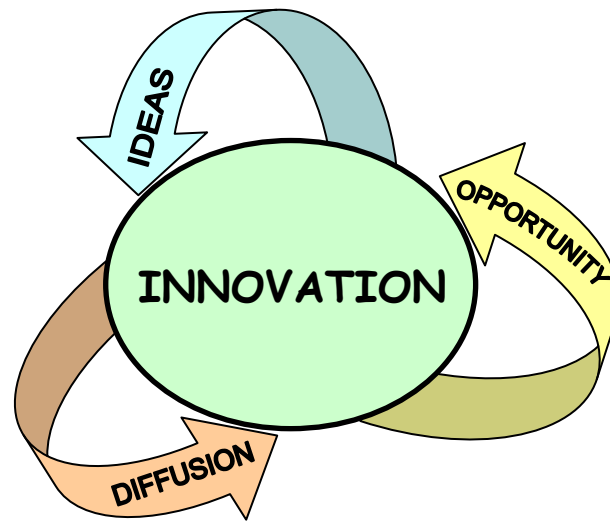


ENERGIZING INNOVATION IN INTEGRATED PROJECT DELIVERY RESEARCH PROJECT

Research Summary



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TABLE OF CONTENTS

Acknowledgment	ii
Executive Summary	iii
INTRODUCTION	1
STUDY GOALS AND OBJECTIVES	2
RESEARCH ACTIVITIES	2
Benchmarking Survey and Interviews	3
Innovative Products Survey	4
Project Case Studies	4
Industry Input and Validation	5
RESEARCH FINDINGS	6
Respondent Demographics	6
Innovation in Practice	7
Presence of Innovation (Lagging Indicators)	13
Innovation Enablers and Impacting Factors (Leading Indicators)	15
Predicting and Measuring Innovation	27
CONCLUSIONS AND RECOMMENDATIONS	30
Conclusions	30
Recommendations	32
ADDITIONAL RESOURCES	33
REFERENCES	34

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EXECUTIVE SUMMARY

A research study, titled “Energizing Innovation in Integrated Project Delivery” and jointly funded by a partnership between the Design-Build Institute America (DBIA) and the Charles Pankow Foundation (CPF), was conducted by Oregon State University (OSU) to investigate innovation in the construction industry. The goal of the research was to enhance the ability of the construction industry to innovate in its delivery of construction projects through integrated project delivery processes. To meet this goal, the study aimed to determine: the factors that impact innovation on a project; how these factors can be used to measure the level of innovation on a project; and the practices and processes that encourage and facilitate innovation.

Innovation is “the actual use of a non-trivial change and improvement in a process, product, or system that is novel to the institution developing the change”. Innovation includes both the generation of a new product, technology, or process, and its implementation. Additionally, innovation may be the application of a product, technology, or process that already exists but is just new to the organization adopting it.

The research study reflects a wide spectrum of the construction industry. The research findings are based on: an extensive literature review; a survey and interviews of 79 members of the Design-Build Institute of America (DBIA) and the Associated General Contractors (AGC); an on-line survey of 34 firms which have developed innovative products for the construction industry; and in-depth case studies of ten diverse projects of various sizes located in nine states across the U.S. Significant efforts were made to accurately capture the perspectives of the entire construction community and the fundamental properties and practices of innovation.

Innovation provides benefits that are recognized at both the project and organizational levels. These benefits include: increased productivity, cost savings, improved quality and safety, providing a competitive advantage, increased market share, and appearance of new markets. Innovation in the construction industry requires three components: *idea generation*, *opportunity*, and *diffusion*. All three components must exist in order for innovation to occur and thrive. The research activities and data collected reveal project and organizational attributes that stimulate and impact these components and which can be used to measure innovation.

The first step in the process towards enhancing innovation entails getting *people* involved in the innovation process. This step is followed by: establishing an innovation-friendly *environment*, providing the necessary *resources* to support the innovation process, and creating *systems and processes* to provide a structure for enhancing innovation. Lastly, *monitoring and management* practices are implemented to sustain a climate of innovation and continued and effective efforts to enhance innovation.

Innovation is a requirement under the pressures to deliver successful projects and maintain a profitable firm. Applying the practices identified in this research lead to enhanced innovation through better communication amongst project team members, integration of the design and construction disciplines, more efficient designs, development of unique ways of completing work, and sharing of the lessons learned. The end-result will be projects that successfully meet and exceed cost, quality, schedule, and safety goals.

INTRODUCTION

In 2006, the Design-Build Institute of America (DBIA) and the Charles Pankow Foundation (CPF) jointly funded a research study conducted by Oregon State University (OSU) titled “Energizing Innovation in Integrated Project Delivery.” The intent of the study was to determine: the factors that impact innovation on a construction project; how these factors can be used to measure the level of innovation on a construction project; and the practices and processes that encourage and facilitate innovation. Upon meeting these objectives, the overall goal of the research is to enhance the ability of the construction industry to innovate in its delivery of construction projects through integrated project delivery processes. The research activities were completed in August 2007 and accompanying documents finalized in December 2007.

The term “innovation” is used in various ways. Slaughter (1998) defines innovation as the “actual use of a non-trivial change and improvement in a process, product, or system that is novel to the institution developing the change.” Further, the term *innovation* is distinguished from *invention*, in that invention constitutes a detailed design or physical manifestation that is novel when compared to the existing practices—whether the invention is actually employed in practice or not. Innovation, however, includes invention and application of the invention. Additionally, innovation may be the application of a technology or method that is within the realm of existing practices but is just new to the organization adopting it. Lastly, innovation is not problem solving on one project. Innovation is systemic, whether it occurs throughout a firm or a work industry.

Innovation within a project, company, and work industry provides the opportunity for significant benefits. Implementing a process, system, or product that is new to the organization that adopts it can lead to decreases in cost and schedule, and improvements in quality and safety. Other benefits as a result of innovation that have been exposed in previous research include an increase in market share, a competitive advantage, and increased technical feasibility of projects (Madewell 1986; Slaughter 1998; Macomber 2002). It is clear from previous research and anecdotal comments from industry practitioners that innovation is key to continued success and profitability. This is true for the construction industry as well as for all other work industries.

While the prospective benefits from innovation are apparent, there is a general perception amongst some professionals in the construction industry that innovation in construction is rare. This perspective often stems in part from comparisons of the construction industry to other fast paced and changing industries, such as the electronics and medical industries, and from the barriers to innovation that exist within the construction industry. Such barriers include the traditional contracting method which separates areas of expertise and creates obstacles to the transfer of constructive knowledge and the ability of a project team member to impact the work of other disciplines to positively benefit the project.

Instances of innovation in the construction industry, however, have been documented by researchers (Slaughter 1998). Innovation does exist and, in some sectors occurs to a great extent. For innovation to occur and thrive, enabling conditions must exist. The problem addressed by this research study is that although attempts have been made to categorize innovation drivers and identify actual instances of innovation, additional studies are needed that discover specific

techniques that promote innovation and identify how to measure the level of innovation achieved. Previous studies have focused on individual technologies at the project level, yet the interrelationship among the industry providers is often cited as both an inhibitor and enhancer of an innovative environment. Integrated project delivery offers a broadened relationship between industry providers and is viewed as a means to encourage and attain the benefits of innovation. Hence, examination of innovation in the construction industry within the context of integrated project delivery is needed to understand how to leverage this collaborative process to optimize innovation.

STUDY GOALS AND OBJECTIVES

The overall goal of this research study was to enhance the ability of the construction industry to innovate in its delivery of construction projects through integrated project delivery processes. Achieving this goal can be accomplished through an increase in knowledge about construction innovation and the development of practices and guidelines to overcome associated barriers and support achieving innovation. Recognizing that the qualities of integrated project delivery processes promote innovation, the environment under which the research was conducted is that of projects delivered using integrated project delivery methods. Meeting this goal required determination of: the factors that impact innovation on a project; how these factors can be used to measure the level of innovation; and the practices and processes that encourage and facilitate innovation. The specific objectives developed for the research study were as follows:

1. Determine the current extent of innovation within the construction industry.
2. Identify incentives that encourage the generation and implementation of innovative ideas.
3. Identify barriers to exploring and implementing new ideas.
4. Identify means for encouraging innovation and overcoming the barriers to innovation.
5. Determine how innovation can be measured and interpreted using a variety of metrics.
6. Create practical guidelines for enhancing innovation on a project.

The research was designed to focus on the U.S. construction industry and incorporate projects that have been completed within the last 3-5 years. Projects of different sizes and types, including buildings, heavy civil, and industrial projects, were studied to balance the distribution of projects and reflect the breadth of the construction industry. All aspects of integrated project delivery, including design, construction, and project management, were examined. In addition, an assessment was conducted based on the composition of the integrated project delivery team, i.e., fully integrated vs. joint venture. Accordingly, the intended audience of the research findings is the construction community. It is expected that the construction community will integrate the findings into their project development processes through the suggested practices and guidelines established from the research.

RESEARCH ACTIVITIES

The research plan for the study is based on observations of the interactions among the key players in the construction industry, previous research experience, the opportunities and

resources available to the researchers, and the challenges and obstacles to conducting scientifically-based research on construction projects and construction performance. The foundation for the research plan was the analysis of key project data to discover those environments and practices which most encourage innovation. The following tasks were planned and undertaken for the research study:

1. Review Current Literature and Identify Innovation Metrics
2. Investigate Current Innovation and Collect Pilot Data
3. Preliminary Analysis and Confirm/Update Research Methodology
4. Prepare and Present Interim Report
5. Identify Case Study Projects
6. Case Study Interviews and Data Collection
7. Data Analysis and Validation of Results
8. Prepare and Present Final Report
9. Prepare and Submit Draft Monograph

Following the completion of Task 3, an additional task to study innovation at the product level was added by the researchers to the research. The researchers recognized that much of the innovation that takes place within the construction industry occurs through the introduction of new products and technologies which, in some cases, are developed by manufacturing companies outside the industry. The development of these products goes through the same basic innovation process as the innovation that occurs on projects. Hence, Tasks 5 and 6 were augmented to include a survey of companies which have developed individual innovations.

Benchmarking Survey and Interviews

The second task in the research study involved investigating the current level and extent of innovation in the construction industry. This involved conducting interviews of construction industry personnel. To broaden the study sample, an on-line survey was added to the study. Using the results of the literature review, a questionnaire was developed for use in the on-line survey. In addition to asking for personal and organizational demographic information, the questionnaire solicited information about the types of innovations that occur, the rate of innovation, organizational features that support innovation, metrics used to assess innovation, and personal beliefs about the organization's ability to innovate and performance with respect to innovation. Several open-ended, exploratory questions were added to the questionnaire for use only in the interviews to gain in-depth information about specific innovations and the innovation that occurs in the organization.

Following the development of the questionnaire, a list of construction industry personnel to survey was created. The list was compiled using outreach contact lists of the Oregon State University Construction Engineering Management Program and personal contact lists of the researchers. The personnel on the list work in architecture, engineering, and construction firms located throughout the West Coast. From this list, a small sample was selected for interviews. Selection for interview was made based on the type of firm/discipline in order to get a good cross-section of the industry, e.g., small and large firms, general contractors and subcontractors,

architects and engineers, and various design disciplines. Consideration was also given to their proximity relative to Oregon State University in order to fit within travel limitations.

A total of 27 people were selected for interview (8 A/E's, 9 GC's, 3 sub's, 1 supplier, 3 owners/developers, and 3 other). Those selected for interview were contacted to ask for their participation in the study. From this effort, a total of ten interviews were conducted.

The questionnaire was also placed on-line and e-mails were sent out to the other people on the contact list asking that they complete the survey on-line. A total of 272 e-mails were sent out, of which 75 were returned as undeliverable, leaving 197 people contacted regarding the on-line survey. In addition, the Associated General Contractors (AGC) Oregon-Columbia Chapter and the national office of the Design-Build Institute of America (DBIA) distributed e-mails to their membership asking that they complete the survey. The e-mail went out to 1,073 AGC Oregon-Columbia Chapter members, and approximately 2,700 DBIA members.

Innovative Products Survey

To investigate innovation at the product development level, the benchmarking survey was followed by a survey of firms which have developed innovative products. This task began with the creation of a list of newly developed innovations in the construction industry. Two sources were used to create this list. The first source was the Construction Innovation Forum's NOVA Award website (<http://www.cif.org/>). The second source of innovations was the Emerging Construction Technologies (ECT) website sponsored by Purdue University and the Construction Industry Institute (<http://www.new-technologies.org/ECT/Index.html>). A total of 233 innovative products were identified from the two websites, for which e-mail addresses of 189 of the products were identified. A questionnaire similar to that used for the benchmarking survey was developed and e-mailed to the 189 product manufacturers.

Project Case Studies

The third research effort consisted of conducting case study reviews of construction projects. In order to understand the factors that distinguish innovative projects, a study sample was created which consisted of two types of projects: award-winning and "regular" projects. It was conjectured that award-winning projects were different than other projects because they were in some way innovative. The recognition given to the award-winning projects was assumed to be reflective of new and unique features on the projects which made them stand out from other projects. While other factors may have impacted their receipt of awards, such as project size, type, or architectural design, the peer review process conducted to receive the awards was assumed to account for these factors. "Regular" projects were those which have not received any recognition for their design and construction. The regular projects were included in the study sample to act as a comparison group and isolate those factors that impact innovation. It was hypothesized that the award-winning projects would contain features or exhibit characteristics that made them innovative, and that these features and characteristics would not be present, at all or to as great an extent, in the regular projects.

The list of award-winning projects was created from a variety of sources. Various regional and national owner, designer, and constructor organizations and publications (i.e., DBIA, AGC, ASCE, ENR, and other construction industry publications) regularly give out awards for projects that stand out in their design and construction. The websites of these sources were searched for projects that have received awards in the past 5 years, from which a list of 20 award-winning projects was created. The 20 projects were selected from the following sources: ASCE OPAL award; DBIA national design-build award; Greatbuildings.com; Oregon.gov Great Buildings of the Year; Buildings.com; CIF NOVA award; and AIA.

The list of regular projects was created using Engineering News-Record (ENR). ENR regularly posts advertisements for projects that are out for bid. Projects of all different types, sizes, and locations are advertised. Issues of ENR from the past 5 years were reviewed and a list was created of the projects advertised. Using this initial list, 20 projects were randomly selected.

The lists of 20 award-winning projects and 20 regular projects were combined to create a sample of 40 projects. From this combined list, a total of 20 projects were randomly selected to be case studies. Information about the 20 case study projects, including contact information, was collected via the websites described above and other websites located through on-line searches.

To assist with the interviews, an interview template was created. The questions asked for information about: the demographics of the respondent (title, years of experience, etc.); organizational characteristics (e.g., upper management support, communication, and recognition and rewards); project level practices (e.g., delivery method, competition, and extent of collaboration across disciplines); the innovative aspects of the project; and the success which the project had related to cost, schedule, quality, safety, and other outcomes.

Personnel involved in the projects were contacted for interviews about the projects. Each contact person was sent the interview template to review the questions before the interview. A day and time were scheduled for the interview and the interviews conducted over the phone and in-person. The responses to the interviews were recorded in a spreadsheet for analysis.

Industry Input and Validation

The study also included several activities to validate the findings. The goal of the validation efforts was to provide a “second opinion” about the study findings based on industry knowledge and opinion, to identify whether anything is missing from the results which should be investigated further, and to ensure the applicability and relevance of the suggested practices.

The research findings were presented to the industry for input on three different occasions. Preliminary findings from the benchmarking survey were presented at the fall meeting of the Industry Advisory Board (IAB) for the Construction Engineering Management (CEM) Program at Oregon State University (OSU). Secondly, the final research findings were presented to the combined industry advisory boards of the CEM Program and the Civil Engineering Program at OSU at a board meeting in June 2007. Industry input on the final research findings was also solicited from the Advisory Council and leadership of the Charles Pankow Foundation during a presentation of the research study at a Council meeting in June 2007 in Portland, Oregon. At all

three meetings, the boards were asked to verify and provide input on the research findings during the presentation.

The last validation effort entailed distributing the study findings to the previous study participants for their confirmation of the results. Each of the questionnaires used for the benchmarking and innovative product surveys asked the respondents whether they could be contacted for further information. A list was created of those who responded positively to this question. The people who were interviewed as part of the case studies were also added to this list, creating a combined list of 85 people (47 from the benchmarking survey, 30 from the innovative products survey, and 8 from the case studies). A questionnaire was developed that contained the guidelines, suggested practices, and factors that were found to influence innovation. The questionnaire asked the respondent to rate the impact of the factors on innovation and to provide additional comments. For each factor, the questionnaire also asked the respondent to provide an implementation example and a justification for the rating. The questionnaire was e-mailed to the list of 85 people. Thirteen of the e-mails were returned as undeliverable and, therefore, the questionnaire was distributed to 72 people.

RESEARCH FINDINGS

Respondent Demographics

A total of 79 survey responses were recorded from the benchmarking interviews (10) and on-line questionnaire (69). The responses came from a wide variety of construction industry personnel including personnel in the positions of company president, CEO, COO, project manager, and estimator. The years of experience of the respondents in the construction industry ranged from three to 50 years (mean and median = 26 years). The respondents work for firms that are both small and large. The annual revenue of the respondents' firms ranged from \$900,000 to \$3.2 billion (mean = \$296 million; median = \$43.5 million). Sixty-three percent of the responses came from personnel located in primarily the West Coast states (CA, OR, WA), and the remainder (37%) came from other states across the country (AL, CO, FL, HI, IA, IN, KA, KY, MA, MI, MO, NE, NJ, NY, OH, PA, TX, and VA).

The innovative products questionnaire sent to the 189 firms which have developed products for implementation in the construction industry was completed and returned by 34 respondents (18.0% response rate). The respondents who completed the questionnaire had experience working in the construction industry that ranged from 2 to 46 years (mean = 23.3 years), and held a variety of positions including: President, CEO, CIO, Project Manager, Technical Director, Marketing Director, and Scientific Director. The services provided by the firms in which the respondents work are primarily: engineering design (36%), construction management (27%), specialty contracting (18%), and general contracting (12%). The 34 innovations developed by the responding firms can be grouped into the following categories: information technologies (3), computer-based technologies (3), construction equipment (6), construction means and methods (8), and facility end products (14).

Efforts to contact personnel involved in the 20 case study projects resulted in a total of 10 completed case studies (50% response rate). A summary description of the projects is provided in Table 1. The projects are located in nine different states across the U.S. within the Southwest, Northwest, Midwest, Southeast, Northeast, East Coast regions. In terms of size, based on approximate dollar value, two of the projects are small, four are medium, and four are large. Most of the projects (7) were new projects, while the remaining (3) were renovation projects. The types of project delivery methods utilized on the projects included both integrated delivery methods (5), such as design-build and construction manager/general contractor, and the traditional design-bid-build method (5). The sample consisted of both publicly-funded and privately-funded projects. Six projects were privately-funded, and four were publicly-funded. Seven of the projects came from the award-winning projects list, and the other three were from the regular projects list.

Table 1. Case Study Demographics

Project	Location (State)	Size (\$)	Type	Delivery Method	Funding Source	Status
A	OR	Small	New	DB	Private	Award
B	MI	Large	New	CM/DB	Private	Award
C	NV	Medium	New	DBB	Public	Regular
D	CA	Large	New	DB	Private	Award
E	FL	Medium	New	DBB	Private	Regular
F	WA	Large	New	DBB	Private	Award
G	GA	Small	Renovation	DB	Public	Regular
H	MD	Medium	Renovation	DBB	Public	Award
I	MA	Large	Renovation	CM/DB	Public	Award
J	CA	Medium	New	DBB	Private	Award

A total of 23 interviews were conducted on the ten case study projects. Interviews were conducted with the owner, architect/engineer of record, general contractor, subcontractors, and construction managers. In each case, significant efforts were made to interview as many people as possible and especially those from the owner, architect/engineer, and constructor organizations. In addition, for the award-winning projects, people involved in the innovative efforts on the projects were targeted for interviews. In many cases, the number of interviews was limited by the availability and interest of the people targeted.

Innovation in Practice

Types of Innovations

The benchmarking survey and interviews asked the respondents: “What new products, technologies, or processes, that either your firm developed or were developed outside your firm, have been implemented on your projects or within your firm in the past 10 years?” A total of 76 innovations were listed in all of the responses to this question. The innovations ranged to a great extent and can be grouped into six categories: Information Technologies; Computer-based Electronic Devices; Design and Construction End Products; Construction Means and Methods; Contracting; and Other. Of the 76 innovations, those listed by three or more respondents, and

those that are otherwise notable, are shown in Table 2. It should be noted that not all of the innovations mentioned in the survey responses fit within the definition of innovation as established for this research study. Some products and processes that were mentioned by the respondents were trivial in nature, a solution to solve a problem on only one project, or a different design feature that is aesthetically pleasing.

Table 2. Types of Innovations

Category	Benchmarking Survey	Innovative Products Survey
Information Technologies	Internet-based project management (8) Estimating templates (4)	Project information management system (1) Lessons learned systems (2)
Computer-based Electronic Devices	3D CAD (7) Personal Digital Assistants (3) GPS Grade Control (4)	Bid Express Project control system Leak noise correlator
End Products (Design and Construction)	New forming systems (9)	Material products (5) Mechanical products (7) Electrical products (2)
Construction Means and Methods	Work platform to allow workers to operate over water (1)	Concrete formwork/placement (5) Task management (2) Welding (1)
Contracting	Innovations in Design-Build (6) Partnering (1)	
Construction Equipment		Heavy/civil equipment components (5) Concrete materials washout (1)
Other	LEED (1)	

Sources of Innovations

Several questions in all three parts of the study were aimed at exposing where innovative ideas begin. In the benchmarking study the respondents indicated that approximately 54% of the innovations started from within the firm while the remainder (46%) came from outside the firm. When asked specifically about those innovations that originated internally and the source of the innovative idea, project manager was mentioned by 69% of the respondents, the most of any other internal source. Upper management (63%) and superintendent (51%) were also mentioned frequently. Other personnel involved in projects were mentioned to a lesser extent: foreman (35%), project engineer (32%), field worker (23%), and project architect (17%).

The benchmarking study also asked the source of innovations that originated externally. The survey respondents identified suppliers as the primary external source of innovation (54% of respondents). Other sources commonly mentioned were: owner (29%), architect (28%), design engineer (24%), subcontractor (24%), and other industry (24%).

Motivation for Innovation

The survey respondents and personnel interviewed in the benchmarking survey were asked to indicate the impetus for the innovations. A summary of the responses from the benchmarking

survey is shown in Figure 1. The most common response was cost savings, which was identified by 64 of the 79 respondents (81%). This was followed closely by increasing productivity and efficiency (77%), and improve quality (69%). Schedule reduction and creating a competitive advantage were also highly ranked.

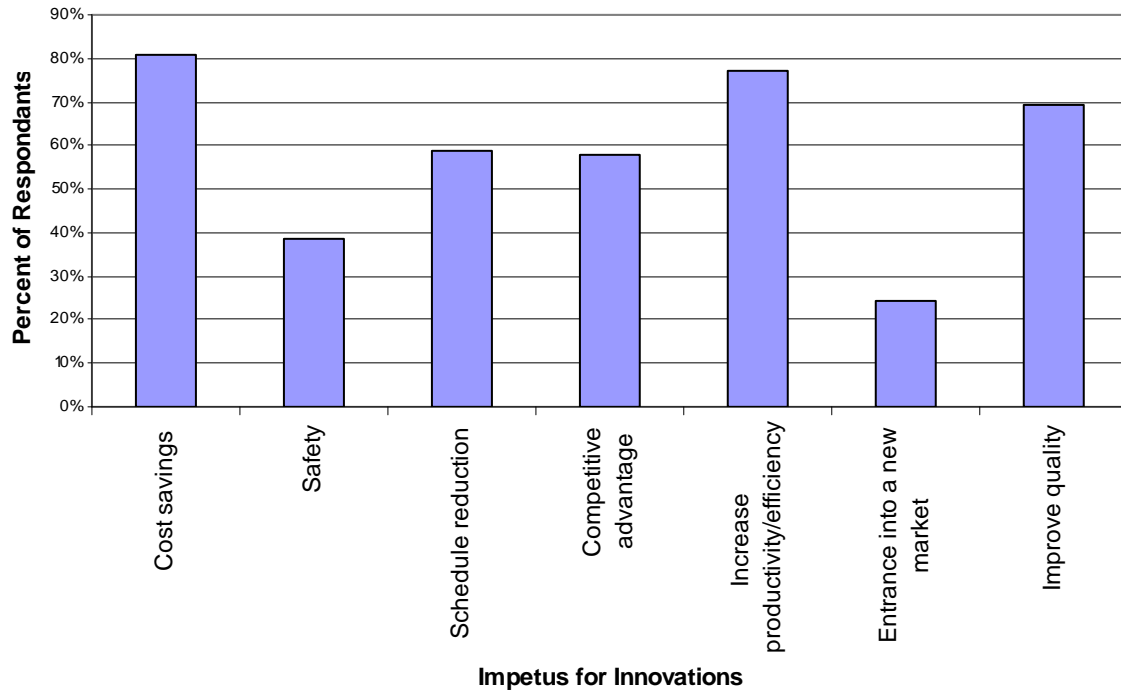


Figure 1. Motivation for Innovation (Benchmarking Survey)

Enablers of Innovation

Enablers of innovation were also addressed in the surveys and interviews. In the benchmarking survey, support from the upper management of the firm was the most commonly cited factor that enables innovation. Fifty-three of the 79 respondents (67%) cited upper management support as important to successful innovations. This was followed by the level of communication within the firm (53%) and a culture of innovation (43%). A roughly equal level of importance was placed on the level of communication amongst the project team members (37%), the complexity and sophistication of projects (37%), and overlap of design and construction phases (36%).

The benchmarking survey respondents were also asked to rate using a scale of 1-5 (1 = high ability to innovate; 5 = low ability to innovate) their firm's ability to innovate within specific project delivery methods. The results from this question are shown in Figure 2. Design-Build was rated as the delivery method that allows the greatest ability to innovate, receiving an average rating of 1.7. This was followed by CM/GC (2.4), CM @ Risk (2.8), CM (3.3), and Design-Bid-Build (3.5). These results are similar to that found in the literature. Those project delivery methods which are structured to permit more integration of design and construction expertise tend to promote innovation to occur.

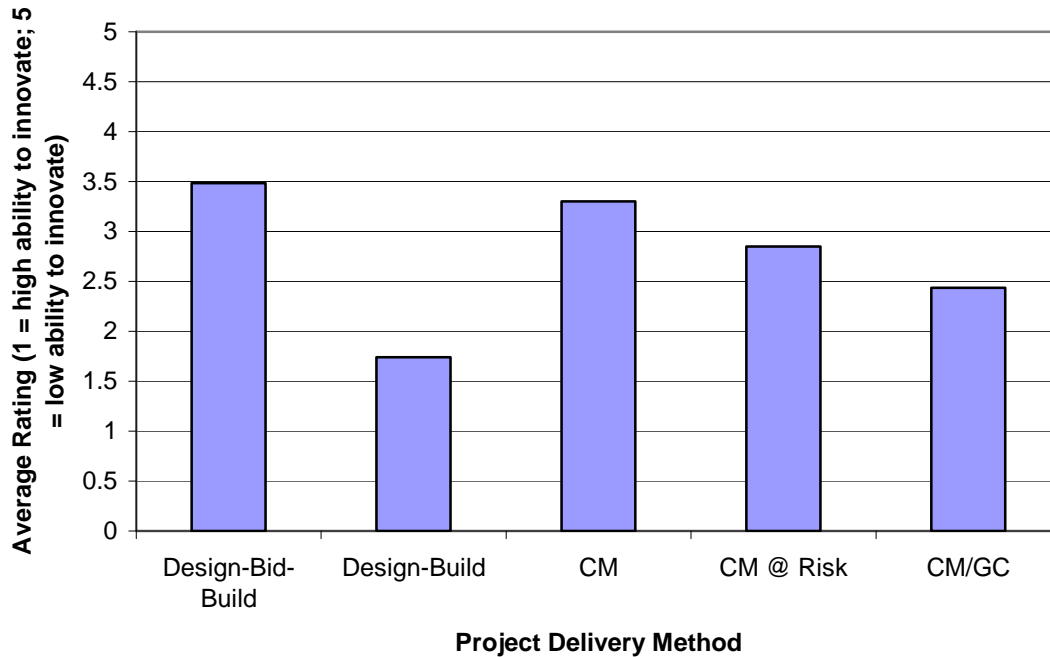


Figure 2. Ability to Innovate within a Project Delivery Method (Benchmarking Survey)
 (Note: A lower number indicates a greater ability to innovate.)

Barriers to Innovation

Barriers to innovation were explored in the study as well. Figure 3 shows the results from the benchmarking survey. When asked about what barriers exist, either within the respondent’s firm or external to the firm, which limit innovation within the respondent’s firm, the most common responses from the benchmarking survey were: not applicable to all projects (41%); not recognized by clients (40%); and fear of change (36%). Competitive bidding was also identified by a significant number of the respondents (31%). This result correlates with the results of related to enablers, which shows the respondents’ lower rating of Design-Bid-Build as a delivery method that allows for innovation. Other barriers to innovation that were noted by a significant percentage of the respondents are: low return on investment (27%); long payback period (26%); industry regulations and codes (23%); low investment in R&D (23%); and risk of failure (21%).

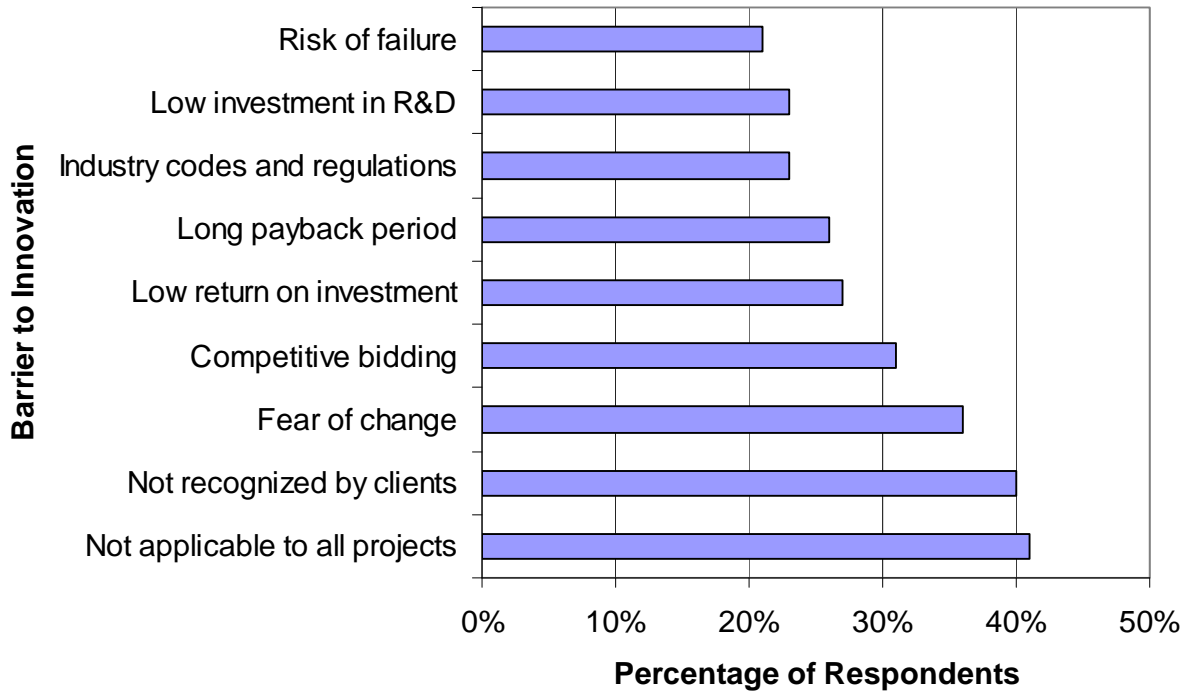


Figure 3. Barriers to Innovation (Benchmarking Survey)

Benefits and Outcomes of Innovation

Participants in the research study were asked to identify the benefits and outcomes of innovation. No limitation was placed on the type of outcome provided. While the respondents recognized that there are barriers to innovation, they also acknowledged that innovation does occur and has some benefits. In the benchmarking survey, one question asked, “What are the impacts/outcomes of innovation within your firm?” The impacts which were most often cited by the respondents were: increased productivity (75%); cost savings (68%); improved quality (68%); and competitive advantage (61%). Other impacts of innovation, and the corresponding percentage of respondents who cited the impacts, were: increased market share (43%); improved safety (40%); marketing (33%); and appearance of new markets (31%).

The contribution of innovations to the profit of a firm was also investigated in the benchmarking survey. The respondents were asked how much the innovations in their firm contribute to the overall percentage of profit earned by their firm. The majority of respondents (43%) stated that innovations contribute only a small percentage to the firm’s profit. A moderate percentage and a high percentage were cited by 29% and 9% of the respondents, respectively. Difficulties in linking innovations to profit may affect the responses to this question. Confounding factors can make it difficult to identify the impacts of an innovation on profit realized. Lacking a clear understanding of how innovation affects profit can negatively impact motivation to change and hamper attempts at innovation.

The outcomes identified by the respondents in the benchmarking survey were also commonly cited as motivators of innovation (shown in Figure 1). Figure 4 shows a comparison between the

benefits and motivators identified in the survey responses. As seen in the figure, some realized benefits were not identified as motivators for the innovations such as improved market share and marketing. It is interesting to note that schedule was identified as a motivator of the innovation, but not recognized as a benefit. However, schedule is closely related to productivity which is listed as a benefit.

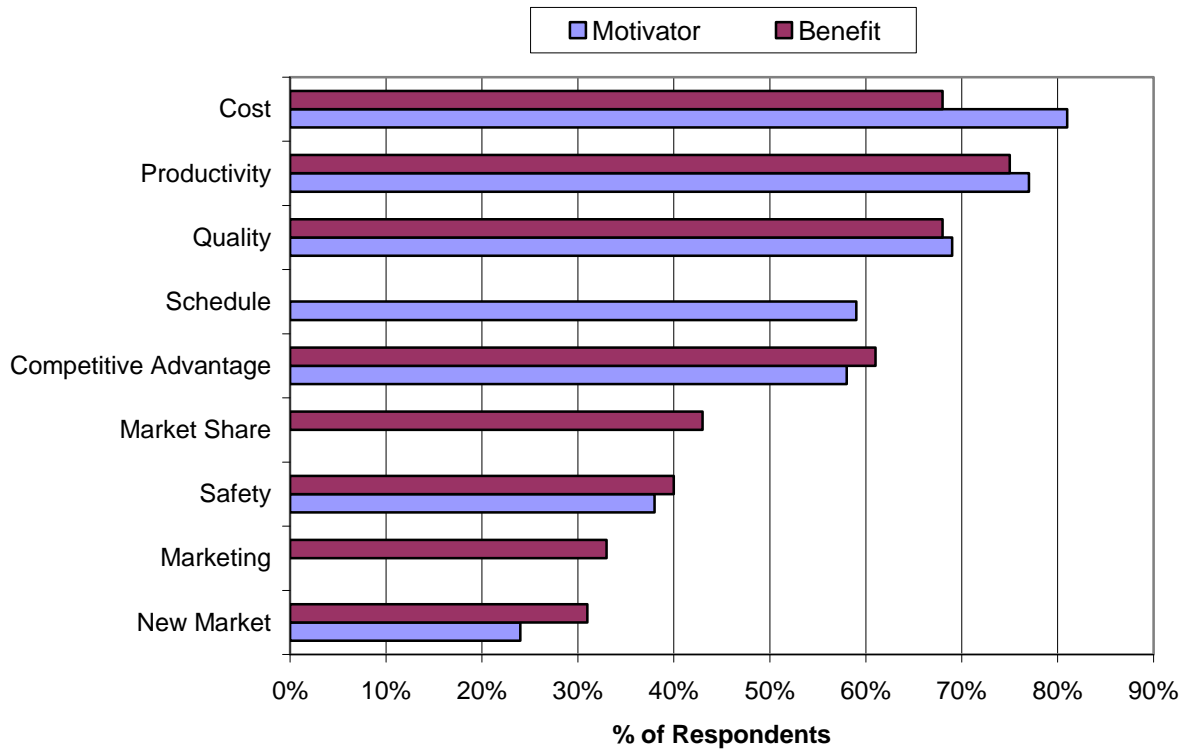


Figure 4. Comparison of Benefits and Motivators (Benchmarking Survey)

Metrics and Assessment

Part of the research study was aimed at identifying metrics to measure innovation on projects. The surveys and interviews solicited input on the metrics used in industry to assess the impact of an innovation and the success at innovating. In the benchmarking survey, several questions were asked that pertained to the firm’s assessment and tracking of innovations and the metrics used in the process. With regards to the question, “How does your firm measure the success/failure of an innovation?”, project team input/comments was cited most often (50% of the respondents). The other means for assessing the performance of an innovation which the respondents cited frequently were: quality performance (45%); productivity analysis (42%); client feedback (41%); and budget analysis (40%). It should be noted that approximately 13% of the respondents stated that no assessment was conducted of the success or failure of innovations in their firm.

The benchmarking survey respondents were also asked to give their perception of how well the firm measures and tracks innovations, and how important it is to their firm. Figure 5 summarizes the responses to these questions. Most of the respondents rate their firms as having a low or moderate ability to measure and track innovations. Approximately 8% of the respondents stated

that they have no ability to measure or track innovations. With regards to the importance placed on this assessment effort, the most common response was that it is moderately important (37%). Roughly an equal number of respondents feel that it is minimally important (24%) as those that feel it to be significantly important (23%).

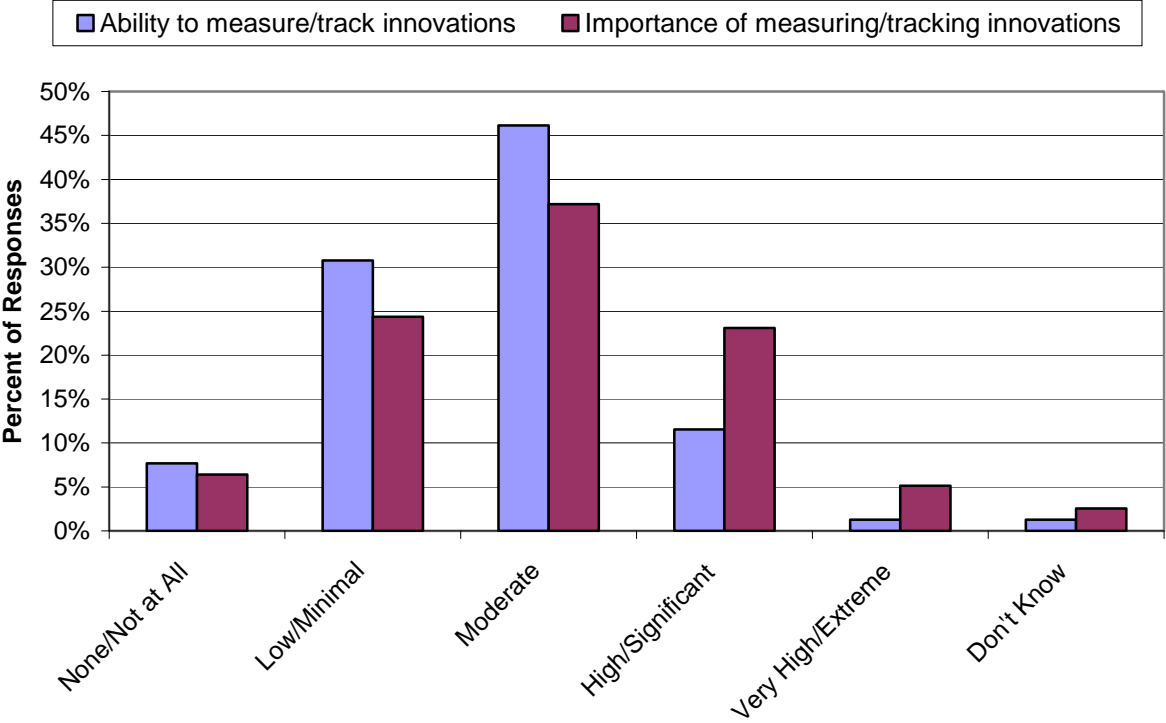


Figure 5. Ability to Measure/Track Innovations and Importance of Measuring/Tracking Innovations (Benchmarking Survey)

Presence of Innovation (Lagging Indicators)

Returning to the definition of innovation established for the research study, innovation is identified by positive change in a process, product, or system. The change that occurs is a result of the innovation. One way to directly measure innovation is to measure change in the way a project is designed, constructed, and delivered. Comparing a present state to a previous state allows for determining whether change has occurred. If the change is positive, a result of a new idea or concept, and is significant (i.e., non-trivial), then it would be considered innovation. Hence, the research efforts focused on determining if unique change occurred and if the change was non-trivial.

It may be the case that a project experiences multiple innovations. When multiple innovations create change over time, the frequency of the change can be measured. The frequency with which change occurs is also an indication of the magnitude of innovation. Therefore, the research considered the number of feasible new ideas implemented over the course of each project. The extent to which the innovative process is occurring is not only reflected in the

number of new ideas implemented, but also in the number of feasible new ideas generated and tested. Generating, testing, and evaluating new ideas may or may not lead to new products, processes, or systems implemented. However these efforts are an indication of whether the innovation process is present and whether innovation is occurring.

As stated previously, the innovation must also be diffused beyond just the initial project or setting in which it is employed. Lacking diffusion to other projects within a firm or the industry, the change is simply problem solving. Its value to the firm and industry is validated when it is accepted and applied after its initial demonstration and use. Therefore, the extent and speed to which a new product, process, or system has diffused throughout a firm or the industry is an indicator of whether innovation has occurred. This aspect of innovation was evaluated in the research as well.

Implementing an innovation often requires education and training of those who put the innovation into practice. This is especially true of non-trivial change which requires significant modifications to work practices and conditions. This can be accomplished by providing continuing education and training for current employees or by hiring new employees who have specialized skills and knowledge. Hence, the amount of new training and education that is required for employees as a direct result of changes in their work can also reflect the innovation that occurs. The research utilized the amount of required employee training and education as an indicator of innovation.

Literature identifies other impacts from innovation that include: increased profit, lower cost, decreased schedules, improved safety performance, improved quality, increased market share, and the presence of a competitive advantage. These benefits were exposed in the benchmarking survey as well. The extent to which these impacts occurred on the case study projects was also used as an indicator of whether innovation occurred on the projects.

In summary, the following factors were used as indicators of whether innovation occurred, and the extent of innovation, on the projects evaluated in the research study:

- Change in, and impact of, work products, systems, and processes
- Number of feasible new ideas generated, tested, and implemented
- Amount of new training and continuing education required for employees as a result of changes in their work
- Extent and pace of diffusion to other projects and industry
- Impact on: profit, cost, schedule, safety, quality, market share, and competitiveness

The strength of the relationship between each factor and innovation varies. The amount of change that occurs, the number of new ideas implemented, and the extent of diffusion are direct indicators of innovation. The amount of new training and continuing education required is an indirect indicator but closely tied to innovation. It is assumed that the additional required training and education would not be needed if innovation did not occur. The impact on profit, cost, schedule, safety, quality, market share, and competitiveness are indirect indicators as well, and more difficult to tie to innovation. Many different project characteristics and processes can create the impacts and it is difficult to isolate innovation as the causal factor.

Innovation Enablers and Impacting Factors (Leading Indicators)

The next step in the analysis was to investigate the relationship between individual enabling and impacting factors (leading indicators) and the innovation scores calculated from the lagging indicators. Performance metrics identified in the literature review and innovative product survey were selected and evaluated. The analysis with respect to each metric is described below. The research team used its own judgment, knowledge of the projects, and knowledge of innovation and the construction industry to create a rating of each leading indicator. A 1-10 scale was used (1 = not at all and 10 = excellent/extreme). The analyses below show the results using the rating.

Owner Influence

The influence of the owner has been identified in literature as having an impact on innovation on a project. The owner sets the project goals and objectives, enters into contracts to get the project designed and built, and controls the level of resources (dollars, time, etc.) expended on a project. The case study interviews asked several questions regarding owner involvement which can be used to gauge the influence of the owner on innovation. These questions were:

- To what extent was the owner involved or interested in innovation?
- To what extent did the owner allow time to develop innovative ideas?
- To what extent was innovation a project objective of the owner?
- To what extent did the owner include innovation in the budget?

Given the information collected during the case study interviews, the researchers rated the projects, using a scale of 1-10, according to the influence of the owner on innovation on the project. Figure 6 shows that the relationship is very strong ($R^2 = 0.91$).

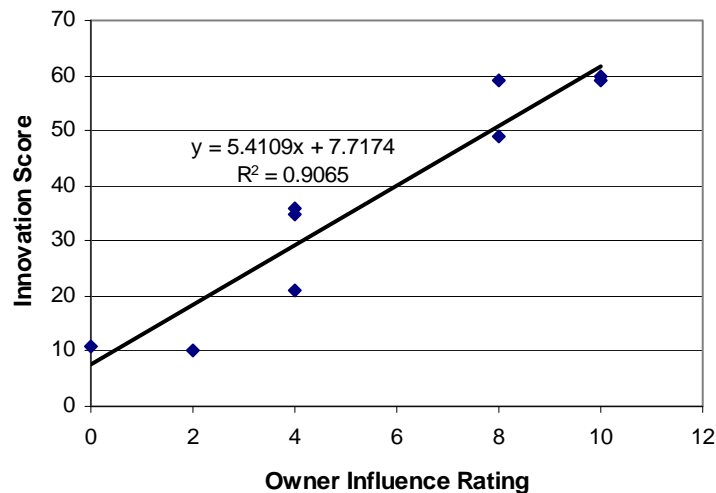


Figure 6. Impact of Owner Influence on Innovation – Researcher Ratings (Case Study Projects)

Presence of an Innovation Champion

During the case study interviews, the participants were asked about the extent to which there was a champion on the project shepherding the innovation and eliminating potential roadblocks. The presence of a champion can be a significant factor in whether an idea gets implemented or not. Using the ratings given by the researcher team as to the extent to which a champion was involved in the success of the innovation, Figure 7 can be created. As seen in the figure, when an innovation champion was present to a greater extent in the case study projects, innovation was increased ($R^2 = 0.79$).

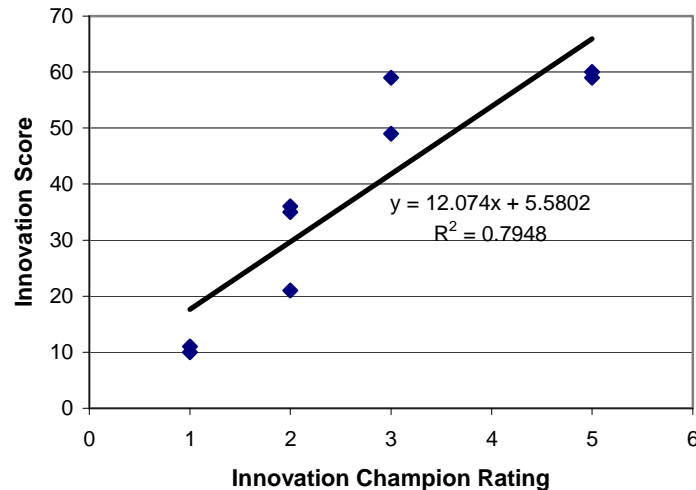


Figure 7. Impact of Innovation Champion on Innovation – Researcher Ratings (Case Study Projects)

Project Team Collaboration

When designing and constructing projects, the work may be conducted through employees working together in teams or by employees working on their own. The collaborative nature of working in teams can benefit innovation by helping to foster new, feasible ideas based on the input of many individuals and enhance communication. This is especially true if the individuals come from diverse backgrounds and have unique perspectives. The collaboration can occur in face-to-face meetings, conference calls, via e-mail, or any other means of communication.

The case study interviews addressed collaboration by asking the participants about the extent to which the project team members worked together in groups. It is assumed that by working in groups, through any type of communication means (face-to-face, conference calls, e-mail, etc.), collaboration will result and innovation will be enhanced. Figure 8 shows the relationship using the ratings created by the researchers. The figure shows a positive relationship (i.e., as collaboration increases, so does innovation) between collaboration and innovation ($R^2 = 0.70$).

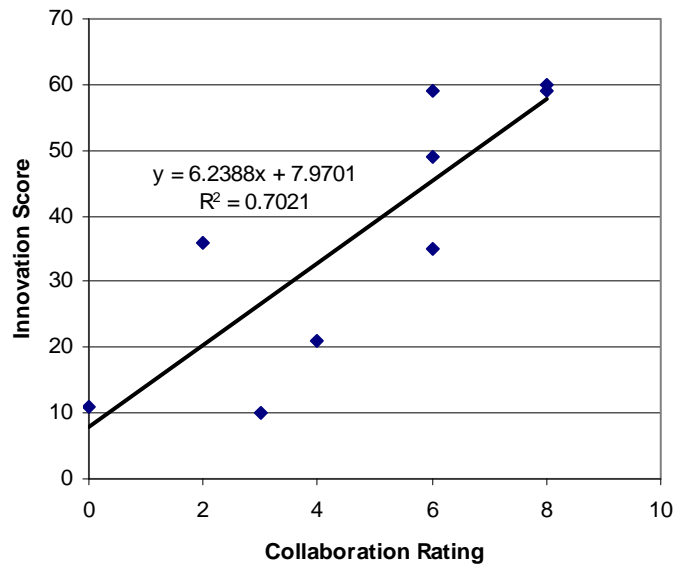


Figure 8. Impact of Project Team Collaboration on Innovation – Researcher Ratings (Case Study Projects)

Degree of Project Team Integration

The integration of firms with different areas of expertise, such as multiple design firms working together and design firms working with construction firms, brings together different perspectives that can facilitate the sharing of knowledge and promote new ideas. The case study interviews addressed the extent that the design and construction were integrated and the extent in which multiple firms on the project worked together as a team. The data reveal a moderate, positive relationship between integration and innovation ($R^2 = 0.52$) as shown in Figure 9.

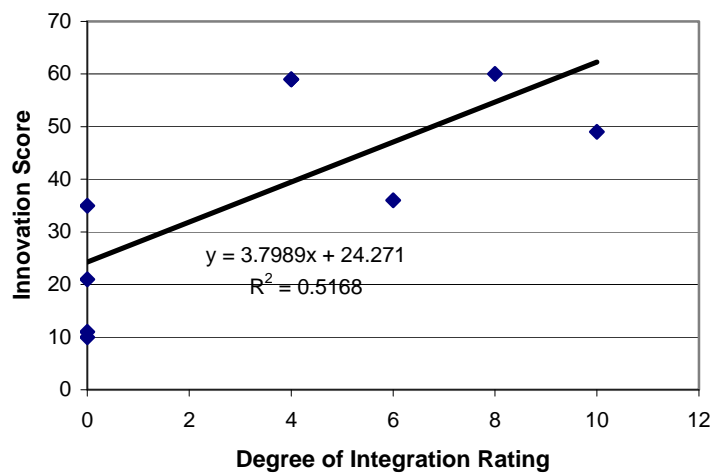


Figure 9. Impact of Project Team Integration on Innovation – Researcher Ratings (Case Study Projects)

Communication

The literature identifies communication between project participants as a factor that affects innovation. Open communication channels over which there is cross-discipline, multi-lateral (i.e., not just top-down) communication allows for sharing of project information and ideas. In addition, when the communication is encouraged, and proactive rather than reactive, a climate exists which supports collaboration and working as a team. The case study interviews explored these factors by asking to what extent was the communication on the project: open, cross-disciplined, unilateral, and encouraged. The responses to these four questions were used to create an aggregate communication rating. Using the researcher ratings, Figure 10 shows that as communication improves, so does innovation ($R^2 = 0.63$).

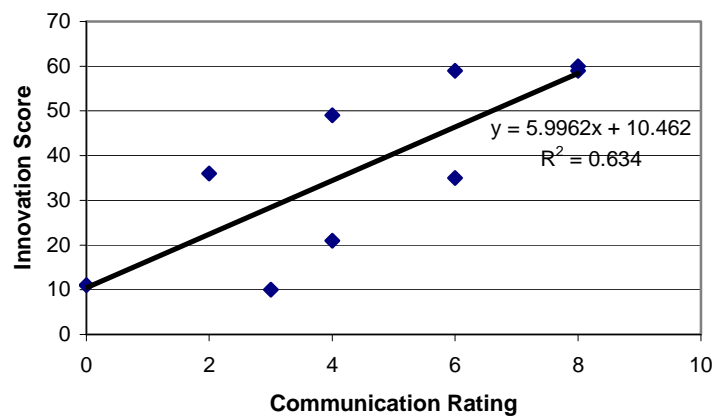


Figure 10. Impact of Communication on Innovation – Researcher Ratings (Case Study Projects)

Lessons Learned/Knowledge Management

The impact of a lessons learned/knowledge management process on innovation was investigated as well. Capturing, organizing, and disseminating lessons learned on one project throughout the firm is a way to diffuse information about innovations and information that can lead to innovations. As discussed previously, diffusion must occur in order to have innovation. The research investigated the impact of a lessons learned/knowledge management system on innovation by asking the following questions:

- Does your firm have formal mechanisms to **capture lessons learned** and to what extent are the mechanisms implemented?
- Does your firm have formal mechanisms to **disseminate lessons learned** and to what extent are the mechanisms implemented?
- Does your firm have formal mechanisms to **disseminate innovations** and to what extent are the mechanisms implemented?
- Does your firm **implement** lessons learned on future/subsequent projects and to what extent are the lessons learned implemented?

The responses to the questions were used to determine an aggregate lessons learned rating for each case study project. Figure 11 shows the relationship to the researcher innovation ratings, which is a strong, positive relationship between lessons learned and innovation ($R^2 = 0.79$).

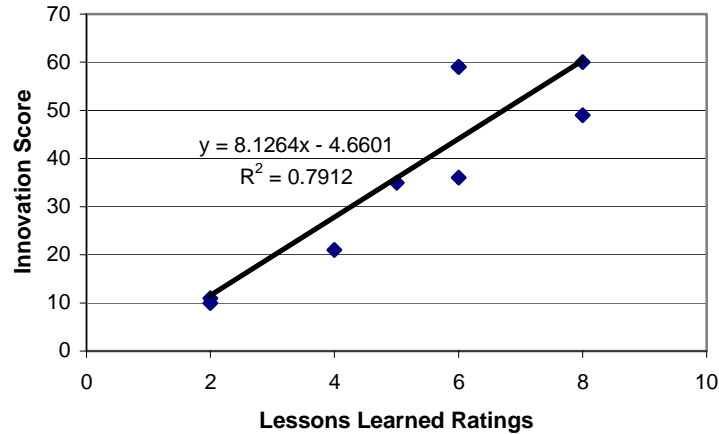


Figure 11. Impact of Lessons Learned Process on Innovation – Researcher Ratings (Case Study Projects)

Upper Management Support

The support of upper management within a firm significantly impacts many aspects of projects. In the benchmarking survey, upper management support was most commonly identified factor that enables innovation. Support can be provided in many different ways. In the case study interviews, upper management support was investigated through the following questions:

- To what extent is innovation part of your firm’s organizational strategy?
- To what extent is innovation part of your firm’s mission statement?
- To what extent is innovation part of your firm’s business plan?
- To what extent is innovation part of your firm’s budget?
- To what extent does your firm hold innovation meetings?
- To what extent were employees allotted time to explore new ideas?
- To what extent does your firm market innovation?

Using the researcher ratings of upper management support, the correlation is shown in Figure 12. The analysis reveals a moderate to strong relationship between upper management support and innovation for the case study projects using the researcher ratings ($R^2 = 0.79$).

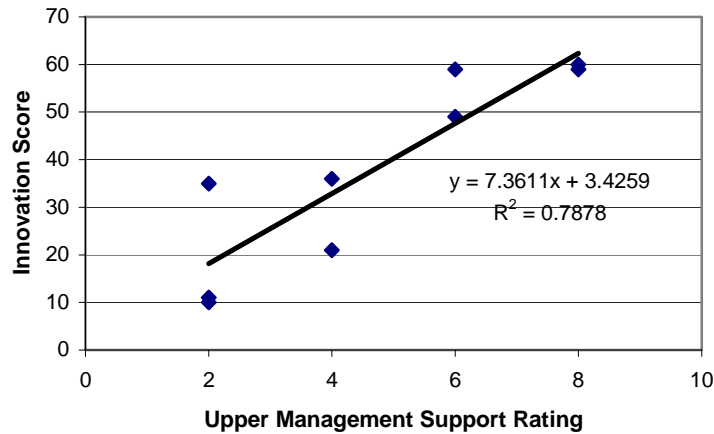


Figure 12. Impact of Upper Management Support on Innovation – Researcher Ratings (Case Study Projects)

Research and Development

Research and development of new concepts, technologies, and processes can be instrumental in, and is often a requirement for, the innovation process. Formal R&D programs within engineering and construction firms are not common, especially within small- and medium-sized firms. It is perhaps the case, however, that R&D occurs at a more informal level where those involved in the innovative change, and perhaps along with the innovation champion, try out and develop the new idea on different occasions. The extent to which this occurs can impact success at innovation. The case study interviews used four questions to assess R&D:

- To what extent does your firm perform R&D?
- To what extent does your firm include R&D in project budgets?
- To what extent was there time allowed for R&D on this project?
- To what extent was R&D supported by your firm for this project?

Similar to the other leading indicators, aggregate ratings were calculated based on the responses to all four of the questions. Figure 13 shows the relationships between R&D and innovation using the research team ratings. The figure shows a very strong, positive relationship, i.e., as R&D increases, innovation also increases ($R^2 = 0.89$).

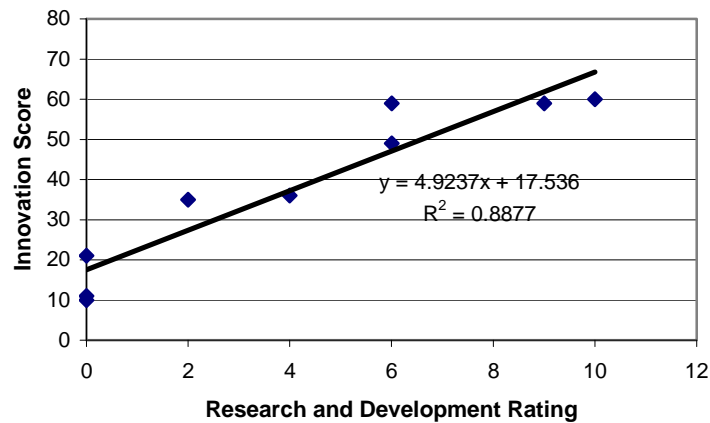


Figure 13. Impact of R&D on Innovation – Researcher Ratings (Case Study Projects)

Employee Recognition

Recognizing employees for their ingenuity and motivation for positive change on projects is a way of encouraging innovation to occur. This recognition can be provided in many different ways (e.g., letter of appreciation, award, promotion, etc.), and publicly or in private.

Recognition of employees was identified by the Industry Advisory Board as an enabler of innovation. The research assessed the impact of recognition on innovation through three questions asked during the case study interviews:

- Does your firm have formal mechanisms to recognize the contributions of individuals and to what extent are the mechanisms implemented?
- Does your firm have formal mechanisms to recognize the contributions of teams and to what extent are the mechanisms implemented?
- Does your firm have formal mechanisms to recognize the contributions of subcontractors and to what extent are the mechanisms implemented?

Unfortunately, insufficient additional information was gained in the case study interviews for the research team to develop its own reliable rating of employee recognition on the case study projects. Therefore, no relationship with innovation using researcher ratings was investigated.

Organizational Climate

The culture of an organization with respect to innovation was identified in the literature as an impact to innovation. When the organizational culture is open, accepting of new ideas, and willing to change, the potential for innovation is increased. Closed, conservative, and highly standardized organizations exhibit a culture that is not conducive to innovation. However, organizational culture is difficult to measure. Assessing organizational culture requires in-depth study of both explicit features and tacit knowledge within an organization, and is beyond the scope of this study.

Part of what makes up an organization’s culture is the climate (or environment) in which the employees work. Climate is characterized by the employment surroundings, both physical and

organizational, within which the employee acts. Examples of factors that impact organizational climate with respect to innovation include upper management’s emphasis on innovation and whether formal recognition is given to those employees who innovate. The case studies and benchmarking survey data gathered allowed for assessing the impact of organizational climate on innovation. To evaluate how an organization’s climate impacts the level of innovation, an aggregate organizational climate score was created in a manner similar to that used for determining the innovation score.

Using the case studies, an assessment of the organizational climate was developed using a combination of five of the leading indicators described above: project team collaboration, degree of project team integration, communication, upper management support, and employee recognition. Each of these indicators is viewed as having an impact on the work climate that employees experience with respect to innovation. Using the researcher ratings, the data show a very strong positive correlation between organizational climate and innovation ($R^2 = 0.88$), as shown in Figure 14.

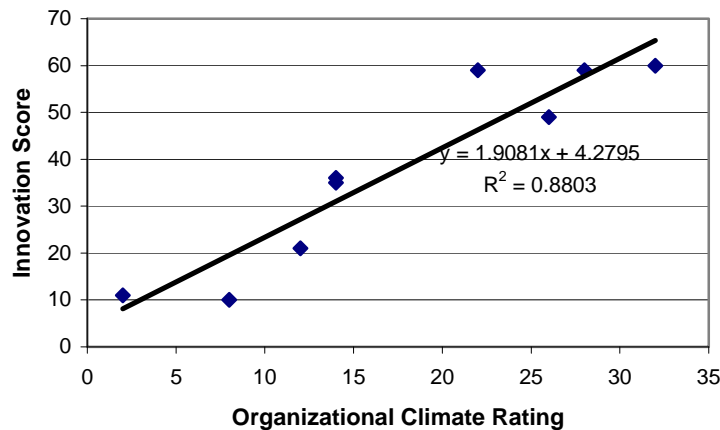


Figure 14. Impact of Organizational Climate on Innovation – Researcher Ratings (Case Study Projects)

Organizational Structure

Innovation literature reveals that organizational structure also can have an impact on innovation. Formally including innovation in an organization’s strategic plan and administration emphasizes the importance of innovation to the employees which can motivate workers in the innovation process. An organization’s structure should, however, not be overly restrictive, complicated, or multi-layered, and stifle opportunities for developing and implementing new ideas. In a manner similar to organizational climate, to gauge the impact of an organizations structure on innovation, organizational structure scores were calculated using aggregates of the case study and benchmarking survey data.

The following leading indicators were used to calculate an aggregate organizational structure score from the case study interviews: presence of an innovation champion, lessons learned/knowledge management, upper management support, and research and development.

Each of these indicators takes part in establishing the organizational structure with respect to innovation. An organizational structure rating was created using the research team ratings and compared to the innovation scores of the projects (see Figure 15). Using the researcher ratings, the data show a strong, positive correlation between organizational structure and innovation ($R^2 = 0.90$).

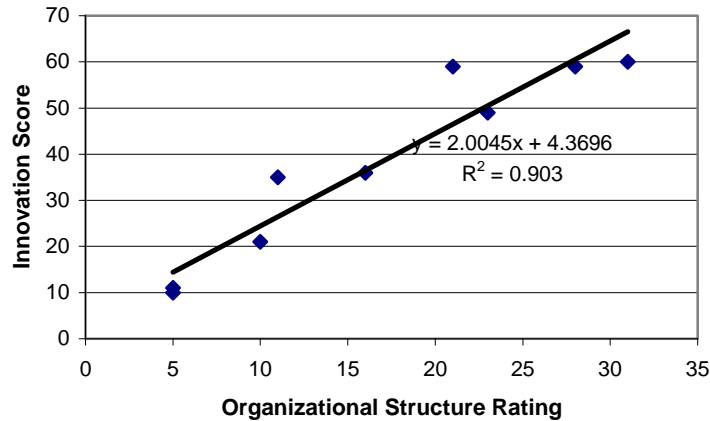


Figure 15. Impact of Organizational Structure on Innovation – Researcher Ratings (Case Study Projects)

Work Type

The case studies solicited input about whether the project was a new (“greenfield”) project or a renovation/maintenance project. As shown previously in Table 1, six of the ten case study projects (60%) were new projects and the remaining were renovation projects. Figure 16 shows the average innovation scores for the new and the renovation case study projects. Innovation was found to be greater on the new projects in the case study sample.

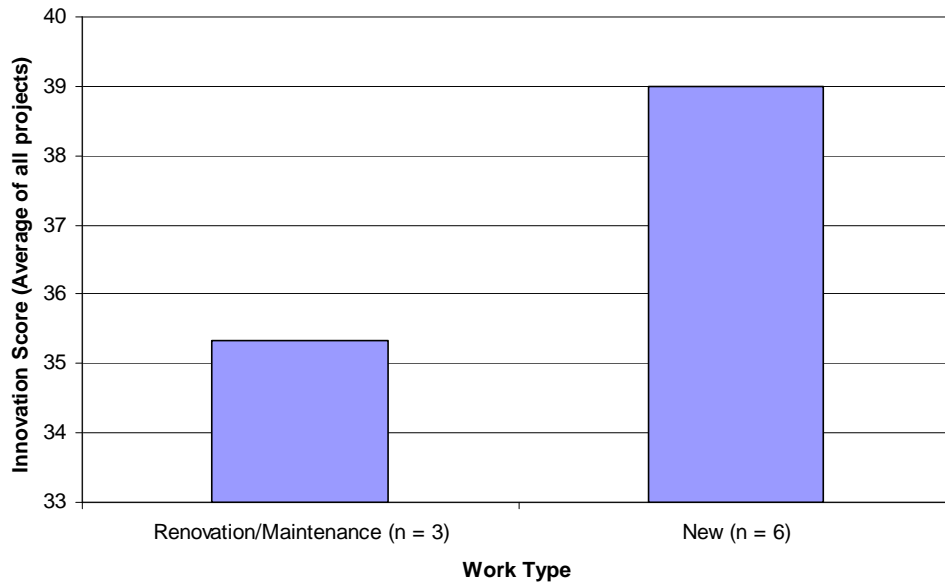


Figure 16. Impact of Work Type on Innovation (Case Study Projects)

Project Size

The case study data was also analyzed to determine if there was a relationship between project size and innovation. The size of each project was based on the approximate dollar value of the project. Small projects were categorized as those valued at less than \$20 million. Medium projects are those between \$20 million and \$100 million, and projects greater than \$100 million were categorized as large projects. Figure 17 shows the innovation scores for the projects based on size. Innovation score was highest for large projects.

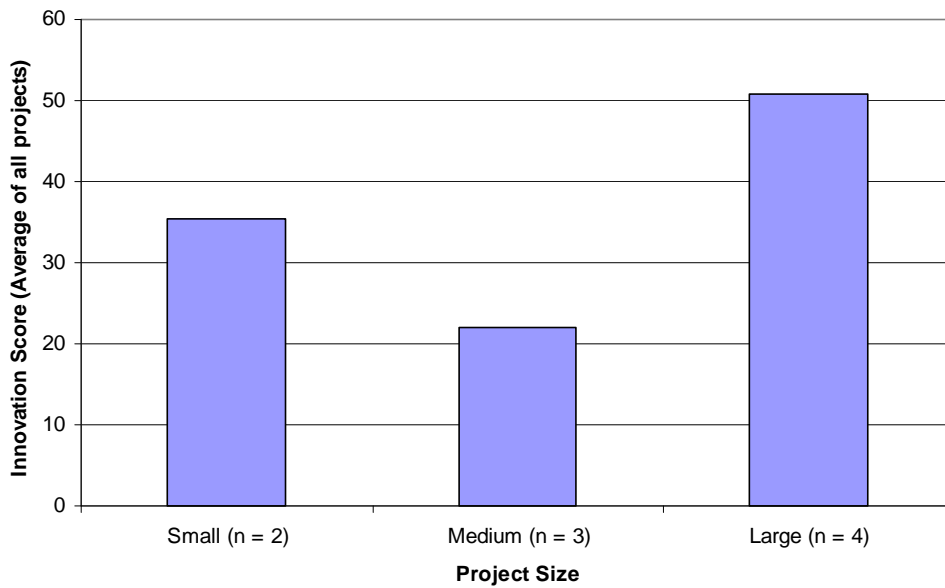


Figure 17. Impact of Project Size on Innovation (Case Study Projects)

Firm Size

The benchmarking survey provided data to investigate the impact of firm size on innovation. Figure 18 shows a plot of the innovation scores versus the annual revenue of the firm (in \$ millions). As can be seen from the figure, there appears to be no relationship between annual revenue and innovation score for the firms in the study sample. The size of the firm, based on annual revenue, does not appear to impact the level of innovation that occurs on the projects built by the firm. Good ideas can come from many different places. While large firms may have more resources to devote to R&D of the new ideas, the structure and procedures needed to run a large firm may impact diffusion of new ideas. Large firms with significant resources may also be more risk averse since they “have something to lose”.

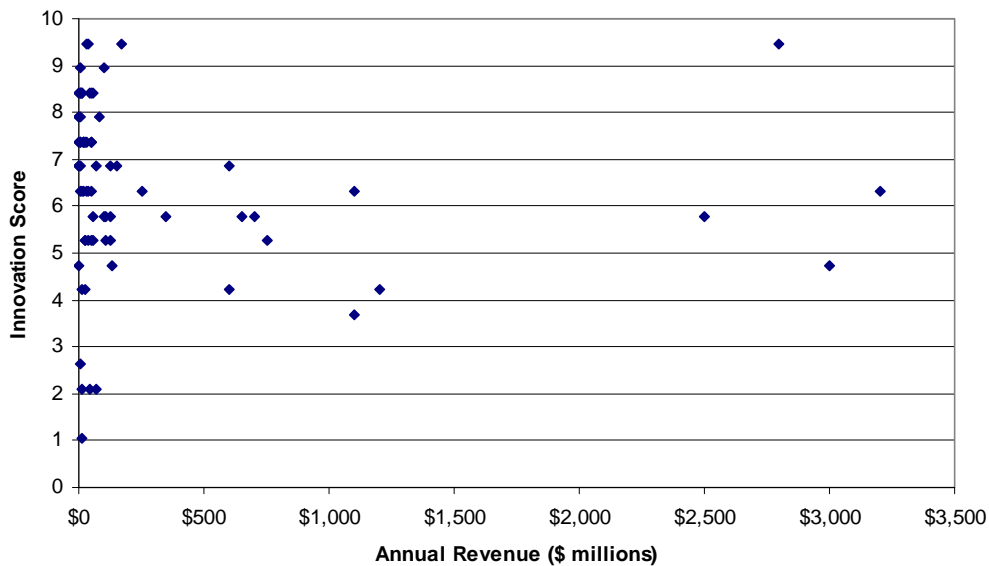


Figure 18. Impact of Firm Size on Innovation (Benchmarking Survey)

Project Delivery Method

The contracting method used to delivery a project can impact the extent to which project team members collaborate, communicate, and share information to the benefit of innovation on the project. In addition, some project delivery methods allow for integration of discipline expertise earlier in the project lifecycle which can have a positive impact on innovation. Figure 19 shows a comparison of project delivery methods used on a project with respect to the innovation score for the case study projects. Innovation scores were higher on average for the design-build projects in the study sample. The nature of design-build projects which integrate the project team disciplines enables the generation and implementation of innovative ideas.

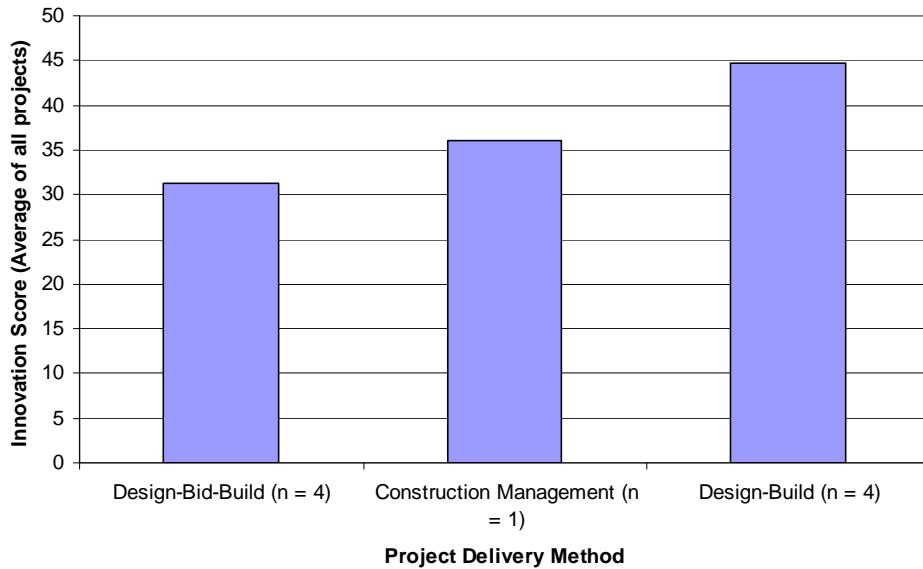


Figure 19. Impact of Project Delivery Method on Innovation (Case Study Projects)

In the benchmarking survey, responses to the question regarding the firm’s ability to innovate within various project delivery methods indicate that those methods which integrate design and construction expertise, such as Design-Build and CM/GC, tend to allow firms to innovate at a greater level. This relationship was also tested using the benchmarking innovation score. Using the demographics question which asked for the approximate percentage distribution of project delivery methods in which their firm participates, the responding firms were designated as DBB, DB, CM/GC, CM @ Risk, or CM based on the amount of work which they perform within each delivery method. A firm was classified as delivering primarily within one delivery method if the firm delivers at least 75% of projects within one specific delivery type. For example, a firm delivering at least 75% of their work via DBB was classified as a DBB firm. Firms which do not have at least 75% of their work within one delivery method were omitted from this particular analysis. The results from this categorization with respect to innovation score are shown in Figure 20. Innovation success score was the highest for CM/GC (7.5), followed by DBB (6.3), DB (5.7), and CM @ Risk (5.3). No firms performed more than 75 percent of their work using the CM delivery method.

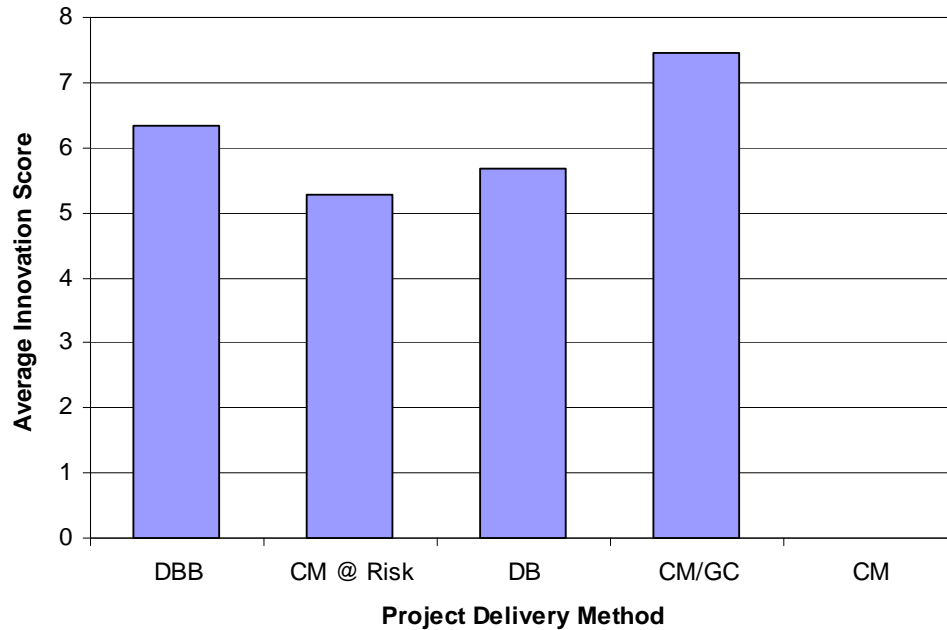


Figure 20. Impact of Project Delivery Method on Innovation (Benchmarking Survey)

Predicting and Measuring Innovation

The analysis described above indicates that there are many factors that affect innovation on a project. These include: owner influence, presence of an innovation champion, project team collaboration, degree of project team integration, communication, lessons learned/knowledge management, upper management support, research and development, and employee recognition. Each of these factors impacts innovation to some extent on its own. Measuring the magnitude and extent to which each factor is present on a project and within a firm can provide a means to predict the level of innovation that occurs on a project.

When considered together, the factors can be used to more accurately predict innovation. This is illustrated in Figure 21 which shows the relationship between the combined leading indicator scores (the sum of all of the ratings for the different leading indicators) based on the researcher ratings and innovation on the projects. The data reveals a very strong, positive correlation between the indicators and innovation ($R^2 = 0.91$).

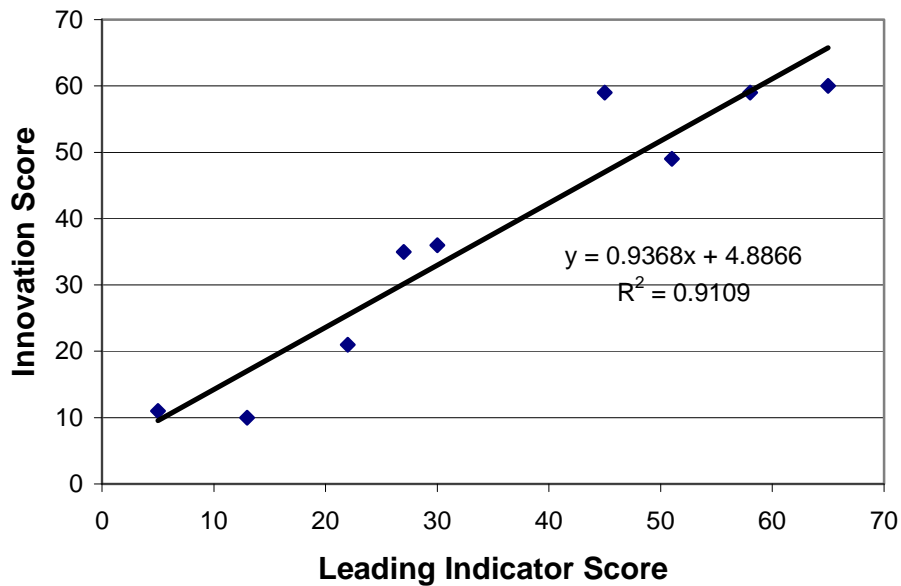


Figure 21. Impact of Leading Indicators on Innovation – Researcher Ratings (Case Study Projects)

Taking the study findings from research to practice requires recognition of design and construction practices and the qualities and characteristics of the construction industry. Measuring each leading indicator on a project may in some cases be difficult because of the nature of the indicator and the characteristics and capabilities of the project and firm. The influence of the owner, for example, cannot be directly measured and may be impacted by many factors. Assessing several indirect factors may provide a feasible means of measuring owner influence accurately. On the other hand, the presence of an innovation champion would be easier to measure. Suggested ways to measure the leading indicators in practice are provided below. For some factors a simple Yes/No response is appropriate, whereas for other factors a rating is required to indicate level or magnitude (such as a 1-5 rating).

- Owner Influence
 - The extent to which innovation is an objective of the owner.
 - The level of support (monetary, time, encouragement, etc.) given by the owner to innovation on the project.
- Innovation Champion
 - The presence of a champion, sponsor, or initiator for an innovation, or for innovation within a project or firm.
 - The percentage of the innovation champion’s role and responsibilities that include innovation.
- Project Team Collaboration
 - Use of a centralized project office where all participants work in a common setting.

- Level of involvement of all project team members in project meetings, constructability reviews, Value Engineering, and other quality control efforts.
- Project Team Integration
 - Use of an integrated project delivery method (e.g., design-build).
 - The extent to which multiple project team members worked as a team.
 - The extent to which different disciplines are involved in each project function.
 - Whether the design and construction phases overlap.
 - Diversity of the project team.
- Communication
 - The extent to which communication channels are open.
 - The extent to which communication is cross-discipline.
 - The extent to which communication is encouraged and proactive.
 - The extent to which communication is not unilateral.
 - The extent of face-to-face communication.
- Lessons Learned/Knowledge Management
 - The presence of a lessons learned process and program.
 - The extent to which lessons learned are captured and disseminated.
 - The extent to which innovations are disseminated and used on subsequent projects.
- Upper Management Support
 - Innovation as part of organizational strategy, mission statement, and business plan.
 - Whether innovation is part of the project and firm's budget.
 - The extent to which innovations are used in marketing the company.
 - The level of resources (monetary, time, etc.) devoted to innovation.
 - The extent to which R&D is supported by upper management.
- Research and Development
 - The extent to which the firm performs R&D on potential new products, processes, and systems.
 - The presence of an R&D budget.
 - The allowance of time to research and develop new products, processes, and systems.
- Employee Recognition
 - Whether employees are recognized for their contributions to innovation on a project.
 - The type and value of the recognition provided.

In addition to identifying leading indicators to predict the level and opportunity for innovation, the research exposed lagging indicators that can be used to measure the presence of innovation. These lagging indicators are:

- Change in, and impact of, work products, systems, and processes
- Number of feasible new ideas generated, tested, and implemented
- Amount of new training and continuing education required for employees as a result of changes in their work
- Extent and pace of diffusion to other projects and industry

- Impact on: profit, cost, schedule, safety, quality, market share, and competitiveness

When measuring lagging indicators, it is important to compare the measurement to a benchmarked value to get a sense of the magnitude and extent of change. For example, in order to measure how much change occurred due to the implementation of a new product, an assessment of the initial state before the change is required. Comparison of the ending state to the initial state indicates whether change has occurred.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In its simplest form, innovation is positive change as a result of new ideas. While a perception exists that innovation in the construction industry is lacking, decreasing cost and schedule, improving productivity, quality, and safety, and meeting or exceeding projected goals often require innovation. This is true for construction as well as other industries. Innovation within a project, company, and work industry provides the opportunity to realize significant benefits and, in a competitive market, is a requirement for continued existence. All companies must innovate at some level in order to stay competitive. Therefore, innovation in the construction industry may take place at a low rate compared to other industries due to the structure and characteristics of the industry and projects, but it does, and must, occur in a competitive market. Industry dynamics is interrelated with competitive advantage and financial success, making it necessary to place strategic change in a competitive context and identify what kinds of changes lead to strategic innovation and ultimately benefits for an organization (Egbu 2001).

This research study afforded learning about innovation within the context of the construction industry and meeting the six research objectives established for the study. The research activities conducted in this study provide an understanding of the current level and extent of innovation in the construction industry and the factors that impact the innovation process.

While many feel that innovation in construction is non-existent, the research revealed that it does occur at varying rates. While some firms incorporate change at a high rate, others are slow to change. Innovation is taking place on many fronts and commonly in the areas of information technologies, mobile computing devices, construction means and methods, and contracting. Approximately 180 worker-hours are expended on developing and implementing each innovation, and on average almost five months are required to take an innovation from initial concept through implementation.

It was also found that common motivators for innovation are: increasing productivity, reducing cost, staying competitive, and being recognized as a leader in the industry. At the project level, simply solving problems in order to build a project and bring it in on time and within budget is also a motivating factor. These motivating factors are similarly recognized as benefits of innovation.

Enablers of innovation were found to include: support from upper management, good communication within the firm, and the overlap of design and construction phases that is common within integrated project delivery methods. Barriers to innovation, however, can, and do, exist at the project, organization, and industry levels. Some of the barriers to innovation include: aversion to risk/change, lack of resources, low return on investment, and strict regulations and codes.

In terms of encouraging innovation and overcoming the barriers to innovation, the climate and structure of an organization and project were identified by the project participants as impacts to innovation. An open, accepting, and positive organizational climate surrounding the workplace encourages the generation and acceptance of new ideas. Similarly, an organizational structure that highlights and supports efforts to explore and try new ideas as a core value and strategy also benefits innovation.

Measuring and tracking innovations was identified as being important to the study participants. However, the respondents felt that their firms' ability to measure and track innovations was low to moderate. This perhaps is recognition of a lack of metrics, difficulty in measuring innovation, or a lack of tools available to assist in measuring innovation. The construction industry would benefit from the availability of a guideline or tool to assist them in this process.

The process of innovation involves different components and activities to generate and develop new ideas and bring them to reality. Innovation in the construction industry requires three components: *idea generation*, *opportunity*, and *diffusion*. Each component is important to the innovation process and all three components must exist in order for innovation to occur and thrive.

- *Idea Generation*. Innovation starts with an idea. New ideas are conceived and then developed, implemented, and diffused throughout an organization and the industry. The new ideas may be conceived by those working on a project or in a firm, or come from another firm or industry.
- *Opportunity*. Innovation also requires an opportunity or need to develop, implement, and test a new product, process, or system. Opportunities commonly arise in relation to problem solving on a project or in a firm. Project team efforts to solve unique problems expose and elicit innovative solutions. The opportunity to develop, implement, and evaluate the innovative solutions requires the freedom to do so as well as resources (time, funding, labor, equipment, etc.). It is facilitated by sponsors of innovation who eliminate roadblocks and provide support for continued development of the innovation.
- *Diffusion*. Many innovative solutions come about from the need to solve a problem on a project or within a firm. Innovation, however, occurs when that solution is used on subsequent projects or diffused throughout the industry. Lacking diffusion, the innovative process is simply problem solving. Diffusion to other projects and the industry confirms the value of the innovation and leads to positive change.

The research resulted in the development of guidelines and suggested practices for firms to follow to encourage innovation on projects. The guidelines are organized into five main steps: *People, Environment, Resources, Systems and Processes*, and *Monitoring and Management*.

Guidelines that pertain to *People* include methods of selecting, training, and organizing employees in such a way that the innovative capacity of the workforce is maximized. *Environment* consists of those techniques that organizations can utilize to create project settings where innovation may flourish, such as promoting communication amongst the project team, locating employees at a centralized site, and implementing R&D efforts. *Resources* addresses the monetary, time, and other resources that stimulate and support the innovation process and maintain an innovative climate. *Systems and Processes* includes those organizational and project management techniques, work processes, and contracting structures that positively influence innovation. Finally, *Monitoring and Management* contains suggested practices to assess and manage a firm, program, or crew, over time to benefit innovation, such as employee recognition and rewards, knowledge management programs, and a risk tolerant perspective. It is recommended that firms take these steps at the project and firm level to enhance innovation.

Recommendations

The barriers identified in the research study impact the extent to which innovation occurs. However, all of the identified barriers can be overcome. It is recommended that a firm and the construction industry make the following changes to overcome the barriers and enhance innovation in the industry:

- Implement contracting strategies and project delivery processes that promote collaboration, integrate the project team members, and encourage diversity amongst the project team.
- Provide and increase the amount of funding for research and development of new products, processes, and systems.
- Develop models to map the connection between an innovation and project outcomes such as profit, schedule, quality, safety, and sustainability. This will provide practitioners with a tool to understand the implications of the innovations.
- Encourage continued and advanced education and exploration of “the world outside construction”.
- Create organizational processes and structures that demonstrate the support of upper management for innovation at both the firm and project levels.
- Recognize employees for their innovative efforts and create environments to stimulate these efforts.
- Develop incentive programs to share the benefits derived from innovation with those who initiate and implement the innovations.
- Conduct thorough risk assessments of new ideas to understand the uncertainty and threats associated with change, and manage the identified risk to bring it to an acceptable level.
- Revise regulations, codes, and bidding procedures to encourage generation of new ideas, collaboration between project team members, and trying new methods.

As with most research studies of complex and far-reaching topics, conducting the studies leads to additional questions and the identification of further needed research. Further research is suggested on the following topics:

- Development of models to objectively assess the risk associated with implementing change in a firm and on a project.
- Development of a practical handbook for use by a project team that extends the utility of the *Innovation Manual of Practice* and maximizes a typical team’s potential to actually employ and benefit from innovative approaches.
- Development of a tool to assist design and construction firms to measure innovation.
- Development of models and programs which academic institutions can implement in the educational process to create and support an environment of inquiry and discovery.
- Development of a “Leadership in Innovation Rating System” to grade design and construction firms on their innovation capabilities and their success at innovation on projects.
- Identification of the characteristics of the innovation adopters in the construction industry.
- Further research and development of new technologies, systems, and processes that have been identified as promising innovations for the construction industry.
- Identification of new technologies, systems, and processes that have the potential to become innovations within the construction industry.
- Development of a structure and process that better links academic and research institutions with industry to guide and support the movement of new ideas from research to practice.

ADDITIONAL RESOURCES

Products for implementation and dissemination of the research findings were produced as part of the research study. The objective of the collection of products is to provide resources to the construction industry to learn about how to enhance innovation on projects and to assist the industry in their implementation. The products produced from the research are described below, and are available on the Pankow Reports webpage under Publications on the SPUR (San Francisco Planning & Urban Research Association) website at: www.spur.org/pankowreports/.

- *Annotated Bibliography.* An annotated bibliography was created that provides a list of published references on innovation, on innovation in the construction industry, and on other related topics. The bibliography contains references, with electronic links where available, to journal articles, trade publications, and websites. An abstract of the document is included if available. Also included with the bibliography is a list of five “significant” publications on innovation that are key to understanding innovation in the construction industry.
- *Innovation Manual of Practice.* An Innovation Manual of Practice was developed to assist practitioners with implementing the research findings. The manual contains several components. An implementation flowchart is provided that indicates steps to take to enhance and maintain innovation. The flowchart presents overarching guidelines to follow to generate innovative ideas, create opportunities for innovative change to occur, and foster diffusion of innovations throughout a firm and the construction industry. Suggested practices are given for each guideline to offer examples for practical implementation. Guidelines and suggested practices are provided that apply at both the

project and firm levels and, when applied, are intended to enhance innovation on construction projects.

- *Innovation Slide Presentation.* A slide presentation was created to present the research in an electronic format on-line. The presentation provides those interested in the research a means to quickly learn about the study and results, and provides a resource for communicating the study results to others for education and training purposes.
- *Final Report.* A final research report is available that provides a comprehensive description of the research study, findings, conclusions, and recommendations. The final report is designed to be read and used by academics and others interested in the specific methods used and data collected in the study.

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