, CEO), 28% are from middle management (i.e., director of certain unit within the organization, senior manager, project manager), and 13% are from low management level (i.e., field manager, assistant project manager, project engineer). Seven percent of the respondents fill positions that do not indicate managerial responsibilities. For those respondents, the managerial level is marked as NA (Not Available) as shown in Figure 1.

Figure 2 shows the types of participating firms (i.e., General Contractor, Construction Management Firm, Subcontractor, Design/Build). Thirty one firms (43%) are GCs, 7 firms (10%) are CMs, 21 firms (29%) are both GCs and CMs, 3 firms (4%) are D/B firms, 2 firms (3%) are subcontractors, 4 firms (5%) are GCs, CMs, and D/B firms, and 6 firms (6%) have other combinations among those types as shown in the figure.

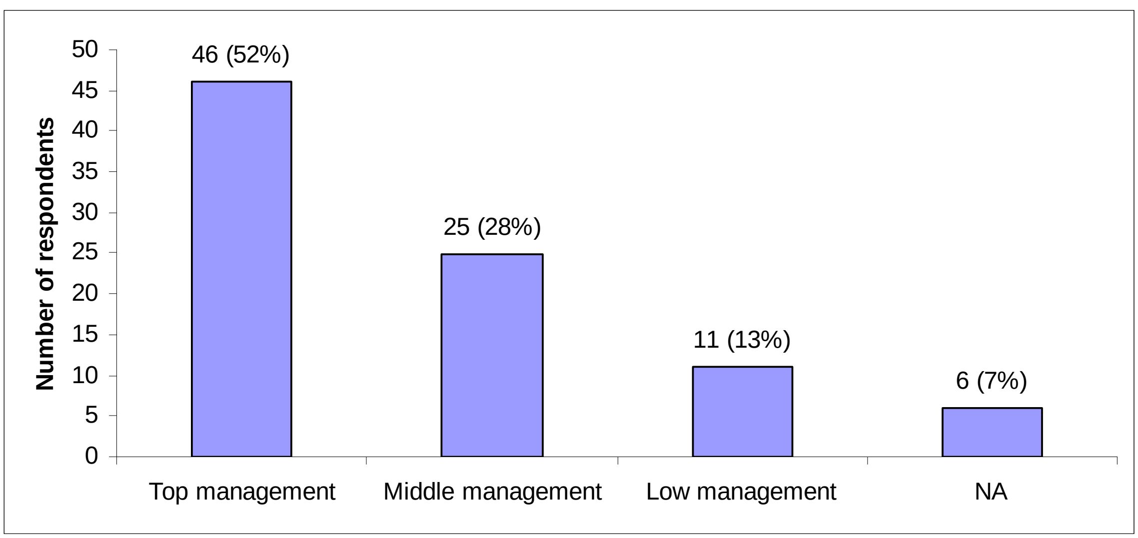

Figure 1: Respondents' Managerial Level

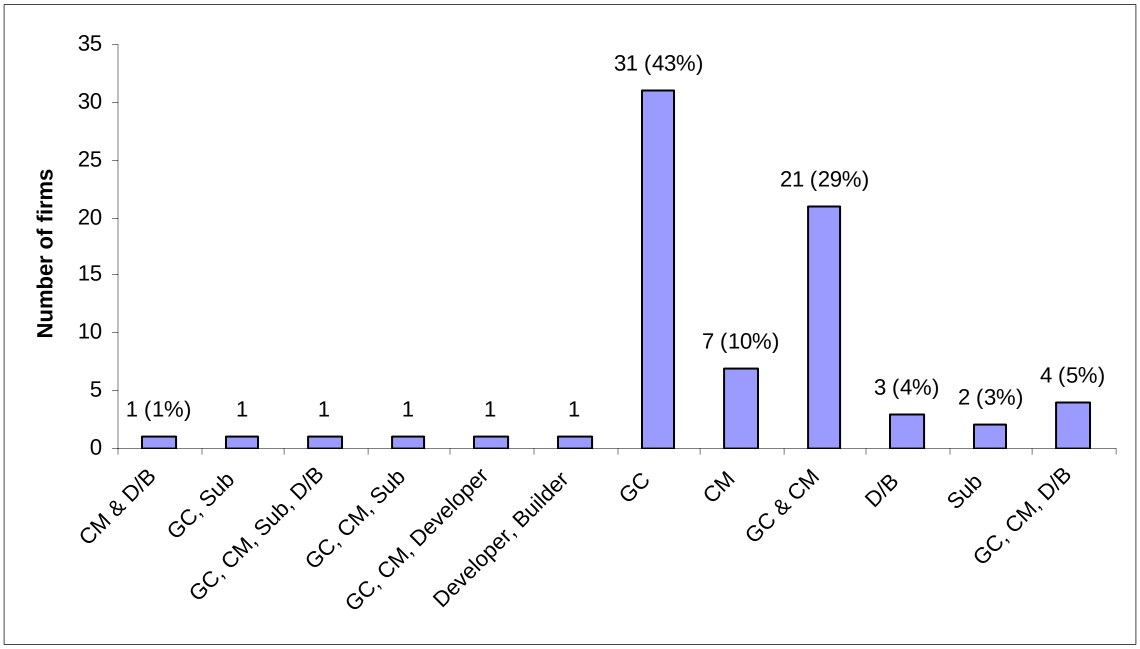

Figure 2: Types of Firms

Figure 3 shows the industry sectors of the participating firms (i.e., residential construction, commercial construction, highway and heavy construction, etc.). Seven percent are residential, 31% are commercial, 4% are industrial, 4% are highway and heavy, 8% are residential and commercial, 23% are commercial and industrial, 12% are residential, commercial, and industrial, and 11% have other industry sector combinations.

Figure 4 exhibits the sizes of the participating firms in terms of revenue. Fifty percent of the firms are over $50 million revenue, 18% are in the range of $(25-50) million, 23% are in the range of $(5-25) million, 8% are in the range of $(1-5) million, and 1% make less than $1 million in revenue.

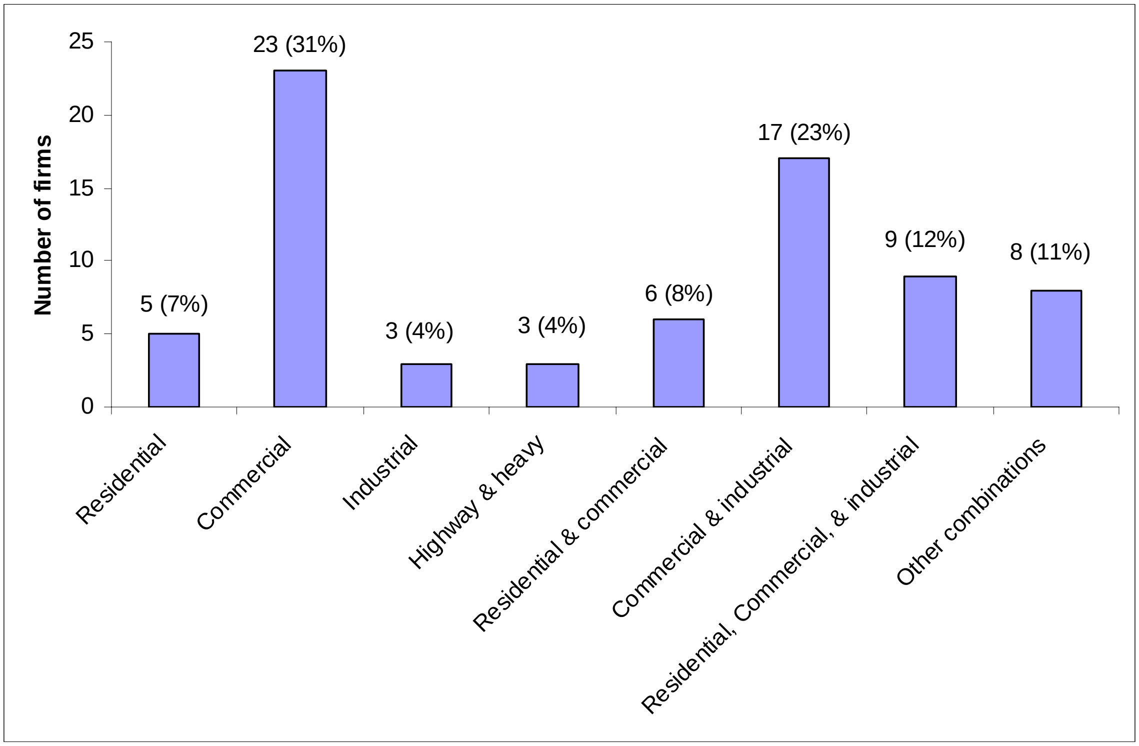

Figure 3: Firms' Industry Sectors

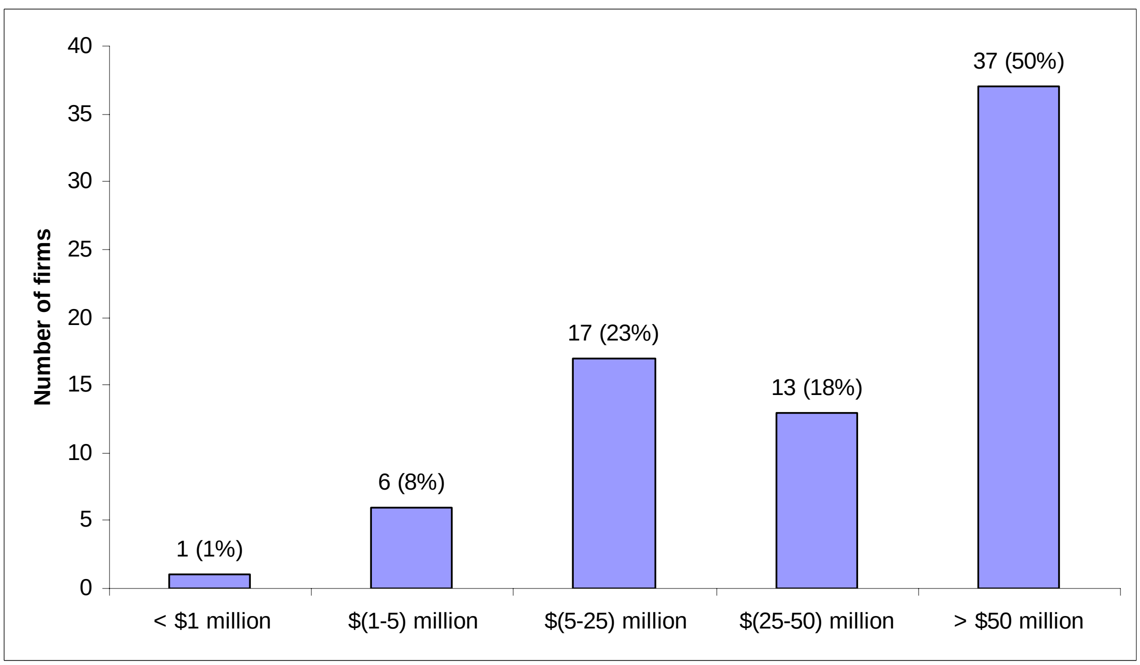

Figure 4: Firms' Revenue

4.2 Industry Perception about IT Impacts and Payoffs

In the fifth part of the questionnaire, the researchers made several evaluative statements regarding the impact and payoffs of IT and asked the respondents to select one of four answers to these statements: “strongly agree,” “slightly agree,” “slightly disagree,” or “strongly disagree.”

Figure 5 indicates the respondents’ opinions in reference to the statement “IT has a positive impact on firm’s competitive advantage.” Forty one respondents (47%) strongly agreed with the statement, 36 respondents (41%) slightly agreed, 3 respondents (3%) slightly disagreed, 1 respondent (1%) strongly disagreed, and 7 respondents (8%) did not provide a response to the statement.

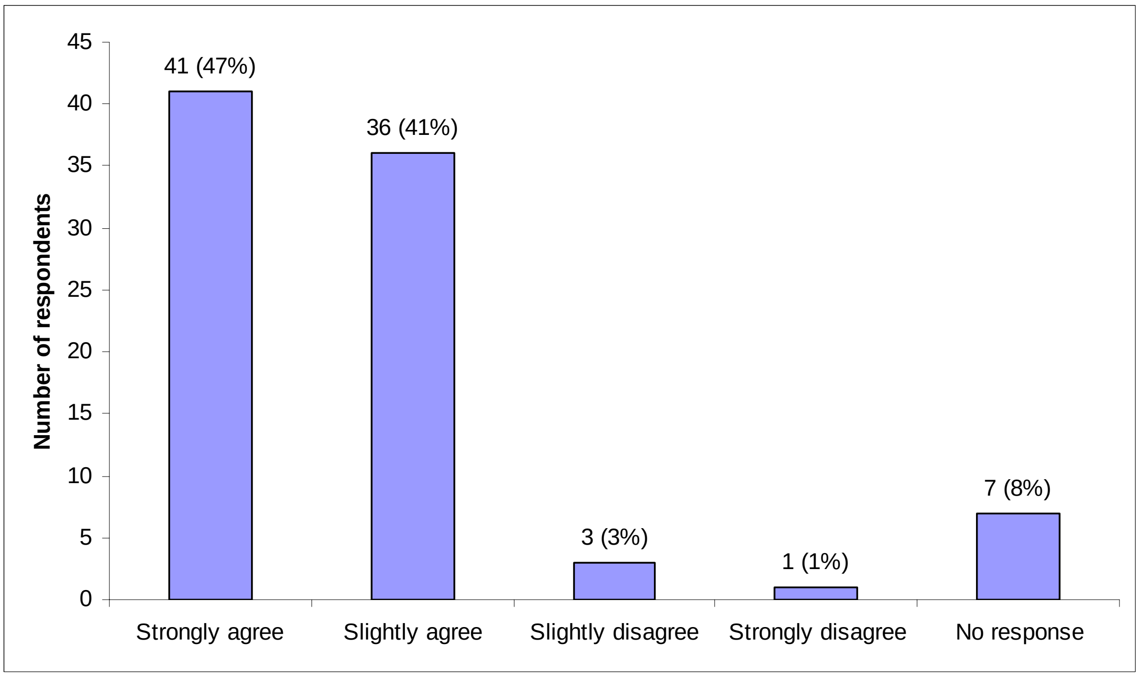

Figure 5: Responses to the Statement “IT has a positive impact on firm’s competitive advantage”

Figure 6 shows the participants’ responses to the statement “IT has a positive impact on firm’s profitability”. Forty eight percent strongly agreed that IT has a positive impact on their firm’s profitability, 41% slightly agreed, 2% slightly disagreed, 1% strongly disagreed, and 8% made no response to the statement.

Figure 7 exhibits the respondents’ views on the positive impact of IT on schedule performance. Thirty eight respondents (43%) strongly agreed that IT has a positive impact on schedule performance, 34 respondents (39%) slightly agreed, 8 respondents (9%) slightly agreed, 2 respondents (2%) slightly disagreed, 1 respondent (1%) strongly disagreed, and 6 respondents (7%) made no response.

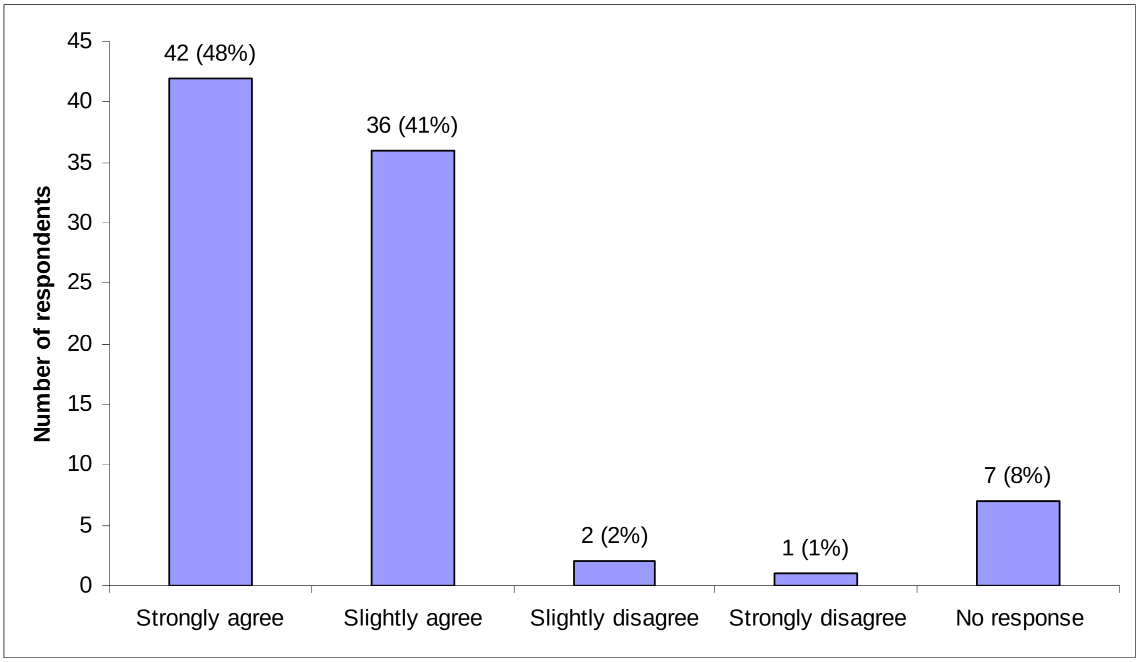

Figure 6: Responses to the Statement "IT has a positive impact on firm's profitability"

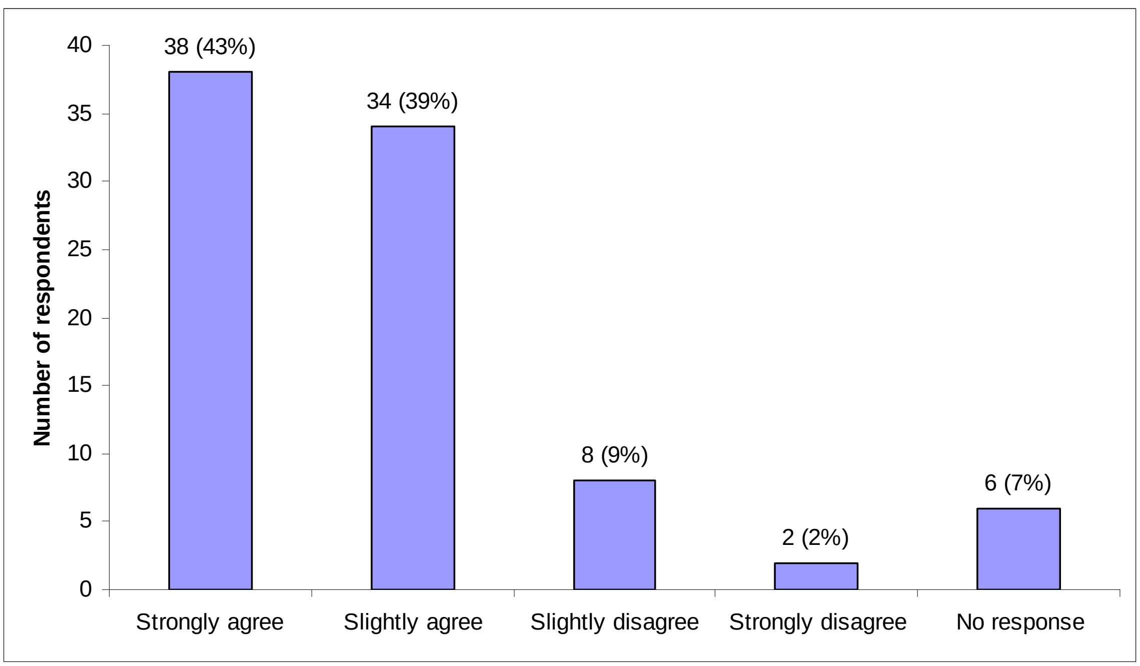

Figure 7: Responses to the Statement "IT has a positive impact on schedule performance"

Figure 8 demonstrates the respondents' views on the positive impact of IT on cost performance. Thirty eight percent strongly agreed that IT has a positive impact on cost performance, 44% slightly agreed, 9% slightly disagreed, 2% strongly disagreed, and 7% made no response.

Figure 9 shows respondents' opinions when it comes to customer satisfaction and IT. Twenty three respondents (26%) strongly agreed that IT has a positive impact on customer satisfaction, 48 respondents (55%) slightly agreed, 10 respondents (10%) slightly disagreed, 1 respondent (1%) strongly disagreed, and 6 respondents (7%) made no response.

Figure 10 illustrates the respondents' views in reference to the statement "IT has a positive impact on safety performance." Eight percent strongly agreed with the statement, 52% slightly agreed, 25% slightly disagreed, 7% strongly disagreed, and 8% did not provide a response.

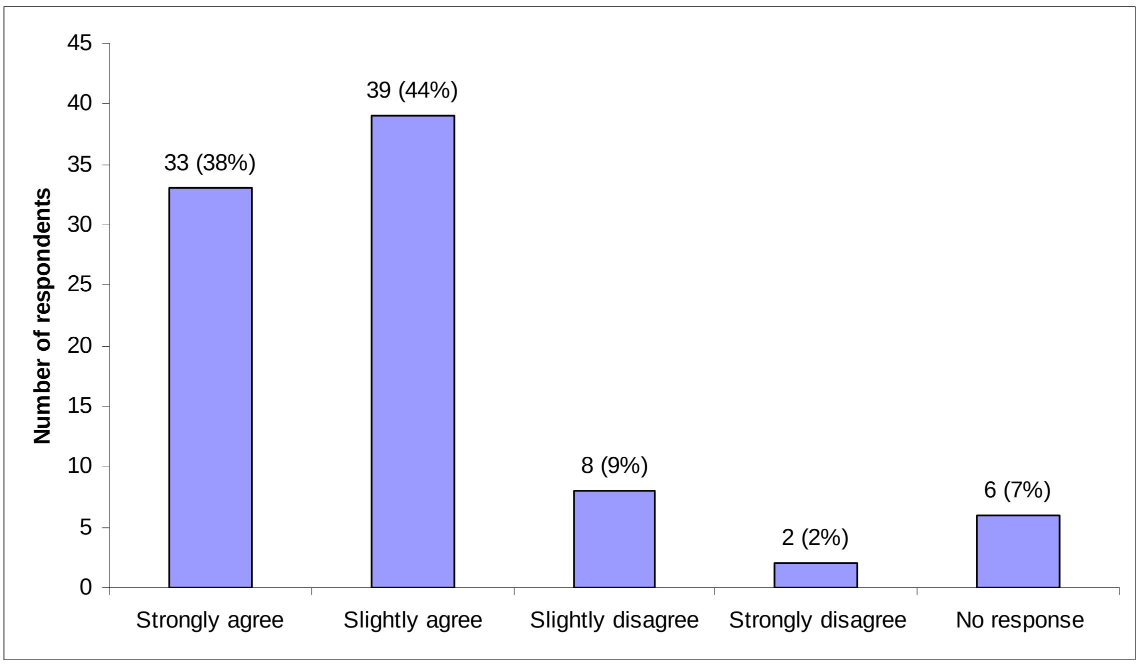

Figure 8: Responses to the Statement "IT has a positive impact on cost performance"

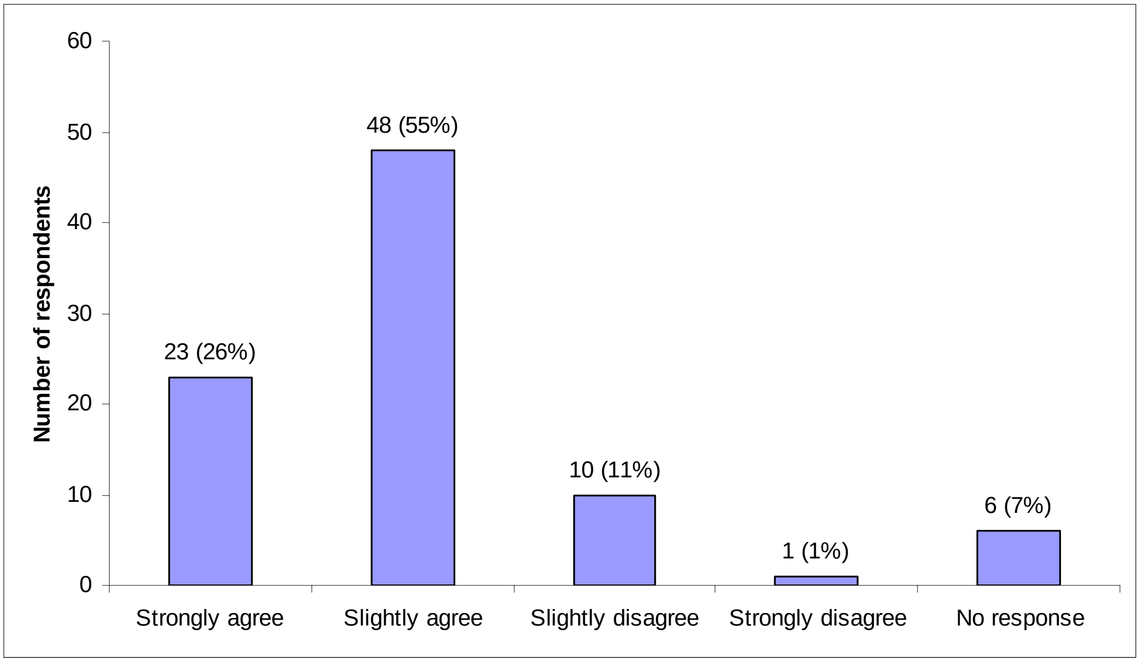

Figure 9: Responses to the Statement "IT has a positive impact on customer satisfaction"

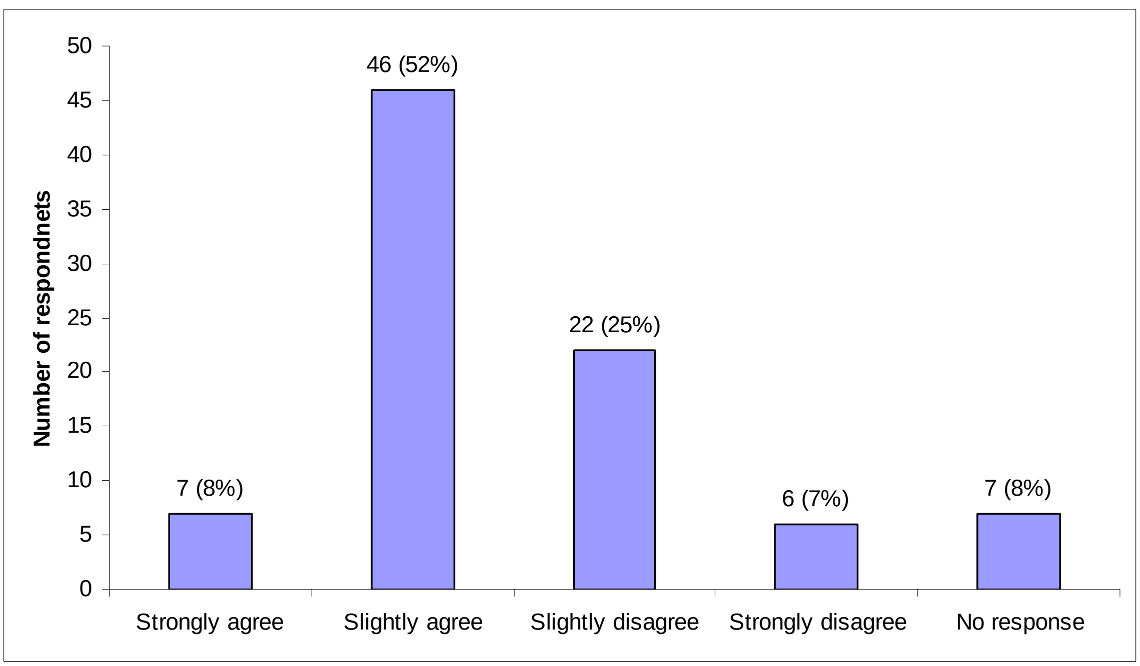

Figure 10: Responses to the Statement "IT has a positive impact on safety performance"

Figure 11 shows the respondents' views in reference to the statement "the construction industry is not experiencing the payoffs of IT due to lack of investment." Nine respondents (10%) strongly agreed with the statement, 43 respondents (49%) slightly agreed, 25 respondents (28%) slightly disagreed, 4 respondents (5%) strongly disagreed, and 7 respondents (8%) made no response.

Figure 12 shows the participants' responses to the statement "the construction industry is not experiencing the payoffs of IT due to the fact that the industry is still learning to take advantage of IT." Thirty four percent strongly agreed with the statement, 49% slightly agreed, 8% slightly disagreed, 1% strongly disagreed, and 8% did not respond to this statement.

Figure 13 documents the respondents' opinions regarding the statement "the construction industry is not experiencing the payoffs of IT due to the fact that the technology is still immature with respect to the needs of the industry." Twenty two respondents (25%) strongly agreed with the statement, 29 respondents (33%) slightly agreed, 24 respondents (27%) slightly disagreed, 6 respondents (7%) strongly disagreed, and 7 respondents (8%) did not respond to this statement.

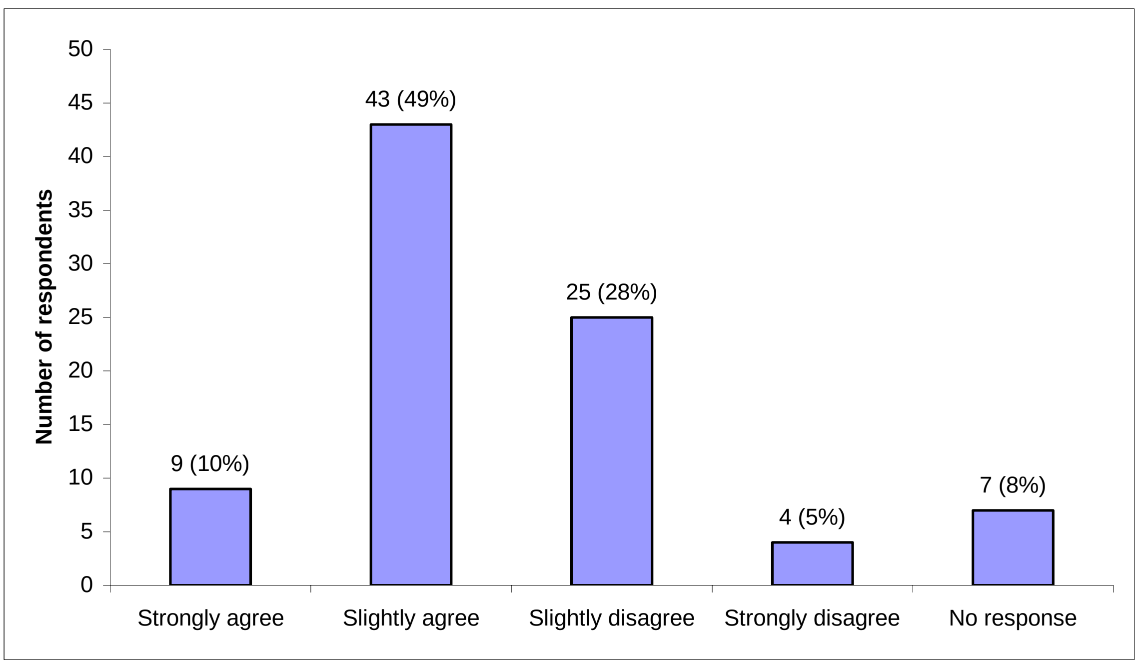

Figure 11: Responses to the Statement "the construction industry is not experiencing the payoffs of IT due to lack of investment"

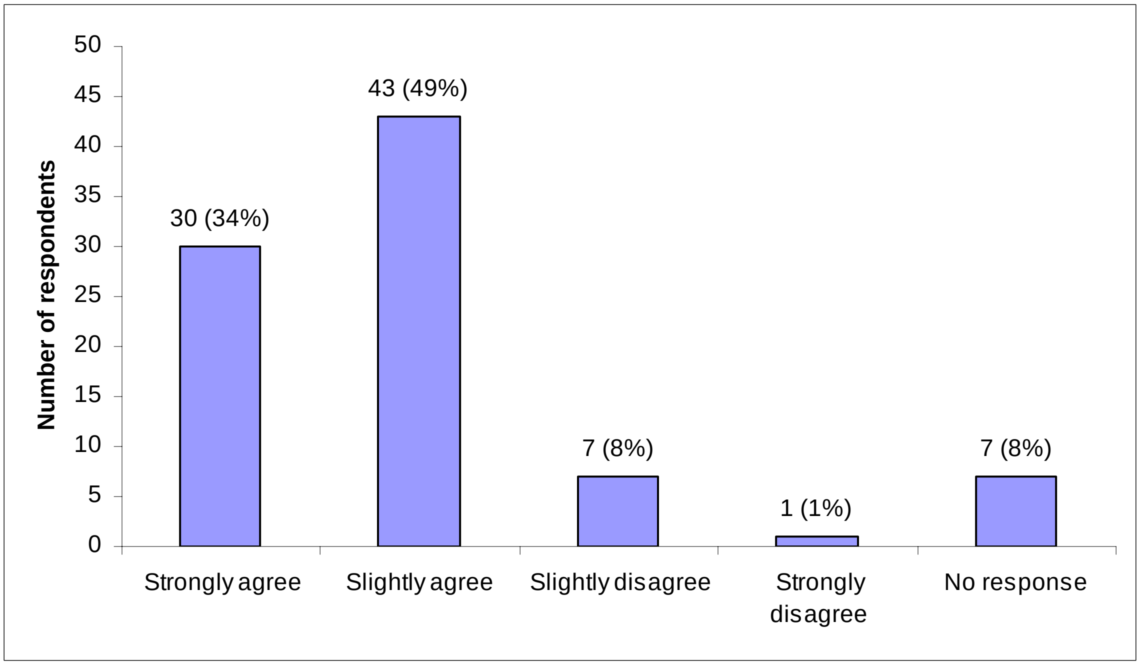

Figure 12: Responses to the Statement "the construction industry is not experiencing the payoffs of IT due to the fact that the industry is still learning to take advantage of IT"

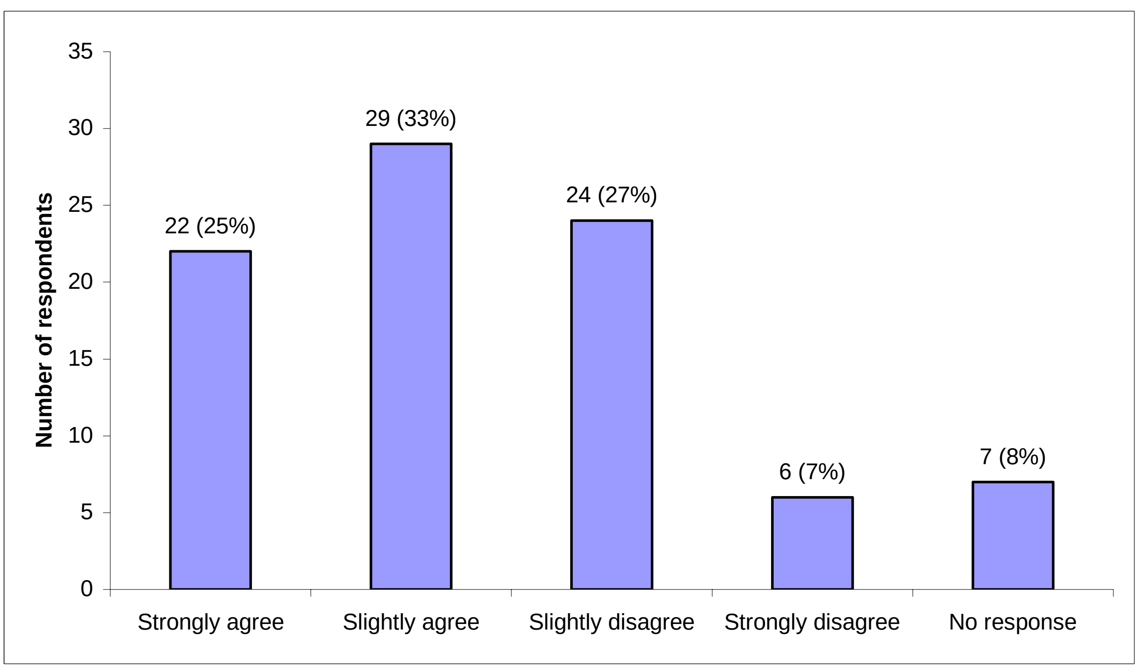

Figure 13: Responses to the Statement "the construction industry is not experiencing the payoffs of IT due to the fact that the technology is still immature with respect to the needs of the industry"

Figure 14 shows the respondents' views on the statement "the construction industry is not experiencing the payoffs of IT due to the fact that IT expands the scope of work offsetting specific productivity gains." Thirteen percent of the respondents strongly agreed with the statement, 37% slightly agreed, 34% slightly disagreed, 8% strongly disagreed, and 8% provided no response.

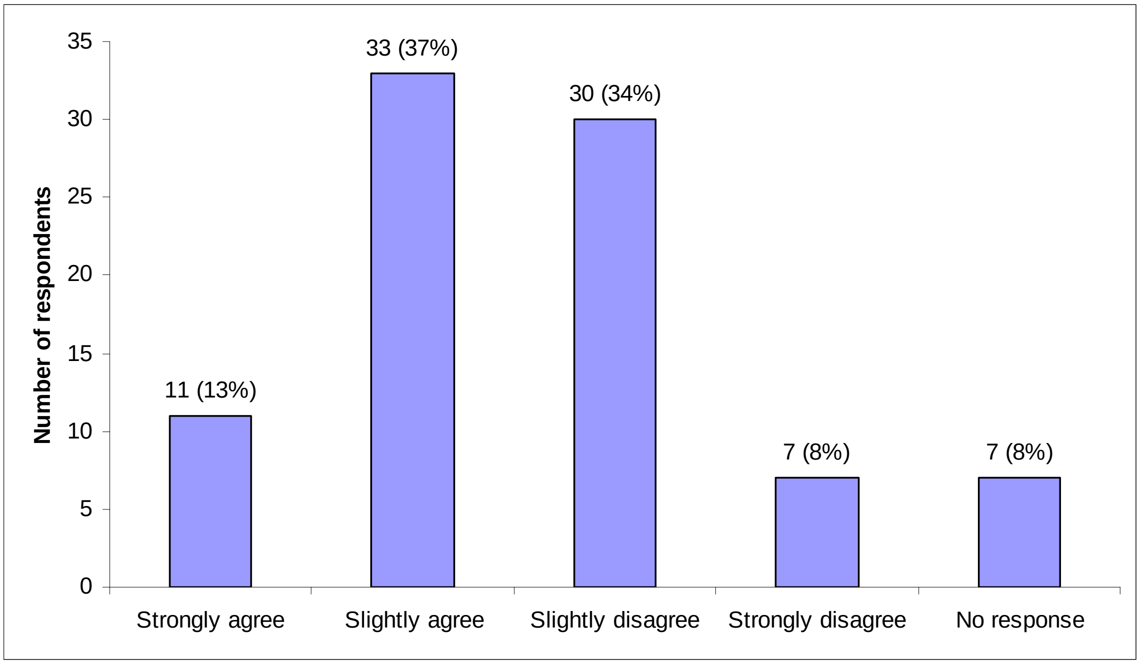

Figure 14: Responses to the Statement "the construction industry is not experiencing the payoffs of IT due to the fact that IT expands the scope of work offsetting specific productivity gains."

4.3 Information Technology Use

Table 3 provides the ITindex descriptive statistics by firm size and for all sizes combined. The mean of the ITindex for all firms combined is 3.761 with a standard deviation of 1.63. These numbers are consistent with the numbers reported by O'Connor et al. (2000). The mean and standard deviation for the O'Connor et al. (2000) study are 3.849 and 1.86, respectively. The minimum and maximum values of the ITindex are 0.897 and 8.205, respectively.

Table 3 shows both the 25th and 75th quartiles of the ITindex. For all firms combined, the 25th and 75th quartiles are 2.411 and 4.785, respectively. The 25th quartile indicates that 25% of the firms have an ITindex of less than 2.411. The 75th quartile, on the other hand, shows that 25% of the firms have an ITindex of more than 4.785. Following the method in the study by O'Connor et al. (2000) to ensure that the response data is genuinely representative, a minimum response rate of 70% of work functions was applied. Acceptable work function assessments included any of the three technology level responses (1-2-3) or an N/A response. In other words, the number of responses on the 1, 2, and 3 levels, and N/A responses divided by the total number of work functions should be equal to, or greater than 70%. Five firms did not pass the 70% minimum response rate and therefore had no ITindex.

Table 3: ITindex Descriptive Statistics

Firm Revenue	Number of Firms	ITindex					
		Mean	Sd*	Min.	Max.	25th Quartile	75th Quartile
< $1 Million	1	1.92	--	--	--	--	--
$(1-5) million	6	2.524	0.972	1.061	3.83	1.946	3.478
$(5-25) million	15	3.83	1.391	1.143	6.609	2.679	4.211
$(25-50) million	12	3.499	1.501	1.064	6.667	2.336	4.203
> $50 million	35	4.277	1.708	0.897	8.205	2.88	5.119
All	69	3.761	1.63	0.897	8.205	2.411	4.785

*Standard deviation

4.4 Impact of IT on Performance

Regression analysis was used to investigate the six hypotheses that IT has a positive impact on firm performance (see Table 2). Table 4 summarizes the regression models investigated. For all regression models, the ITindex is the sole explanatory variable. Since several of the respondent firms have missing information for certain performance metrics, it is impossible to generate a statistically valid sample of a composite score of firm performance for all five metrics. Instead, the composite scores for the combinations of schedule, cost, customer satisfaction, and profit (SCCP) and of schedule, cost, customer satisfaction, and safety (SCCE) are used. A further composite model of schedule and cost performance (SC) is also generated. The composite scores are calculated by using DEA. These three sets of scores (SCCP, SCCE, and SC) are used to investigate the first hypothesis that IT utilization is positively associated with firm performance. In addition to the three regression models for composite or firm performance metrics, there are five regression models for the individual performance metrics to test the hypotheses that IT utilization is positively associated with each metric. Table 4 also shows the number of firms that are used in each regression model; note that the 64 firms for the individual metrics represent different sets of firms from the complete sample.

Table 4: Regression Models

Model No.	Dependent Variable	Explanatory Variable	Number of Firms
1	SCCP score (composite score of schedule performance, cost performance, customer satisfaction, and profit)	ITindex	47
2	SCCE score (composite score of schedule performance, cost performance, customer satisfaction, and EMR)		34
3	SC score (composite score of schedule performance and cost performance)		46
4	Schedule Performance (%)		64
5	Cost Performance (%)		64
6	Customer Satisfaction (%)		64
7	Profit		64
8	EMR		64

Because the sample contained firms in different industries and of different sizes, eight indicator variables were used to distinguish them. While indicator variables allow for discrimination between different classes in the study population, for the purposes of this study they serve primarily as a mechanism to reduce error and potential bias in the regression analysis of the independent and dependent variables (Fox 1997).

Tables 5 and 6 summarize the use of these indicator variables. Two indicator variables are used for revenue size: "Small" and "Midsize." The "Small" indicator variable refers to firms of revenue size $(1-5) million. The "Midsize" indicator variable refers to firms with a revenue size that ranges between $5 million and $50 million. Five indicator variables are used for type of construction (See Table 6). These indicator variables are: Residential (R), Commercial (C), Industrial (I), Highway & heavy (H), and Subcontractor (S).

Table 5: The Use of Firm Size Indicator Variables

	Value of Indicator Variable "Small"	**Value of Indicator Variable "Midsize"**
Small Firm $(1-5) Million	1	0
Midsize Firm $ (5-50) Million	0	1
Large Firm $ (over 50) Million	0	0

Table 6: The Use of Firm Type Indicator Variables

	Value of Indicator Variable				
	"R"	"C"	"I"	"H"	"S"
Residential	1	0	0	0	0
Commercial	0	1	0	0	0
Industrial	0	0	1	0	0
Highway & heavy	0	0	0	1	0
Subcontractor	0	0	0	0	1

The regression results for the composite firm performance metrics (SCCP, SCCE, and SC) indicate that that IT utilization is positively associated with firm performance, with a coefficient of determination (R^2) values between 0.355 and 0.485. As generally interpreted, these R^2 values indicate that 35-48% of firm performance can be explained by the independent variable (IT utilization). Similar results are found for the individual metrics of schedule cost performance with R^2 values of 0.354 and 0.377, respectively. No significant correlation was found between IT utilization and customer satisfaction, safety, and profitability. The R^2 values and the regression equation for each model are summarized in Table 7.

Table 7: Summary for Regression Analysis of ITindex and Performance

Model No.	Dependent Variable	Regression Equation	R2 (%)	No. of Firms
1	SCCP score	= 0.785 + 0.0241 ITindex + 0.0758 Commercial	35.5	47
2	SCCE score	= 0.893 + 0.0176 ITindex - 0.110 Residential	36.1	34
3	SC score	= 0.714 + 0.0205 ITindex + 0.0603 Midsize - 0.0772 Residential + 0.112 Commercial + 0.0912 Highway&heavy	48.5	46
4	Schedule Performance	= 54.9 + 5.13 ITindex + 16.2 Commercial - 11.8 Industrial	35.4	64
5	Cost Performance	= 70.2 + 2.95 ITindex + 16.1 Small + 10.4 Midsize - 7.49 Residential - 15.9 Highway&heavy	37.7	
6	Customer Satisfaction	Not significant	0.022	
7	Profit		0.058	
8	EMR		0.013	

One model is discussed in more detail; Figure 15 plots the regression line on a scatter graph for the SCCP model. The regression equation is:

$$SCCP = 0.785 + 0.0241\ ITindex + 0.0758\ Commercial$$

The regression equation shows that for every 1 unit increase in the ITindex, holding the commercial variable fixed, there is 2.41% increase in the SCCP score. Compared to the rest of the contractors, commercial contractors have a 7.58% higher SCCP score. No other indicator variables are useful in discriminating between types of firms in the population. Note that in Figure 15 several firms have an SCCP score of 1.0; in the context of the DEA scoring, these firms represent the efficient frontier of the sample studied. Firms with a score less than 1.0 are relatively less efficient than the most efficient firms in the sample.

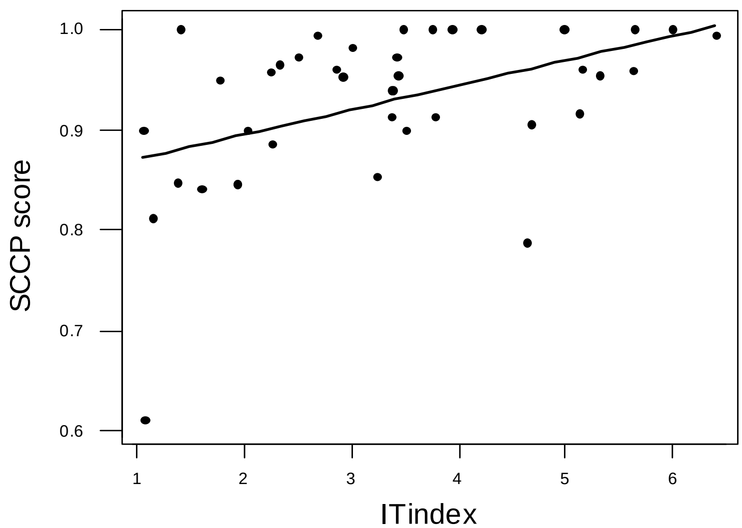

Figure 15: Regression Plot for SCCP Score and ITindex

F and t tests are used to assess the goodness of the model and its individual parameters, respectively. Associated with each test is a p-value that expresses the probability that the results of the test are not significant. A probability of less than 0.05 is generally considered an acceptable standard of significance (Fox 1997). For the SCCP regression model, the p-values are 0.000 for the F test and 0.001 for the t-test. These low probabilities allow for the exclusion of the null hypothesis and for the inference that the model and parameters are adequate.

Analysis of the residual errors provides further confidence in the SCCP regression model. Figures 16 and 17 show that the underlying assumptions of linear regression (linearity, equal variance, and independence of errors) are not violated, since the residuals are randomly scattered with no particular trend. Figure 18 lays out the normal probability plot of residuals. This plot does not indicate any violation of the normality assumption. Similar findings for the other models are described in more detail in El-Mashaleh (2003).

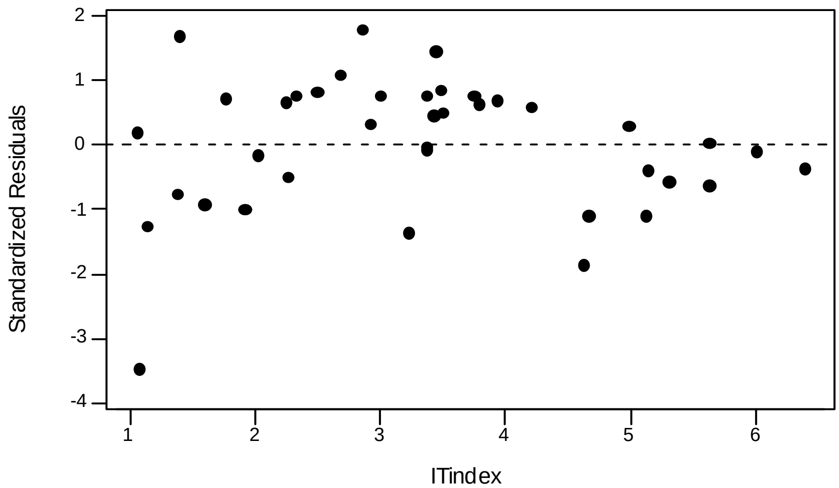

Figure 16: Standardized Residuals versus ITindex

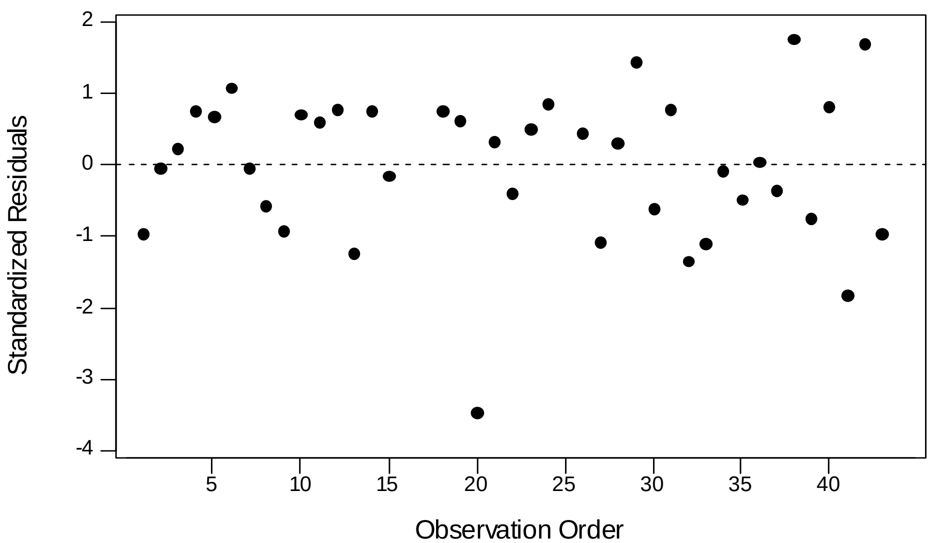

Figure 17: Standardized Residuals versus the Order of the Data

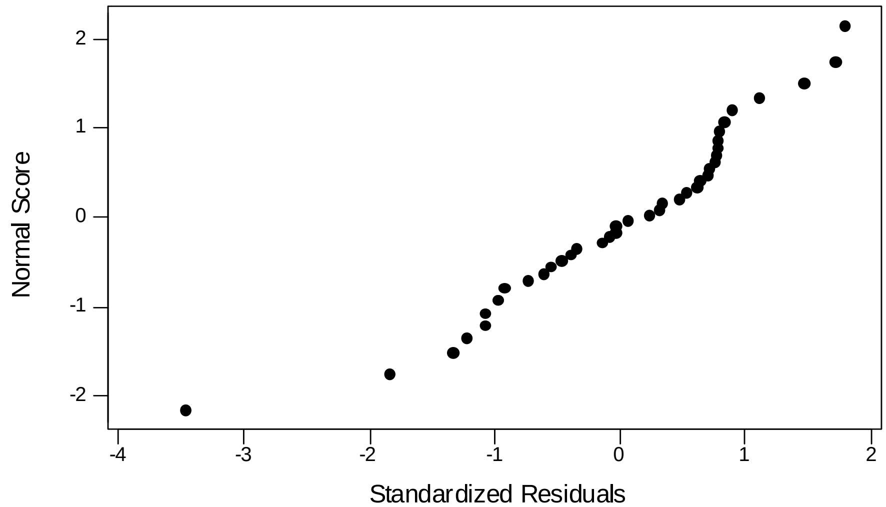

Figure 18: Normal Probability Plot of the Residuals

Table 8 summarizes regression results for each model, including R^2, F- and t-tests, and associated p-values. For the composite or firm performance metrics SCCP, SCCE, and SC, as well as for the metrics for schedule and cost performance, the t-test and the F-test indicate that the regression terms and the regression model are significant at the 0.05 level of significance. Supporting plots of the regression line and the scatter graph for SCCE, SC, schedule and cost are shown in Figures 19-22.

Regression models for the individual metrics of customer satisfaction, profit, and safety do not show any significant relationship between ITindex and performance, with low R^2 values and high p-values for the F- and t-tests. As such, Hypotheses 1, 2, and 3 (that IT utilization is positively correlated with firm, schedule, and cost performance) are answered affirmatively. However, Hypotheses 4, 5, and 6 (that IT utilization is positively correlated with customer satisfaction, profit, and safety) cannot be supported. With respect to the significant findings (models 1-5), the regression equation for each model shows some indicator variables are active (see Table 7). However, there is no pattern across the models suggesting that certain indicators are consistently higher or lower than the main population. Hence the available data do not support further extension of the research hypothesis for subsets of the population studied.

Table 8: Summary of Regression Results for Each Model.

Model no.	Dependent Variable	R^2	ITindex			
			F	p	t	p
1	SCCP	0.355	10.17	0.000	3.44	0.001
2	SCCE	0.361	7.34	0.003	2.48	0.020
3	SC	0.485	6.41	0.000	2.39	0.023
4	Schedule	0.354	10.43	0.000	3.75	0.000
5	Cost	0.377	6.53	0.000	2.82	0.007
6	Customer Satisfaction	0.022	1.36	0.249	1.16	0.249
7	Profit	0.058	2.34	0.134	-1.53	0.134
8	EMR	0.013	0.41	0.528	-0.64	0.528

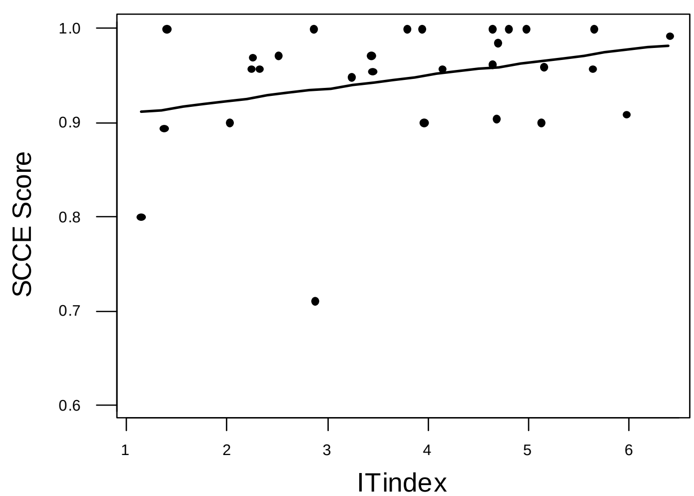

Figure 19: Regression Plot for SCCE Score and ITindex

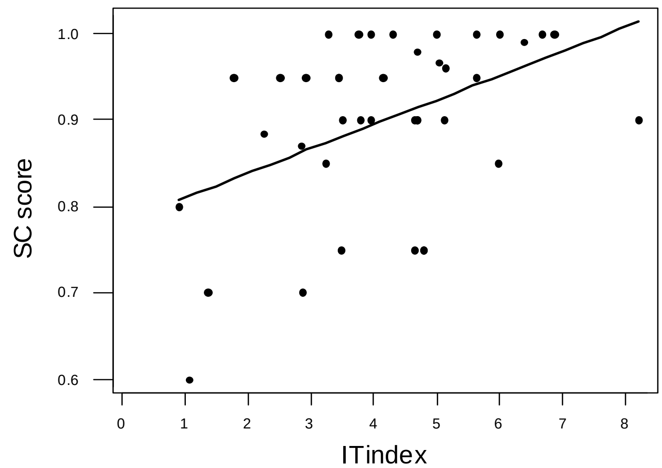

Figure 20: Regression Plot for SC Score and ITindex

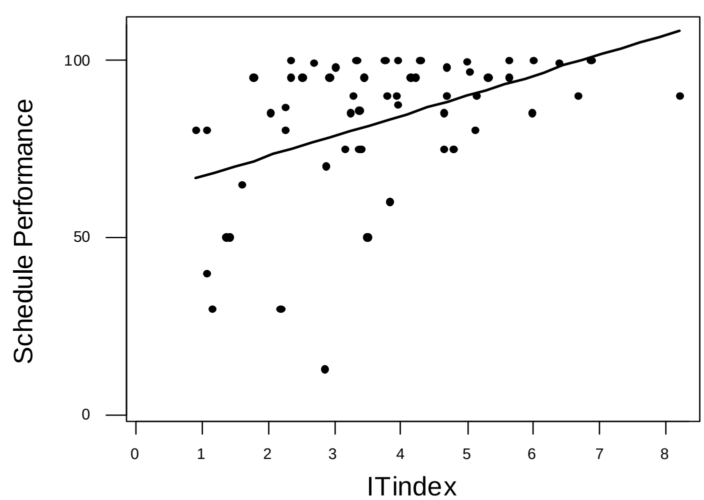

Figure 21: Regression Plot for Schedule Performance and ITindex

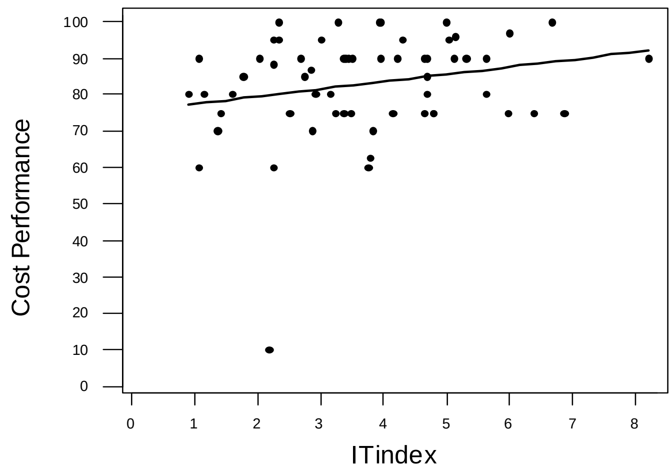

Figure 22: Regression Plot for Cost Performance and ITindex

CHAPTER 5 CONCLUSIONS

To the authors' knowledge, this research is the first quantitative assessment of the impact of IT on construction firm performance across several metrics. Based on data collected from 74 construction firms, this paper provides empirical evidence that IT has a positive impact on performance. For every increase in ITindex or IT utilization, there is a positive increase in firm performance, schedule performance, and cost performance. Firm performance measures used in this study are composite scores of several metrics of performance: schedule performance, cost performance, customer satisfaction, EMR, and profit. This builds on and enhances prior research into IT use in the industry, as well as makes a case for generalizing existing IT research on specific technologies.

Of course, this study is only a starting point. It perhaps is best conceived of as a snapshot of IT use and performance as reported by firms in the southeastern US. Since the success of a firm is determined by a number of factors, the fact that 35~48% of composite performance is explained by IT use strongly indicates the value of IT. The authors find these regression results strong enough to warrant an extension of the research to a larger population and to a longitudinal study. A larger population allows for a generalization of the findings and would likely provide insight into the relationship between profitability and performance, particularly if the population were to include more subcontractors. Moreover, a longitudinal study would allow for the tracking of firms' IT implementation levels and success over time. Such a long term view would enable both the identification of learning effects as well as a better grasp of the relationship between IT use and safety.

With respect to management decisions about investment in IT, this study generally supports increased investment. The authors' caution managers that the findings relate to IT use as opposed to investment, and hence the study does not directly support return on investment calculations. At the same time, some managers may perceive the lack of observed correlation between profitability and IT use among the sample population (primarily general contractors and construction managers) as an indication that investment in IT is not justified. Such an opinion is not supported by the data, since no significant positive or negative relationship was found. Because a strong correlation was found between IT use and schedule and cost performance, it is the authors' opinion that managers would be wise to continue to invest in IT, however cautiously.

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APPENDIX

Contractors Research Survey

Firm Performance and Technology Benchmarking

The purpose of this 20-minute survey is to investigate the relationship between "Technology" and "Firm Performance". Technology is studied in terms of how much technology is incorporated in the different tasks used to execute projects. Firm Performance is approached from several standpoints: schedule, cost, safety, customer satisfaction, profit, and resource utilization.

The anticipated benefits for your participation include benchmarking your firm performance compared to other firms in the construction industry and understanding the impact of technology on that performance. You will also receive a free electronic copy of the research report if you choose so.

Please Read the Informed Consent Before Filling out the Survey

Part 1: Respondent Information

Company name **Identities are kept CONFIDENTIAL**	
Respondent position	
Number of years in current position	
Respondent name (OPTIONAL and CONFIDENTIAL	
Would you like to receive free electronic copy of the research report? **If yes, please specify e-mail address to send copy to.** **E-mails are kept CONFIDENTIAL**	

Part 2: Firm General Information

How do you classify your firm? Please check all that apply.	
General Contractor (GC)	Construction Management Firm (CM)
Subcontractor	Other, please specify
To which of the following industry sectors does your firm belong? Please check all that apply.	
Residential	Commercial
Industrial	Highway and heavy
Other, Please specify	

What is the percentage of your projects that are negotiated bid?			
<25%	25-50%	50-75%	>75%

What is the typical range of project sizes that your firm executes?

What is the approximate revenue of your firm?				
<$1 million	$(1-5) million	$(5-25) million	$(25-50) million	> $50 million

PART 3: Degree of Technology Use

Please indicate the level of Degree of Technology Use for each task in the different phases of a project as shown in the table below. Where:
LEVEL 1: No electronic tools or commonly used electronic tools
LEVEL 2: Specialized stand-alone electronic tools
LEVEL 3: Integrated electronic tools
Please refer to the last page of this questionnaire for detailed definitions and examples of the Degree of Technology Use

ID	Task	Degree of Technology Use				
	Procurement Phase	**Don't know**	**1**	**2**	**3**	**NA**
1	Determine the lead time required to order equipment and materials					
2	Conduct a quantity survey of drawings					
3	Link quantity survey data to the cost estimating process					
4	Link supplier cost quotes to the cost estimating process					
5	Refine the preliminary budget estimate					
6	Develop the milestone schedule					
7	Develop and transmit requests for proposal to suppliers and subs					
8	Prepare and submit shop drawings					
9	Acquire and review shop drawings; send response					
10	Compile quotes from suppliers and subs into a bid or proposal package					
11	Monitor the progress of fabricators					
12	Plan the transportation routes of large items from the fabricator to the job site					

ID	Task	Degree of Technology Use				
Construction Management Phase		**Don't know**	**1**	**2**	**3**	**NA**
13	Develop the construction schedule					
14	Track field work progress and labor cost code charges					
15	Maintain a daily job diary					
16	Update the current cost forecast					
17	Keep all project team members up to date on construction progress					
18	Track the inventory of materials on site					
19	Link field material managers to suppliers					
20	Develop short-term work schedules based on labor, equipment, and material availability					
21	Work crews submit and receive answers to Requests for Information					
22	Builders provide feedback about the effects of design changes, made by owner or A/E, on cost and schedule					
23	Communicate design changes to field personnel					
24	Communicate status of change orders to field					
25	Update as-built drawings					
26	Contractors submit requests for payment					
27	Transfer funds from owner's account to contractor					
Construction Execution Phase		**Don't know**	**1**	**2**	**3**	**NA**
28	Evaluate subsurface conditions					
29	Carry out earth work and grading					
30	Construct rebar charges					
31	Weld pipes					
32	Select the appropriate crane for heavy lifts					
33	Provide an elevated work platform					
34	Fabricate roof trusses					
35	Manipulate and hang sheet rock					
36	Acquire and record laboratory test information					
37	Finish concrete surfaces					
38	Apply paint or coatings					

ID	Task	Degree of Technology Use				
Maintenance and startup phase		**Don't know**	**1**	**2**	**3**	**NA**
39	Conduct pre-operations testing					
40	Train facility operators (e.g. simulation, software)					
41	Use as-built information in personnel training					
42	Track and analyze the maintenance history of important equipment					
43	Develop maintenance plans from maintenance history data					
44	Monitor & assess equipment operations					
45	Facility operators request maintenance or modifications					
46	Update as-built drawings in response to facility modifications					
47	Monitor/track/control facility energy usage					
48	Monitor environmental impact of facility operations (e.g. air/water/ quality)					

Part 4: Firm Overall Performance

Please answer the following questions regarding your firm performance. Please only answer those questions you have specific knowledge of.

Schedule Performance	
For projects closed in the last 2 fiscal years, how often were these projects delivered on/ahead of schedule? (i.e., 40% of the time) **Calculation** (Number of projects completed on/ahead of schedule) / (Total number of projects) * 100%	
Cost Performance	
For projects closed in the last 2 fiscal years, how often were these projects delivered on/under budget? (i.e., 40% of the time) **Calculation** (Number of projects completed on/under budget) / (Total number of projects) * 100%	

Safety Performance	
What is your firm's OSHA recordable incidence rate?	
What is your firm's Experience Modification Rating (EMR)?	
Customer Satisfaction	
What is the percentage of repeated business customers? (i.e., 20% of customers return for a repeat business with the firm)	
Profit	
What is your firm's Net Profit after tax as a % of Total Sales? (for the last fiscal year available) Calculation (Net profit after tax / Total sales) * 100%	
Resource Utilization	
What are your firm's expenses on Safety as a % of Total Sales? (for the last fiscal year available) Expenses are: annual cost of safety programs and safety personnel salaries	
What are your firm's expenses on IT as a % of Total Sales? (for the last fiscal year available) Expenses are: annual cost of software and hardware acquisitions and updates, IT personnel salaries, and annual cost of IT training	
What are your firm's expenses on Project Management as a % of Total Sales? (for the last fiscal year available) Expenses are: project management personnel salaries, annual costs of project management training, and annual costs of project management software acquisitions and updates	
How many full time employees work at your firm? (does not include labor)	

Part 5: Information Technology Impact and Pay offs

Please respond to the following statements regarding information technology (IT) by selecting the answer that most closely matches your opinion

IT has a positive impact on:	Strongly Disagree	Slightly Disagree	Slightly Agree	Strongly Agree
The competitive advantage of the firm				
Firm's profitability				
Schedule performance				
Cost performance				
Customer satisfaction				
Safety performance				
The construction industry is not experiencing the pay offs of IT due to:	**Strongly Disagree**	**Slightly Disagree**	**Slightly Agree**	**Strongly Agree**
Lack of investment				
The industry is still learning on how to take advantage of IT				
Technology is still immature with respect to the needs of the industry				
IT expands the scope of work, offsetting specific productivity gains				

Please provide any comments, feedback, or suggestions

Thank you for your participation