Construction Industry Institute®

Enhancing Innovation in the EPC Industry

Research Summary 243-1

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Enhancing Innovation in the EPC Industry

Prepared by
Construction Industry Institute
Enhancing Innovation Research Team
with additional funding from the
Charles Pankow Foundation

Research Summary 243-1
December 2010

The University of Texas at Austin

Printed in the United States of America.

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Executive Summary

To stay competitive, engineering, procurement, and construction (EPC) organizations must approach innovation with a focus on internal investment and industry-wide adoption. To motivate the EPC industry to move robustly in this direction, industry leaders must challenge the tradition-bound elements of construction culture and manage the adoption of innovation. Fundamental to this shift is the need for an economic perspective that grasps innovation as offering more financial benefit than risk, when managed properly. Taking such a total innovation perspective is crucial to expanding innovation within the EPC industry and within the key areas addressed in this research.

Through a literature search, a structured interview process, and a survey of nearly 200 EPC professionals, this research—co-sponsored by the Charles Pankow Foundation (CPF)—provides empirical evidence that a significant gap exists between an effective approach to innovation and the industry's current approach (even that of the most progressive EPC-based firms). This gap includes the following elements of innovation management: mindset, resources, processes and structure, and changed project environments. Below are the research team's findings on these elements:

- **Mindset**: While EPC firms have a culture that generally affirms the importance of innovation, managers apparently enable innovation only on a project-by-project basis. They tend not to adopt the long-term, multiple-project, risk-tolerant perspective that enables innovation on an organization-wide basis.
- **Resources**: The majority of respondents indicated that their companies lack the resources necessary to identify, nurture, track, and apply innovations. These resources would include expense budgets as well as managing staff to ensure that sufficient time could be devoted to nurturing innovation.
- **Processes and Structure**: The innovation literature makes it clear that innovation will rarely happen when managers' leadership on innovation is passive. Rather, innovation requires active leader

commitment and formalized processes within the organization. This organizational structure should allow employees to methodically identify and evaluate potential innovations. Once identified and assessed, the organization's structured processes should promote to effective implementation of the innovations on appropriate projects.

- **Changed Project Environments**: Successful innovation requires real and sustained commitment from all project entities. Project delivery and contract methods that inhibit collaboration between entities during design and construction, and that prevent risk-taking, are not conducive to the creative integration needed for innovation.

In response to these findings, the research team developed two processes to help advance innovation within EPC organizations: 1) an innovation maturity model and 2) an economic model that demonstrates the value of innovation investment. The Innovation Maturity Model is an evaluation tool that measures the current state of an organization's innovation and provides recommendations for advancing innovation. The economic model developed by the team supports these recommendations by illustrating and communicating the long-term benefits of innovation investment. The challenge for EPC organizations is determining how and where to start on the path to innovation; this progress entails identifying the areas of the organization that need investment to encourage innovation.

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Introduction

Although the ability to innovate is recognized as a fundamental requirement for long-term business success in nearly all industries, the need for innovation has been overlooked and undervalued within the engineering, procurement, and construction (EPC) industry. The EPC industry is noticeably lagging behind other industries—e.g., aerospace and manufacturing—in terms of investment in, adoption of, and development of innovative practices and technologies. Given that the industry is changing significantly as it addresses the introduction of advanced technologies, the aging workforce, globalization, economic integration, and international partnering, its underperformance in the area of innovation is becoming a crisis. Although individual exceptions exist, research of the EPC industry has demonstrated that there are significant economic, organizational, and structural barriers to innovation within construction organizations of all sizes (Toole 1998, Toole 2001, Chinowsky 2001). This body of research suggests that it is critical to identifying how the EPC industry can accomplish the following innovation goals:

1. Develop greater emphasis on the economic and competitive benefits of innovation given the structural constraints of the industry.
2. Implement processes that drive innovation as a normal part of business functions.
3. Change the culture to view innovation as key to improving project delivery and to creating the long-term success of EPC organizations and the EPC industry.

In response to this need to enhance innovation within organizations and across the industry, the Construction Industry Institute (CII) established Research Team 243 to explore and document the current levels of innovation in the EPC industry, identify opportunities for enhanced levels of innovation, and develop best practices for becoming

more innovative. In collaboration with leaders from the Charles Pankow Foundation (CPF), the study's co-sponsor, CII formed the research team and charged it with developing a framework for analyzing, adopting, and fostering innovations. This effort is aimed at enhancing project operations, processes, and, ultimately, long-term competitiveness.

With these research goals in mind, the team developed its scope, process, and objectives. The team set out to review the relevant literature, conduct interviews and surveys to determine existing attitudes and management practices relating to innovation, and to identify ways to increase innovation in the EPC industry. The team also chose to analyze innovation management best practices in other industries to determine whether any can be applied to the EPC industry. The research was to answer the following research questions:

1. Is innovation perceived to lead to higher profit margins? If so, what metrics do contractors use, or can they use, to measure the direct and indirect benefits of innovation?
2. What are the key perceived drivers of innovation? Can and do managers apply microeconomic and financial concepts and tools to their decisions on innovation?
3. What are the key perceived barriers to innovation?
4. What organizational cultures, staffing, structure, and processes enable innovation?
5. What market segments/niches are most conducive to innovation?
6. Do perceptions vary between types of entities (i.e., owners, designers, general contractors, sub-contractors, and suppliers), market segments, and type of innovation (product or process)?
7. What economic scenarios make it imperative for an organization to aggressively adopt innovation as a core competitive principle?

This research summary discusses the team's research process and methodology, the data it collected, its findings, and its recommendations for individual organizations.

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Research Process and Methodology

The team collaborated on the research through face-to-face meetings, phone calls, and emails. After two face-to-face meetings on the CII research process, the scope and goals of the research project, and the creation of a preliminary research plan, the team conducted a literature review and developed the Innovation Maturity Model. The team's research process was comprised of the following steps, described below: literature review, Charles Pankow Foundation (CPF) research, interviews, online survey, development of an economic model, development of an innovation maturity model.

Literature review: The team reviewed the literature on innovation within the (EPC) industry and in other industries. The review included literature on innovation in both domestic and international firms. The team searched academic journal articles, practitioner journal and magazine articles, academic books, and popular press books. Copies and references from some of the literature were obtained through the courtesy of Professor John Gambatese and his graduate assistant, Matthew Hallowell, at Oregon State University (OSU). Both were completing a research project on construction innovation for the Charles Pankow Foundation. All of the literature was reviewed and summarized by RT 243. This step provided valuable background to current industry thinking on innovation.

Charles Pankow Foundation research: The OSU research on innovation sponsored by the Charles Pankow Foundation was studied closely by members of the RT 243 team to prevent any duplication of effort. One difference between the two teams' research lies in their respective definitions of innovation. The OSU-CPF researchers' defined 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." The RT 243 team adopted the following, slightly narrower, definition:

> **Innovation is the act of introducing a significant improvement in a process, product, or system that is novel to the organization, may cause individuals to view things differently, and results in competitive advantage, increased value for the client, or benefit to stockholders.**

One other difference in approach was that a significant portion of the CPF research involved case studies of specific innovations and/or organizations, while the RT 243 research effort involved surveying a large number of individuals and organizations.

Interviews: Drawing from the literature review, the team drafted a script for structured interviews. For the initial set of interviews, all team members interviewed one or two managers within their respective organizations; the team conducted approximately 15 of these initial interviews. After this initial round of interviews, the script was modified slightly, and the team conducted approximately ten additional interviews of managers at EPC and non-EPC firms thought to be innovative.

One key finding of the interviews proved to be the most critical methodological challenge for the research team: EPC firms do not measure or manage to the innovation-related metrics identified in the literature review. The team therefore reluctantly concluded that it would be impossible to empirically demonstrate the relationship between innovation investment and business success. Moreover, it was clear that it would not be possible to identify innovation best practices with any objective metrics on the innovation-related activities of innovative firms. Given this absence of objective innovation metrics, the team chose to identify innovative firms by asking survey participants whether they considered their respective organizations innovative relative to the rest of the EPC industry.

Online Survey: Once the literature review and interviews and were completed, the team developed and distributed an online survey to a number of CII members and non-members. The survey consisted of five closed-ended demographic questions, eight closed-ended innovation-related questions, and 34 Likert-scale questions associated with eight innovation topic questions. (For example, there were 11 Likert-scale questions associated with innovation culture.) The team first analyzed the survey data using Microsoft Excel to develop some descriptive statistics and then used Minitab for the remaining descriptive statistics and all inferential statistics.

Economic Model: The team developed an economic model to illustrate the benefits of investing in innovation and adopting a broader risk perspective. Utilizing economic theory that was originally applied to such diverse market sectors as agriculture and manufacturing, the team established a risk analysis perspective that validates the benefit of innovation investment when viewed over iterative generations of innovation investment.

Innovation Maturity Model: Finally, RT 243 developed the Innovation Maturity Model. By correlating organizational attributes and economic metrics, this tool evaluates an organization's current innovation status and generates a set of recommendations for improving its innovation status. The model is currently being tested in several CII member organizations to validate its structure and recommendations.

3

Background

As a starting point for its innovation research, RT 243 reviewed the current literature regarding innovation. As noted above, this review included literature focused on innovation in the EPC industry as well on innovation in all industries. A bibliography of the most useful items found in the review is provided in Appendix B. Ultimately, many of these items were summarized and shared with the team through a spreadsheet of "literature gems." Some key themes emerged from the literature review, themes that guided the preparation of the team's survey and the Innovation Maturity Model. The brief summary below of these key themes is organized by the research questions the team set out to answer.

1. **Is innovation perceived to lead to higher profit margins? If so, what metrics do contractors use, or can they use, to measure the direct and indirect benefits of innovation?**

   The team did not identify any studies or articles that addressed these questions for the EPC industry, but did find many articles on the perceptions of economists, policy makers, and researchers that innovation is critical for business success in all industries.

   - Innovation-related metrics and statistics are limited and can be misleading because they focus on Research & Development expenditures and patents, which are only a small subset of innovation activities (Seaden and Manseau 2001).
   - The construction industry's low investment in innovation has contributed to the EPC's very low growth in productivity since 1964 (25 percent compared to 250 percent for other industries). Given that productivity directly affects the bottom line, this statistic implies that EPC leaders should invest more in innovation to improve their firms' financial success (LePatner 2007).

2. **What are the key perceived drivers of innovation? Can and do managers apply microeconomic and financial concepts and tools to innovation decisions?**

   - Adoption of innovative products and processes can directly improve the achievement of product and firm goals because they can decrease project cost and duration and increase the performance of the final structure or system (Toole 1998).
   - Innovation should be evaluated on the basis of the overall value that results, a value that transcends product and service metrics (Dikmen et al. 2005).
   - Innovation can contribute to a competitive advantage through improved firm reputation, easier work processes, and an improved ability to attract new employees (Slaughter 1998).

3. **What are the key perceived barriers to innovation?**

   Several authors describe barriers to innovation that are particularly applicable in the EPC industry. These barriers include the following:

   - Many organizations focus on optimizing the current value system rather than pursuing more radical, systemic improvements (Hamel 2006).
   - Lack of innovation is not due to individual employees lacking innovative ideas, but instead are attibutable to a lack of mechanisms for implementing these ideas (Sawhney and Wolcott 2004).
   - The lack of economies of scale and the thin financial cushioning of EPC organizations hinder innovation; these built-in barriers to innovation are only strengthened by the process interdependency of the many separate firms working on construction projects, each trying to maximize its own profits (LePatner 2007).

4. What organizational cultures, staffing, structure and processes enable innovation?

The majority of the literature reviewed by the research team focuses on the organizational characteristics that facilitate innovation. The key innovation-facilitating characteristics are described below.

Culture

- All employees must constantly question the status quo (Sawhney and Wolcott 2004). The entire organization must be committed to and involved in innovation activities (Daniel 2007).
- All employees must recognize that innovation is not limited to R&D, but can encompass or be manifested in all aspects of an organization's activities (Chesborough 2003).

Leadership

- Top management must be visibly committed to innovation and there must be at least one champion in every firm (Oden 1997, Bossink 2004, Boston Consulting Group 2007).
- Strategic clarity and consistency are important for sustained innovation (Rosenbloom and Cusumano 1987, Oden 1997, Delphi Group 2006).
- Managers must take a long-term, holistic view of the innovation process (Oden 1997, Sawhney and Wolcott 2004).
- Managers must recognize that radical innovations can result from a series of incremental innovations (Rosenbloom and Cusumano 1987, Sawhney and Wolcott 2004).

Learning

- Organizational learning and knowledge management are critical for sustained innovation (Rosenbloom and Cusumano 1987, Oden 1997, Delphi Group 2006, Boston Consulting Group 2007).

Collaboration

- Linkages within and between organizations must be created to enable the collaboration and trust that are critical for innovation (Oden 1997, Sawhney and Wolcott 2004, Hamel 2006, Kanter 2006, Boston Consulting Group 2007).
- Ideas must be brought into the firm from outside the firm, including from researchers and consultants (Bossink 2004). A not-invented-here syndrome should not be tolerated (Chesborough 2003, *Economist* 2007).

Customers

- The organization must focus on customer needs and should have close ties with customers (Rosenbloom and Cusumano 1987, Seaden and Manseau 2001, Oden 1997).

Risk Perspective

- Mistakes must be tolerated and learned from and should not lead to punishment. (Sawhney and Wolcott 2004, Kanter 2006, Boston Consulting Group 2007, *Economist* 2007).

Resources

- Resources (i.e., time, money, and people) must be formally invested into innovation activities (Boston Consulting Group 2007, Daniel 2007).

Processes

- Innovation-related processes must be established (Oden 1997, Delphi Group 2006, Daniel 2007), including those needed to reduce uncertainty about innovations (Toole 1998).

4

Data Analysis

Basing its survey on the literature review, the team gathered data on innovation-related attitudes and practices within the EPC industry. Surveys were completed by 83 EPC companies (in addition to the 46 Board of Advisors surveys) and by 11 non-EPC companies through Surveymonkey.com. Seventy-one percent of the respondents were contractors, giving the survey findings a slight bias toward contractor opinions. One-third of the sample worked on both public and private projects, and more than twice as many of the remaining firms worked primarily on private projects. One-half of the respondents were most familiar with the building sector of the construction market, and approximately one-third of the sample was most familiar with heavy industrial construction. Nearly 50 percent of the respondents considered themselves construction managers, and nearly 30 percent considered themselves project managers. Nearly 50 percent of the respondents had worked for over 20 years in capital project delivery, while approximately 30 percent had worked in this area for fewer than 10 years. None of the demographic characteristics were significantly correlated with whether the respondent indicated that his or her organization was innovative. For example, a statistical *T*-test indicated that owner organizations were no more or less likely to identify their organization as innovative as were contractor organizations.

The tables below highlight the descriptive statistics for key questions in the study. For each question, a comparison is provided between the answers from individuals who considered their firms innovative and the answers from individuals who considered their firms non-innovative. The team used this comparison to determine what self-identified innovative firms do differently from those that self-identify as non-innovative.

The difference between the averages of the two groups is considered statistically significant if there is only a five percent chance that the differences are due to chance alone. Two sample *T*-test were used to analyze statistical significance.

Innovation Perception

The first three survey questions deal with perceptions of innovation in the EPC industry, of individual organizations, and respondents' satisfaction with the level of innovation in their firms. In response to the first question, only 26 percent of the respondents considered the EPC industry mostly or highly innovative. Significantly more respondents (52 percent) rated the industry as mostly or highly non-innovative. Building on this perception, the majority (52 percent) of the respondents reported that their respective firms were mostly or highly innovative compared to the rest of the EPC industry. This trend towards a feeling that the industry is lacking innovation is reflected in the feeling of most respondents (61 percent) that they are less than satisfied with the level of innovation in their respective firms.

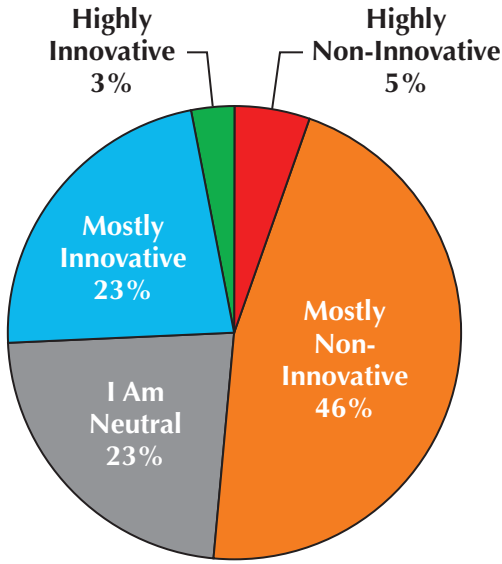

Figure 1. Perception of how innovative the EPC industry currently is

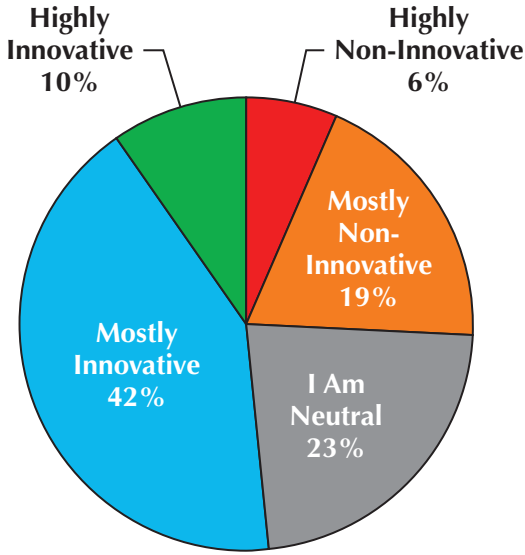

Figure 2. Perception of how innovative the respondent's organization is in comparison to the EPC industry

Innovation Actions

The survey's second area of interest concerned where innovation currently occurs in the participants' own organizations and where they believed innovation should occur. The majority of respondents (71 percent) indicated that innovation occurs mostly on individual projects. Only 10 percent indicated that innovation occurs through organizational practices. However, respondents that viewed their firms as innovative were more apt to report innovation occurring through departmental or organizational practices, rather than on individual projects.

Figure 3. Where innovation is most needed in the organization

In terms of the latter question, the majority of respondents (60 percent) indicated that innovation needs to occur on an organization-wide basis. An additional one-quarter of the respondents indicated that innovation is needed most at the departmental level. Respondents from innovative firms were more likely to report that innovation occurs at the departmental or corporate level than were respondents who reported that their firms were non-innovative.

Innovation Processes

The research team found that the implementation of processes that encourage and foster innovation was fundamental to an organization's ability to innovate. As illustrated in Table 1, a large majority of respondents (86 percent) indicated that their respective firms' project-level innovation decision-making processes were *ad hoc* or that they vary widely. Only 14 percent of respondents considered their respective firms' project innovation decision-making processes methodical or rigorous. Table 2 presents similar findings on how innovation decisions are made at the corporate level.

Table 1. Respondents' perception of project-level decision-making processes for innovation

Question: Which statement below best describes your organization's process for making decisions relating to innovation on individual projects?	
Answer	**% answered**
My firm does not make decisions relating to innovation.	5%
My firm has an *ad hoc* process for making innovation decisions.	40%
My firm has processes for making innovation decisions, but they vary widely with the innovation and the project.	41%
My firm has a methodical decision process for making innovation decisions but it does not involve analyzing numbers.	7%
My firm has a rigorous, quantitative process for making innovation decisions, such as rate of return, payback period, net present worth, etc.	7%

Table 2: Respondents' perception of corporate-level decision-making processes for innovation

Question: Which statement best describes your organization's process for making decisions relating to innovation on the corporate level?	
Answer	**% answered**
My firm does not make decisions relating to innovation.	7%
My firm has an ad hoc process for making innovation decisions.	29%
My firm has processes for making innovation decisions, but they vary widely with the innovation and the project.	36%
My firm has a methodical decision process for making innovation decisions but it does not involve analyzing numbers.	11%
My firm has a rigorous, quantitative process for making innovation decisions, such as rate of return, payback period, net present worth, etc.	17%

Innovation Funding

The next topic on the survey was how innovation was funded on specific projects. This question was formulated in response to the literature findings that corporate commitment is an essential element of successful innovation. As illustrated in Figure 6, the majority of innovations proposed on projects (60 percent) are funded from the original project budget. Less than 16 percent of project innovations are funded by corporate sources. Surprisingly, the firms that participants rated as innovative were more likely to have project innovations funded by existing project budgets than were the firms rated as non-innovative by the respondents.

Innovation Drivers

Research on innovation would not be complete without an analysis of the drivers and barriers that affect innovation implementation. As illustrated in Tables 3 and 4, both the drivers and barriers have clear leaders in terms of factors that influence decisions. In terms of drivers, over 50 percent of respondents cited the following four reasons as the main drivers of innovation within their respective organizations:

- Reduce engineering and/or construction cost.
- Increase our profit margins.
- Serve our clients better.
- Reduce engineering and/or construction duration.

In addition, just under 50 percent reported individual ingenuity and or passion as a key driver of innovation within their respective organizations. The responses of the participants who had rated their own firms as innovative did not differ substantially from those of the participants who had rated their own firms as non-innovative.

In terms of barriers, over 50 percent of respondents considered the following three conditions as the biggest hindrances to innovation:

- Schedules and budgets are too tight to take a chance on something new.
- There is a lack of resources (including staff time).
- Owner clients do not recognize the value.

The first two reasons support the findings from the respondents' answers to questions 13 and 14 that most EPC organizations lack the resources to innovate. The responses of the participants who considered their own firms innovative did not differ substantially from those of the participants who considered their own firms non-innovative.

Table 3. What do you think drives innovation in your capital projects organization?

Reason	% checked
Reduce engineering and/or construction cost	72%
Increase our profit margins	63%
Serve our clients better	57%
Reduce engineering and/or construction duration	52%
Individual ingenuity and or passion	49%
Achieve higher performance of the constructed facility	43%
Improve construction safety	29%
Limited resources require innovation	24%
Owners demand innovation	23%
Be more environmentally sustainable	20%
Global competition	16%
Subcontractors propose innovations	14%
Vendors propose innovation	12%
Improve the supply chain	9%
Other (please explain)	3%

Table 4. What are the key perceived barriers to innovation within the capital projects portion of your organization? Please check the factors associated with significant barriers to innovation either on the project level or on the corporate level.

Reason	% checked
Schedules and budgets are too tight to take a chance on something new	70%
Lack of resources (including staff time)	61%
Owner clients do not recognize the value	53%
Lack of a firm strategy for innovating	41%
Requiring project innovation costs to be born solely by the project	39%
Lack of organizational structure to nurture and follow through	35%
Potential reward is outweighed by the risk	33%
Overly restrictive project specifications	29%
Lack of communication between project participants	29%
Too many players in the process	29%
Lack of trust between project participants	22%
Rigid top-down command and control hierarchy	12%

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Enablers of Innovation

The team analyzed the results of the literature review and the data from the survey questions above to determine the main enablers of innovation. This analysis provided the following findings, categorized in key areas:

1. **Innovation is a foundation of the organization culture.** An organization cannot be innovative without having a culture of innovation. Specifically, this means that the value of innovation must be acknowledged throughout the organization. Additionally, cultural norms must be in place in the organization that encourage and facilitate innovation.
2. **Budget allocations must be made in support of innovation.** Innovation requires organizational support. Integral to this support is the regular dedication of budget resources to innovation pursuits; such budget allocations should be more than simply added contingency on individual projects.
3. **Staff allocations must be made in support of innovation.** Along with budget allocations, appropriate allocations of staff are crucial to innovation. Specifically, organizations should make a priority of tasking individuals with identifying opportunities for innovation on their projects.
4. **Processes should be put in place to support innovation.** A key element of innovation success element is the presence of repeatable processes that are understood by each individual. This element was found to be a key difference between firms that the survey participants ranked as high in innovation and those that the participants ranked as low. Without such ready-to-deploy processes, employees will be too busy achieving traditional project and departmental goals to pursue innovation.
5. **A new risk perspective should be adopted.** The findings suggest that, to successfully innovate, it is critical for EPC organizations to change their risk perspectives. Specifically,

it is crucial for companies to understand that successful innovation implementation involves an additional level of risk. Understanding and managing this risk requires a change in perspective from risk aversion to risk management. Some industries, such as insurance and gaming, profit from managing risk by syndicating risk across many companies or operations. EPC firms, in contrast, tend to focus risk on a single project or a single business unit in an attempt to isolate the entire firm from risk. The net effect of each firm trying to isolate itself is to hinder the mitigation of risk across the entire system. EPC firms might also reconsider the effect on risk of multiple iterations of innovation implementations, especially if each implementation benefits from learning from the mistakes of previous iterations. As documented in the economic analysis below, innovation risk can be managed when the focus is changed from individual projects to multiple projects. This change of perspective is the first step to increasing innovation within the organization.

6

The Innovation Maturity Model

At the end of the data collection phase, the team determined that achieving greater innovation is a significant challenge for many EPC firms. Many firms do not understand the organizational commitment required to successfully implement an innovation process. As the discussion above makes clear, issues such as establishing formal mechanisms for allocating resources to innovation-related activities and changing an organization's risk perspective repeatedly emerged as central themes in this research. In response to this finding, the research team identified two elements as necessary for advancing innovation in EPC organizations: 1) an innovation maturity model and 2) an economic model demonstrating the value of innovation investment. The section below discusses the Innovation Maturity Model (Model) and its capacity to evaluate a company's innovation status and provide recommendations for enhancing innovation within the firm.

The Elements of the Innovation Maturity Model

The Innovation Maturity Model—a tool to help EPC organizations determine their status as innovators—was based on the team's research questions, literature review, interviews, and survey findings. The questions in the model are grouped into eight categories:

- culture
- resources
- risk perspective
- customer focus
- learning
- collaboration
- leadership
- processes.

Each category contains a maximum of ten questions, all emphasizing the category's relationship to innovation. Respondents answer questions according to the five-point Likert scale introduced in the original survey.

The team determined that a weighting was required for the model's questions, since it was apparent that not all of the question topics have equal impact on the innovation process. Some are considered critical to the innovation process, while others are additive in nature and serve to finalize the process. Therefore an important step in developing the model was the establishment of a weighting scheme for it.

Based on their experience at implementing innovation within their own organizations and on their participating in the research effort, the research team members each served as an expert in the weighting process. Each member was given the entire set of model questions and asked to rate the questions in each category on a scale of one to five in terms of their importance to the innovation process. After the first round, the scores were averaged, and the team members were again asked individually to rate the questions—this time with the added benefit of seeing the group average for each question. The revised answers were once again averaged and analyzed to find the ones with the greatest discrepancy in values. The group then discussed these questions to determine whether the question needed clarification or if there were perhaps another reason for the discrepancy. At the conclusion of this process, each of the 60 questions was successfully weighted and finalized in the model.

The Model Recommendations

Once the question-weighting process was complete, the research team focused on the model's second critical component—how to provide recommendations to an organization to improve their innovation. The team developed an individual recommendation for each question in the model; each recommendation was based on the literature review and on the survey results. An example of such a recommendation is as follows:

As illustrated in this example from the culture category, each recommendation provides a succinct discussion of the innovation factor associated with the question and a possible path to enhance the score for that factor. Because the team determined that each organization's particular circumstances are so variable, the recommendations do not

Question: Our organization expects individuals to share ideas through formal forums.	**Recommendation**
	Continuous learning is essential for highly innovative organizations. One of the best ways to really learn about a subject is to prepare to explain or teach it. Companies can stimulate their employees' participation in learning activities by engaging as many employees as possible in defining and optimizing processes and sub-processes. Using the annual performance review to track new techniques and processes learned by employees, and encouraging employees to prepare and deliver presentations on new ideas and approaches in non-threatening environments can both be highly effective. Firms may also want to establish a process improvement suggestion program and track the number of suggestions generated by various employee groups.

dictate a specific set of tasks to be performed. A specific set of tasks can be developed for each recommendation, based on discussions within the organization.

Implementation of the Model

The research team recommends that, to properly evaluate its innovation capability, an organization should begin the process by arranging for at least 20 employees across functional areas and at varying organizational levels to complete the model. Alternatively, each employee could be asked to complete the model evaluation, using a spreadsheet containing the 60 questions. The answers should then be averaged and entered into a model summary spreadsheet. This summary spreadsheet includes the weightings developed for each question. Based on the employee's response and the weighting, a score is calculated for each question. The weighted scores for each question are then summed to provide a total

score for each of the eight categories. This process gives organizations an indication of their innovation maturity in each innovation category. The spreadsheet allows the user to plot the results onto a spider diagram, providing a visual illustration of the organization's maturity in each category on a 0-to-100-percent scale—with the achievement of a 100-percent rating as the goal in each category. (See Figure 4.)

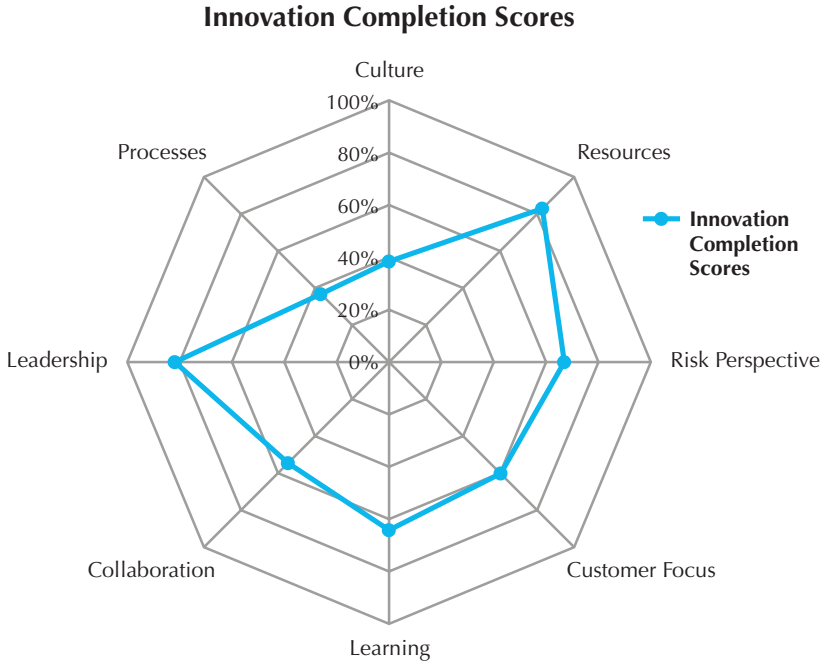

Figure 4. Spider diagram illustrating innovation completion scores for the eight innovation categories

The numerical scores and spider diagram give an organization an indication of the innovation-related areas in which they need improvement (i.e., score lower than 30). In this manner, the model and its associated recommendations provide a benchmark from which to move forward. The expectation is that each organization will review its summary model scores and determine the appropriate set of recommendations, based on its individual needs and circumstances.

7

The Economic Argument

Even though managers in some organizations might recognize the value of the Innovation Maturity Model, their perception of the risks involved in pursuing its recommendations may make them hesitate. To address this obstacle to using the tool, the research team developed an economic model to communicate why and how managers should change their perspective on innovation investment and return.

One important result of the literature review was the finding that risk is a key factor in the decision to innovate. Moreover, there is a wealth of literature on the economics of decision-making under risk and uncertainty (Charnes et al. 1964; French 1986, Pratt et al. 1995). The research shows that decisions are made to a large extent on the basis of how risk averse an individual or firm is. A decision maker with a high level of risk aversion has been shown to be greatly influenced by whether he or she is facing a single uncertain event (such as the turn of a roulette wheel) and the potential severity of a negative outcome—even if the likelihood of such an outcome is remote. The key to enhancing innovation in the EPC industry is to provide the decision maker (i.e., the project manager) with a reasonable level of confidence that investment in innovation will not lead to unreasonable risk. To provide this assurance, the team developed a series of economic models based on decision analytic theory (Faber and Stewart 2003; Kolstad 2004; USACE 2008); these models demonstrate how economic theory applies to the EPC industry and how it can benefit from the lessons learned from previous innovation efforts in other industries.

Current Perspective

From the project manager's perspective, the current structure of construction project implementation does not support innovation investment. The traditional view is that the probability of a negative result outweighs the potential for positive gain for an individual project manager:

the worst case, although unlikely, is catastrophic; innovation is challenging because it requires learning and multiple iterations; and the project bears all of the risk and cost, while others stand to capture the gains.

The Economic Model

By applying economic theory to the current industry perspective on innovation, the research team modeled the risk behavior of project managers, business units, and firms (Zhu et al. 1994; Faber and Stewart 2003; Kolstad, 2004; USACE, 2008). Table 5 presents the risk behavior assumed for each group.

Table 5. Risk behavior assumed for each group

Attribute	Project Manager	Business Unit	Firm
Goal	Maximize predictability	Maximize profitability	Maximize long-term performance
Risk aversion	Single project	Multiple projects	Multiple projects
Model objective	Minimize risk of project delay	Maximize expected profits for single year	Maximize expected profits for multiple years
Model technique	Chance constraints	Stochastic programming	Stochastic programming

In each of these three models, the decision maker is faced with certain probabilities of achieving objectives and a certain range of possible outcomes. (See Figure 5.) A project can start with a known probability of achieving an objective (represented by the height of the curve on the y axis) and a known range of potential project outcomes (represented by the width of the curve along the x axis). The ideal situation for all project managers is to have a very high probability of meeting their objectives with very little variance in potential outcomes (represented by

a tall, narrow curve). Figure 5 illustrates that, before the implementation of an innovation, a notional project has a known probability of meeting a cost objective with some variability in potential outcomes. The figure further shows that in the first year of implementation, the innovation can lower a project's average cost; at the same time, it shows that—because of the uncertainties and potential problems that come with any new technology—the risk of large cost overruns are likely to increase in that first year. This early risk potential is usually the wall that blocks organizations from investing in innovation.

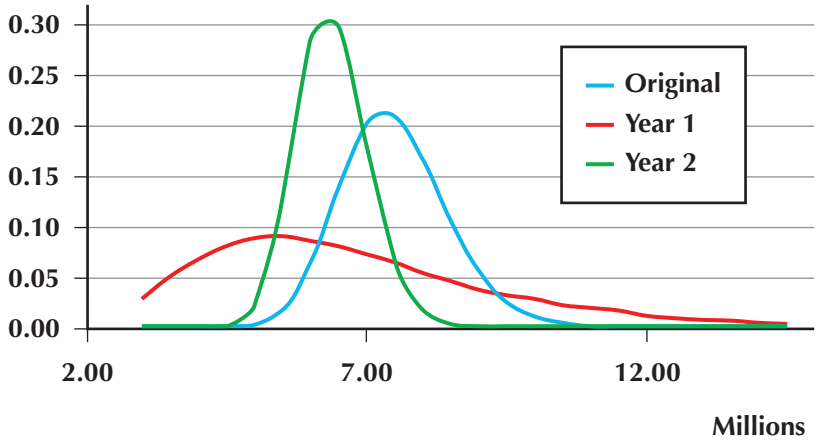

Figure 5. An economic model of innovation investment and benefit over multiple generations

However, the figure further suggests that, once the initial learning period is past and the innovation is used in a second iteration, the variability of the cost is greatly reduced and the risk of large cost overruns actually falls below pre-innovation levels. This combination of greater predictability and lower expected cost is the desired outcome, but it takes several generations of implementing innovations on projects to achieve.

The models suggest that project managers—caught up in the current industry practice of considering innovation one project at a time—have no economic incentive to innovate, since their risk of failure will

actually go up if they adopt an innovation. (For more on the economics of project-based decision-making, see Kolstad 2004 and Kirkwood 2002.) Indeed, for these project managers, implementing an innovation on a single project is the equivalent of one spin of the roulette wheel. Were they able to, however, these same project managers would adopt the innovation in the second generation, when the benefit would be apparent. In contrast, because business unit leaders think in terms of the many projects their groups plan to construct, it might be economical for them to invest in innovation if they can innovate over a large number of projects. Entire firms see the many projects that all of their business units will construct, and can look ahead to the future. Their inherently long-term perspective should motivate firm leaders to continually innovate; because the benefit should be realized over the many projects on the company horizon, they can distribute short-term losses to harvest long-term gains. Moreover, in the team environment that is generated from this wider view of innovation, project managers are not left to function as individual gamblers. Rather, at the outset of an innovation implementation, the entire firm—functioning as an innovative team—absorbs the increased investment, risk, and uncertainty in exchange for greater benefits over the longer term.

Changing the Perspective

For an organization to successfully move from a focus on project-oriented risk to an emphasis on long-term risk distribution, management and individual project managers alike must commit to the shift. To make such a change in perspective on innovation, the following key elements are required:

- **Shift away from single-event thinking.** As discussed above, moving away from a single-project focus toward a project portfolio approach is the foundation of the economic model.
- **Indemnify project managers by creating a syndicate.** The fundamental difficulty with investment in innovation is project managers' concern that the risk of failure is worse that any potential reward an innovation might bring. To change this

perspective, the organization should focus on establishing a collaborative environment in which project managers understand that single instances of underperformance will not result in commensurate penalties. This type of syndicate perspective will favor company success over individual achievement.

- **Experiment frequently and learn continuously.** A key to innovation is experimentation and learning. Therefore, organizations must establish a culture in which learning and knowledge-sharing among project managers is valued. By cultivating an atmosphere that encourages curiosity, experimentation, and learning, organizations can slowly alter their risk perspective and enhance their opportunities for successful investments in innovation.
- **Work for owners who value innovation.** Owners or other employers who demand compliance to unilaterally defined requirements seriously inhibit innovation within their organizations. Progressive owners and contractors could collaboratively spread risk for the benefit of the entire system, rather than try to isolate themselves from risk through contractual language. Owners could also demand innovation on projects—much in the way they have demanded safety—and then support those demands by establishing an innovation-friendly culture, just as they have done to create injury-free workplaces.

Although these elements are not the only ones that will contribute to a change in the industry's risk perspective, they are the building blocks on which construction organizations can increase their risk tolerance and reap greater benefits from innovation.

8

Conclusions

The results of this study show that the EPC industry has a significant opportunity to improve its innovation performance, in spite of its lack of dedicated resources, implementation processes, and innovation-oriented risk management. Because the EPC industry as a whole has underinvested in innovation, the conventional wisdom is that firms do not value innovation or cannot overcome the industry-wide barriers to innovation that are beyond their control. These barriers include the dominance of low-bid contracting, the disjointedness of the value system, and the customers' exclusive near-term focus on time and money.

RT 243 found that most EPC firms do in fact value innovation, but that to implement and benefit from innovation, they must make a fundamental shift away from the industry's limited thinking on innovation and risk. Establishing this broader perspective requires firms to manage short-term increases in risk on individual projects, while focusing on the long-terms gains innovation will bring to their project portfolios. It is up to the leaders of EPC organizations to commit to making this change in perspective and to setting a new tone for risk management. Moreover, given the highly interdependent nature of EPC projects, these leaders must also establish the collaborative linkages that successful innovation often requires—both within their own organizations and with other project organizations.

In summary, industry leaders must make a shift in perspective, commit to establishing repeatable processes, and dedicate resources to innovation. The Innovation Maturity Model introduced in this research summary provides a first step toward evaluating an organization's current innovation status and offers recommendations for increased innovation. Although innovation levels in the EPC industry may currently be low overall, there is nothing fundamentally preventing the industry from improving its status. The RT 243 research presents the industry with an opportunity to make this improvement by establishing a new perspective on the role and potential benefits of innovation.

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