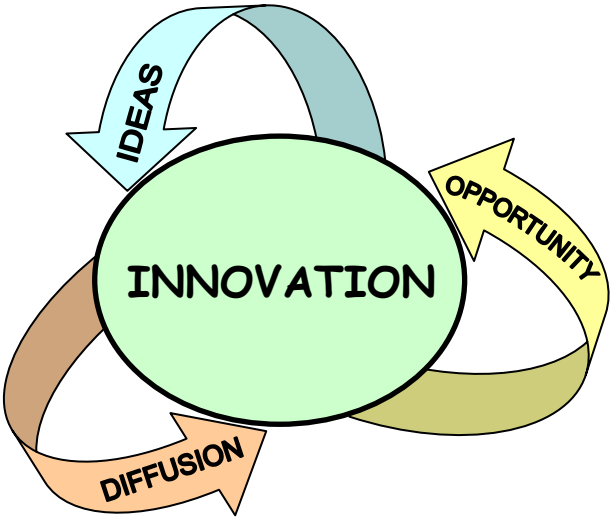
ENERGIZING INNOVATION IN INTEGRATED PROJECT DELIVERY

ANNOTATED BIBLIOGRAPHY



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OSU Oregon State University

DBIA DESIGN-BUILD INSTITUTE OF AMERICA

The Charles Pankow Foundation

ENERGIZING INNOVATION IN INTEGRATED PROJECT DELIVERY

ANNOTATED BIBLIOGRAPHY

By: **John A. Gambatese and Matthew Hallowell**
School of Civil and Construction Engineering
Oregon State University

For: **Charles Pankow Foundation (CPF) and**
Design-Build Institute of America (DBIA)

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Input regarding the content contained in this bibliography is welcomed and encouraged to increase its value and benefit to the construction industry. Comments about the bibliography and suggestions for improvements and additional entries should be directed to Dr. John Gambatese at Oregon State University (john.gambatese@oregonstate.edu).

INTRODUCTION

This document is a bibliography of literature on innovation in the construction industry. The bibliography is a product of a research study titled "Energizing Innovation in Integrated Project Delivery" that was conducted from 2006-07 by Oregon State University and funded by a partnership between the Design-Build Institute of America and the Charles Pankow Foundation. The intent of the bibliography, which contains approximately 80 references to websites and publications, is to provide practitioners in the construction industry with a consolidated resource for studying, exploring, and learning about innovation in the construction industry.

The bibliography was created through an extensive literature search. Keyword searches of article databases, including Compendex, Applied Science and Technology Abstracts (ASTA), National Technical Information Service (NTIS), and TRIS Online, and the World Wide Web (using Google as a search engine) were conducted. The searches were aimed at locating research articles, reports, industry standards, books, and other published documents that address issues related to innovation. Besides the broad topics of innovation and innovation in the construction industry, no criteria were used to regulate or limit the publications included in the bibliography.

Discussion and examination of innovation in the context of the construction industry is on-going and documents on innovation continue to be published. It is likely as well that published materials exist which were not found as part of the literature search conducted to create this bibliography. Therefore, while significant attempts were made to create a comprehensive list of relevant literature, additional references are likely to exist. Other articles, reports, books, and documents may be available. Readers are encouraged to conduct an updated search to locate additional published materials.

CONTENT AND ORGANIZATION

The bibliography is organized into two major sections: websites and publications. Addresses are provided to websites that contain information about innovation in construction and other industries. A list of publications is also provided which contains references to journal articles, trade publications, reports, books, and other publications on innovation.

The list of publications is organized according to various topics and significance. A list of five key publications on innovation is initially provided which are important to understanding innovation in the construction industry and significant contributions to the literature. Readers are encouraged to start with these publications to gain a broad understanding of innovation as it relates to the construction industry. The remaining list of publications is organized into the following topic categories:

- Management and Organizational Issues
- Case Studies
- International Issues
- Metrics
- Diffusion

- Information Technology in Construction
- Issues in Residential and Small-Scale Construction
- Innovation Organizations
- Modeling
- Other Innovation Topics

Brief descriptions and abstracts of the publications are provided when available to assist the reader in searching the literature. Electronic links to the documents and websites are provided if the documents are available on-line. Each of the references can be accessed by clicking on the link. Some links go directly to an electronic ".pdf" file of the document. Other links go to a website that contains further information on the publication and, in many cases, offers guidance for purchasing the document.

BIBLIOGRAPHY USE AND VALUE

The bibliography is intended for use by owners, architects, engineers, constructors, researchers, academics, and other entities who participate in and research the planning, design, construction, operation, and maintenance of constructed facilities. The information provided in the references is applicable to all types of construction projects and organizations. Practitioners can use this document to find literature about innovation that is applicable to their interests and perspective. If a practitioner has minimal or limited knowledge of innovation in the construction industry, it is recommended that he/she begin by reading the five key publications on innovation. To gain a greater and more focused understanding of innovation, the remaining list of publications should be reviewed.

Applying the practices suggested in the literature will initiate and stimulate innovation. Users will find that the practices 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.

INNOVATION WEBSITES

http://www.iti.northwestern.edu/knowledge/bibs/innovation.html. *Infrastructure Innovation Bibliography*, Infrastructure Technology Institute, Northwestern University.

> This site contains references, abstracts and links for books, articles, reports, website, etc. that specifically discuss innovation in the construction industry.

http://netvis.fuqua.duke.edu/iande/index.php?p=references. Innovation and Entrepreneurship, Innovation References (Academic Bibliography), Cummings, J., Duke University.

> This site provides a list of general references for innovation in any work industry.

INNOVATION PUBLICATIONS

Key Publications

Bossink, B.A.G. (2004). "Managing Drivers of Innovation in Construction Networks." *Journal of Construction Engineering and Management,* ASCE, 130(3): 337-345.

> **Abstract:** Various drivers of construction innovation are distinguished and classified in four distinctive categories: environmental pressure, technological capability, knowledge exchange, and boundary spanning. Innovation drivers in these categories are active at the transfirm, intrafirm, and interfirm level in the network of organizations in the construction industry. Empirical research in the Dutch construction industry illustrates that the innovation drivers are used by managers of the authorities, clients, architects, consultants, and contractors to stimulate and facilitate innovation processes. It also exemplifies that driving innovation on the transfirm, intrafirm, and interfirm level in the network of organizations is an opportunity for managers of both public and private organizations to develop, improve, and renew their organizations' positions in the market, the quality of their organizations' projects, and the cooperative structure of the industry as a whole.

Egbu, Charles O. (2001). "Managing Innovation in Construction Organisations: An Examination of Critical Success Factors" Perspectives *on Innovation in Architecture, Engineering and Construction*. C.J. Anumba, C. Egbu, and A. Thorpe, Editors, Centre for Innovative Construction Engineering, Loughborough University, Loughborough, Leicestershire, U.K.

> **Abstract:** Innovation is viewed as a major source of competitive advantage and is perceived to be a pre-requisite for organizational success and survival. The ability to innovate depends largely on the way in which an organisation uses and exploits the resources available to it. The paper explores the importance of knowledge management (KM) and intellectual capital (IC) in organisations. It also considers the critical factors that lead to successful innovations and the role of KM and IC in this regard. The paper argues that effective management of knowledge assets involves a holistic approach to a

host of factors. It is also suggested that there are a host of factors that combine in different ways to produce successful organizational innovations. It recommends that more is needed on the education and training of construction personnel and that these education and training programmes should reflect the nature of innovation and KM dimensions as very complex social processes.

Halim, A. and Haas, R. (2004). "Process and Case Illustration of Construction Innovation." *Journal of Construction Engineering and Management*, ASCE, 130(4): 570-575.

Abstract: This paper describes the major stages and component steps leading to the realization of the technical and commercial potential of a new construction technology. It encompasses a process of innovation and invention, which is generically applicable to any construction innovation. A case illustration of a new asphalt compaction technology is also described within each stage to provide a "real life" example. Motivation for the new technology came from the fact that existing, conventional rollers can cause serious damage to the compacted asphalt mat at the time of construction. This damage is in the form of construction cracks, often termed "roller checking," which can result in accelerated, in-service deterioration. The new technology originally termed the "Asphalt Multi Integrated Roller" (AMIR), overcomes the problems of current rollers through stiffness compatibility with the asphalt mix and a different geometry than conventional rollers. Commercial realization of the technology has been achieved through a new generation of AMIR, termed "HIPAC." The paper also provides background on the issues of concern to pavement engineers, including limitations of current compaction methods. It explains in functional terms the unique difference provided by the new technology. As well, it describes the major hurdles that were overcome to achieve commercial realization.

Park, M., Nepal, M., and Dulaimi, M. (2004). "Dynamic Modeling for Construction Innovation" *Journal of Construction Engineering and Management*, ASCE, 20(4): 170-177.

Abstract: Previous research on construction innovation has commonly recognized the importance of the organizational climate and key individuals, often called "champions," for the success of innovation. However, it rarely focuses on the role of participants at the project level and addresses the dynamics of construction innovation. This paper therefore presents a dynamic innovation model that has been developed using the concept of system dynamics. The model incorporates the influence of several individual and situational factors and highlights two critical elements that drive construction innovations: (1) normative pressure created by project managers through their championing behavior, and (2) instrumental motivation of team members facilitated by a supportive organizational climate. The model is qualified empirically, using the results of a survey of project managers and their project team members working for general contractors in Singapore, by assessing casual relationships for key model variables. Finally, the paper discusses the implications of the model structure for fostering construction innovations.

Slaughter, S. (1998). "Models of Construction Innovation." *Journal of Construction Engineering and Management*, ASCE, 124(3): 226-231.

> **Abstract:** Construction innovation offers the potential for significant company, industry, and societal benefits. The objective of this paper is to present five models of construction innovation, which can provide a basis upon which companies can select and implement the innovations. Based upon current management and economic theories of innovations, the models reflect the unique conditions of constructed facilities, including the scale, complexity, and longevity of the facilities, as well as their organizational and social contexts. The innovations are differentiated by their degree of change from current practice, and their links to other components and systems. The five models are incremental, modular, architectural, system, and radical innovations. Using this categorization of innovations, companies can plan their implementation activities with respect to timing of commitment, coordination among the project team, special resources, and level of supervisory activity. Examples of construction innovations in each category are discussed.

Management and Organizational Issues

Abernathy, W.J. and Utterback, J.M. (1978). "Patterns of Industrial Innovation." *Technology Review*, MIT Press, 80(11), 40-47.

Ahmad, I. (1991). "Restructuring Responsibility and Reward for More Construction Innovation." *Preparing for Construction in the 21st Century: Proceedings of the Construction Congress 1991*, L.M. Chang, Ed., ASCE, 453-458.

Bossink, B.A.G. (2004). "Managing Drivers of Innovation in Construction Networks." *Journal of Construction Engineering and Management*, ASCE, 130(3): 337-345.

> **Abstract:** Various drivers of construction innovation are distinguished and classified in four distinctive categories: environmental pressure, technological capability, knowledge exchange, and boundary spanning. Innovation drivers in these categories are active at the transfirm, intrafirm, and interfirm level in the network of organizations in the construction industry. Empirical research in the Dutch construction industry illustrates that the innovation drivers are used by managers of the authorities, clients, architects, consultants, and contractors to stimulate and facilitate innovation processes. It also exemplifies that driving innovation on the transfirm, intrafirm, and interfirm level in the network of organizations is an opportunity for managers of both public and private organizations to develop, improve, and renew their organizations' positions in the market, the quality of their organizations' projects, and the cooperative structure of the industry as a whole.

Cameron K.S. and Quinn, R.E. (1999). *Diagnosing and Changing Organizational Culture*. Addison-Wesley Publishing Company, Inc., Reading, MA.

Carr, R.I. (2000). "Detroit Owner's Role in Construction Improvement." *Journal of Construction Innovation*, Construction Innovation Forum, Construction Detroit CEO Summit, www.cif.org.

Dikmen, I., Birgonul, M.T., and Artuk, S.U. (2005). "Integrated Framework to Investigate Value Innovations." *Journal of Management in Engineering*, ASCE, 21(2): 81-90.

Abstract: A conceptual framework has been developed to investigate value innovations within construction companies. A visual metaphor has been defined to model the innovation system where the elements of the model are objectives, strategies, environmental barriers/drivers, and organizational factors. The major idea is that none of the elements of the model alone can explain the innovative capability, and elements as well as their interrelations should be considered concurrently to investigate how the innovation system works in construction companies. An application of the framework has been demonstrated by 11 cases taken from the Turkish construction industry. General findings of the research have been reported as well as specific company examples that demonstrate the major mechanisms of the innovation system. The research findings have revealed that environmental factors can have both hindering and supporting impacts on the innovation system, depending on\ other elements of the framework. The type of innovations is strongly related to company targets, strategies, strengths/weaknesses, and environmental factors. Moreover, matching of appropriate strategies with organizational properties leads to an increase in innovative capacity.

Egbu, Charles O. (2001). "Managing Innovation in Construction Organisations: An Examination of Critical Success Factors" Perspectives *on Innovation in Architecture, Engineering and Construction*. C.J. Anumba, C. Egbu, and A. Thorpe Eds., Centre for Innovative Construction Engineering, Loughborough University, Loughborough, Leicestershire, U.K.

Abstract: Innovation is viewed as a major source of competitive advantage and is perceived to be a pre-requisite for organizational success and survival. The ability to innovate depends largely on the way in which an organisation uses and exploits the resources available to it. The paper explores the importance of knowledge management (KM) and intellectual capital (IC) in organisations. It also considers the critical factors that lead to successful innovations and the role of KM and IC in this regard. The paper argues that effective management of knowledge assets involves a holistic approach to a host of factors. It is also suggested that there are a host of factors that combine in different ways to produce successful organizational innovations. It recommends that more is needed on the education and training of construction personnel and that these education and training programmes should reflect the nature of innovation and KM dimensions as very complex social processes.

Farid, F., El-Sharkawy, A., and Austin, L.K. (1993). "Managing for Creativity and Innovation in A/E/C Organizations." *Journal of Management in Engineering*, ASCE, 9(4): 399-409.

Abstract: Progress is the result of creative ideas and innovative activities. Successful organizations rely on their creative employees to develop new products and services that provide them with a competitive edge in the marketplace. Many large organizations,

however, do not demonstrate the leadership necessary to foster creativity by providing a conducive environment and by personally stimulating their creative employees. To address this problem, creativity professionals are characterized, an organizational culture that stimulates creativity is outlined, and blocks to creativity—and ways to overcome them—are discussed. Creativity is combining old ideas or generating new ideas to satisfy a need. Creativity forms something from nothing; innovation shapes that something into products and services. Managing for creativity is to provide the environment, recognition, rewards, and leadership necessary to motivate employees to be creative. Creative professionals have distinctive characteristics; managers should be able to recognize these individuals when filling vacant positions. An organizational culture conducive to the development and testing of creative ideas is essential for stimulating creativity. Creative professionals value recognition and increased self-esteem more than monetary reward.

Hansen, K.L. (1996). "How Strategies Happen: A Decision-Making Framework." *Journal of Management in Engineering*, ASCE, 12(1): 40-48.

Abstract: This multiple-case study investigates the decision to upgrade existing computer-aided design and computer-integrated engineering (CAD/CIE) systems in four international architectural, engineering, and construction (AEC) firms. Conventional methods of viewing strategy formation do not reflect the importance of dynamic elements (clients, champions, technical competence, etc.) in making strategic decisions. Four decision factors developed in this investigation - Tangent (impetus), Titanic (risk), Timing, and Technology - provide a useful vehicle to understand the strategic decision-making process and help to create a knowledge base of strategic issues within the AEC industry. The overall finding is that strategic decisions spring from many sources external to a formal planning process and that the strategy formation process is not linear. The research also identifies several ways for AEC firms to increase the effective use of CAD/CIE.

Jones, M. and Saad, M. (2003). "Managing Innovation in Construction." Thomas Telford Publishing, London.

Ling, F.Y.Y. (2003). "Managing the Implementation of Construction Innovations." *Construction Management and Economics*, 21: 635-649.

Abstract: This study investigates some factors that need to be considered in the management of innovation implementation within construction project organization. The main objective was to find explanatory variables that significantly affect the benefits of an innovation to project *team members* and the *project as a whole*. As part of a larger study on innovation in Singapore's construction industry, a survey was conducted and data from 58 projects that had adopted innovations in Singapore were collected via mailed questionnaire. The questionnaire requested respondents to provide specific data about their projects, the type of innovations adopted and the enablers and barriers to innovation. Four main categories of factors were found to significantly affect the extent to which an innovation will benefit project team members and the project. These are: the level of interest of project team members; working environment; formation of task

groups; and the capabilities of the people involved in the innovation. Research questions relating to modeling innovation success are posed for further study.

Macomber, John D. (2002). "Follow the Money: What Really Drives Construction Innovation." *Proceedings from the Construction Research Congress*, ASCE, 1-9.

Abstract: Technology enthusiasts, academics, and software companies remain concerned about the slow pace of innovation in the construction industry. Tools are widely available that seem to provide eminently sensible and glaringly apparent improvement to the process of design and construction of buildings and facilities. Why aren't they used? Because the monetary implications are not well considered. This paper explores the real business motivations of the construction and design firms who take on risk and reap reward in technology adoption. If they are motivated by enlightened economic self interest, it's clear why innovation is slow. Interested observers who wish to direct their work to the relevant issues can benefit from considering why and how the economic value of innovations actually flows through the system. Several financial models are proposed for representing those impacts. Innovation will come from other sources following disruptive business models. Four major methodologies promise true innovation—supply chain optimization, knowledge management, 3D design, and wrap-up economic models. These are likely to be adopted by new innovators and not by established firms.

O'Connor, J.T. and Yang, L.-R. (2004). "Project Performance versus Use of Technologies at Project and Phase Levels." *Journal of Construction Engineering and Management*, ASCE, 130(3): 322-329.

Abstract: Lack of information regarding technology benefits along with uncertain competitive advantage from new technology has resulted in industry reluctance to implement new technologies. An industry-wide survey was used to collect project data from more than 200 capital facility projects on the issue of technology usage and overall project success. Twenty-two research hypotheses are presented and analyzed according to five different data class variables: industry sector, total installed cost, public versus private, greenfield versus expansion versus renovation, and typical versus advanced projects. Findings pertaining to associations between project success and technology usage at the project and phase level are discussed. The results of this research indicate that several technologies may contribute significantly to project performance in terms of cost and schedule success, particularly for certain types of projects. In addition, project schedule success is more closely associated with technology utilization than is project cost success. Findings from this study can provide companies with information on technology benefits and whether to use certain technologies.

Pavitt, T.C. and Gibb, A.G.F. (2003). "Interface Management within Construction: In particular, Building Facade." *Journal of Construction Engineering and Management*, ASCE, 129(1): 8-15.

Abstract: This paper discusses the need for interface management within construction, with particular reference to building façade interfaces. It categorizes the three different

types of interface management—physical, contractual, and organizational. The implication of interface management in construction contracting is discussed; it is explained how the U.K. procurement trends have changed, affecting the interface management within projects. U.K. cladding procurement is very fragmented, and the paper maps the development of a typical cladding system showing the complexities of interface management. Finally, the paper discusses CladdISS, a U.K. government funded research project to develop a standardized strategy for the design and management of window and cladding interfaces. It explains the principles of CladdISS with reference to process maps, action plans, management strategy, bibliography, advice on standards, materials, maintenance, joints, movement, and tolerances. This will enable strategies to be developed to avoid the endemic interface problems occurring on-site. It will also guide the management of the interfaces throughout the project.

Seaden, G., Guolla, M., et al. (2003). "Strategic Decisions and Innovation in Construction Firms." *Construction Management and Economics*, 21: 603-612.

Abstract: Current research on the process of innovation has focused attention on the crucial role of the business firm as the place where new ideas are developed and then implemented in the marketplace. Based on current knowledge, a model was developed which attempts to replicate the strategic decision-making process in a construction firm. It links perceived business environment variables to various business strategy variables (i.e. marketing, human resources and technology). These two sets of variables are linked to the innovativeness of the firm, measured by the number of advanced technologies and/or business practices currently used. Innovativeness is subsequently linked to outcomes (i.e. profitability, competitive advantage) to assess overall effectiveness. The model was tested empirically, using data from the Survey on Innovation, Advanced Technologies and Practices in the Construction and Related Industries carried out by Statistics Canada in 1999 with 1739 usable responses. The results generally support the proposed model; certain perceived business environment and business strategy variables are significantly related to firm innovativeness, however the link between innovativeness and outcomes requires further confirmation. Many construction firms introduce new approaches in information and construction technologies as well as in business practices. A large number of these were found to provide significant competitive advantage. In general, innovative behaviour varies with the size of the firm.

Tatum, C.B. (1986). "Demands and Means for Construction Innovation." *Construction Innovation: Demands, Successes and Lessons: Proceedings of the Construction Division of ASCE in conjunction with ASCE Convention*, Seattle, Washington, C.B. Tatum, Editor, ASCE, 31-43.

Tatum, C.B. (1991). "Incentives for Technological Innovation in Construction." *Preparing for Construction in the 21st Century: Proceedings of the Construction Congress 1991*, L.M. Chang, Editor, ASCE, 447-452.

Tomala, F. and Senechal, O. (2003). "Innovation Management: A Synthesis of Academic and Industrial Points of View." *International Journal of Project Management*, 22: 281-287.

Abstract: This paper synthesizes several works about innovation management. By blending both academic and industrial points of view, we hope to help those participating in innovative projects become aware of the latest thoughts of other groups involved in innovation management. Our discussion underlines the importance of innovation as well as the various problematical aspects of innovation management. Three principal points are considered: the types of actors involved in innovation, the organizational perimeters for innovation and the types of organization chosen for innovative projects. The case study of the Renault automobile company highlights a new means of managing innovation, called orbital management, which involves a new project structure specific to innovation management.

Train, A. and Egbu, C. (2006). "Maximising the Impact of Knowledge for Innovation in Gaining Competitive Advantage." *Proceedings of the Annual Research Conference of the Royal Institution of Chartered Surveyors*, COBRA 2006, University College, London, Sept. 7-8, 2006.

Case Studies

Bernold, L.E. (1991). "Learning and Innovating in a Construction Technology Laboratory." *Preparing for Construction in the 21st Century: Proceedings of the Construction Congress 1991*, L.M. Chang, Editor, ASCE, 478-483.

Abstract: Construction Engineering and Management program at North Carolina State University created a laboratory facility for students to discover new techniques for common construction tasks. Students used their knowledge of basic engineering principles, construction technology, computers, and mechanical and electronic systems. Tools available to students included state of art computers, robot arms, sensors, conveyors, specialty boards for voice recognition, and data acquisition software. Two undergraduate students developed a prototype brick masonry robot.

Madewell, C.J. (1986). "Innovative Solutions to the Challenges of Heavy Civil Projects." *Construction Innovation: Demands, Successes and Lessons, Proceedings of the Construction Division of ASCE in conjunction with ASCE Convention,* Seattle, WA, C.B. Tatum, Editor, ASCE, 11-17.

Abstract: Describes unique scaffolding system used on Golden Gate Bridge restoration project needed to keep traffic unimpeded. A special rigging system installed modular steel panels weighing 20 tons. No holes or welds were permitted in steel panels. Submerged arc welding was employed due to damp, sea air conditions, and nighttime construction. New Melones Reservoir diversion tunnel in California featured a field fabrication yard to assemble 23 ft diameter by 80 ft long tunnel sections. Special equipment was developed to transport 170-ton sections. An innovative welding procedure was used. Finite element stress analysis on Hanford Waste Storage Tanks project aided tank fabrication and reduced costs. Some of these innovations were imaginative solutions to a construction specification, and others were an alternative to traditional methods, but all involved perseverance and hard work.

International Issues

Garcia, M.A. (2005). "Challenges of the Construction Sector in the Global Economy and the Knowledge Society." *International Journal of Strategic Property Management*, 9: 65-77.

> **Abstract:** Nowadays, the Construction Sector in the EU is one of the most relevant forces of the European economy – It represents the 10% of the total EU GDP and 7% of total employment. Nevertheless, we can define this sector as a very unstructured activity with a wide range of interactions in the value chain. In fact, we can say it's a hyper-sector that has been demonstrating over previous decades, to be market oriented and not too much innovative. Several analyses have concluded the RTD activity in the construction Sector is quite unstructured and a lot of knowledge is produced but not recorded. In most cases, the RTD and innovation activity are focused to solve day to day problems, more than a response to an innovative policy and planned activity. Main innovations have been made in the fields of materials and machinery, and most of them could be considered as a technology transfer form other sectors. The market demand – according to economical cycles, and the financial support have been the main forces that have driven the activity of the Construction Sector. The new landscape ahead, of a global economy and a society based on technology and knowledge creation and valuation, will force this sector to be more active and structured in their RTD and innovation activity.

Kangari, R. and Miyatake, Y. (1997). "Developing and Managing Innovative Construction Technologies in Japan." *Journal of Construction Engineering and Management*, ASCE, 123(1): 72-78.

> **Abstract:** Construction technology innovation is becoming an increasingly important factor for the growth of many large Japanese firms. It has become essential that new construction technologies be identified, obtained on the most reasonable terms, and transferred smoothly to the construction site. This paper describes the four major factors that contribute to the development of innovative construction technology in Japan: (1) strategic alliances; (2) effective information gathering capability; (3) reputation through innovation; and (4) technology fusion. The paper also illustrates the technology evaluation process used by a typical large general contractor in Japan. It is concluded that global technology information gathering has increased the awareness of the large construction firms in Japan to outside technology. To implement synthesis of technology, these companies have participated in cross-industry research projects. The crucial link between innovation and business strategy in a large construction firm in Japan was found to be the long-range technology forecasting that integrates action of today with the vision of tomorrow.

Seaden, G. and Manseau A. (2001). "Public Policy and Construction Innovation." *Building Research and Information*, 29(3): 182-196.

> **Abstract:** The particular roles played by governments through their policies and programmes are considered within a comparative context in order to gain an

understanding of construction innovation systems and processes. The analysis of this question is grounded in a framework which develops: a typology of construction related activities, a precise definition of innovation, the measurement of innovation, and models linking R and D and innovation. Comparative findings suggest that the political and social structures of individual countries do not create radical differences in their national approaches to innovation. However, government structure, the type of national innovation system and the nature of construction institutions influence the choice of specific policy instruments. A summary of findings from a task group is presented which reviews various national policies towards innovation in construction. Country specific observations are drawn from case studies of 15 countries in Europe, North and South America, South Africa and Japan. Often public policy instruments in support of innovation have not been of real benefit to the construction industry. Recommendations are made to improve the focus and utility of future policy initiatives for innovation, including: the creation of collaborative arrangements with industry initiated research and emphasis on performance and sustainability.

Metrics

BFC (2001). Measuring Productivity and Evaluating Innovation in the US Construction Industry. Building Futures Council, Wolff, D.M., East Orange, NJ**:** 1-14.

Dikmen, I., Birgonul, M.T., and Artuk, S.U. (2005). "Integrated Framework to Investigate Value Innovations" *Journal of Management in Engineering*, ASCE, 21(2): 81-90.

Abstract: A conceptual framework has been developed to investigate value innovations within construction companies. A visual metaphor has been defined to model the innovation system where the elements of the model are objectives, strategies, environmental barriers/drivers, and organizational factors. The major idea is that none of the elements of the model alone can explain the innovative capability, and elements as well as their interrelations should be considered concurrently to investigate how the innovation system works in construction companies. An application of the framework has been demonstrated by 11 cases taken from the Turkish construction industry. General findings of the research have been reported as well as specific company examples that demonstrate the major mechanisms of the innovation system. The research findings have revealed that environmental factors can have both hindering and supporting impacts on the innovation system, depending on other elements of the framework. The type of innovations is strongly related to company targets, strategies, strengths/weaknesses, and environmental factors. Moreover, matching of appropriate strategies with organizational properties leads to an increase in innovative capacity.

Gallaher, M.P., O'Connor, A.C., Dettbarn, J.L., Jr., and Gilday, L.T. (2004). Cost Analysis of Inadequate Interoperability in the US Capital Facilities Industry. US Department of Commerce Technology Administration, Gaithersburg, MD**:** 1-210.

Abstract: Interoperability problems in the capital facilities industry stem from the highly fragmented nature of the industry, the industry's continued paper-based business

practices, a lack of standardization, and inconsistent technology adoption among stakeholders. The objective of this study is to identify and estimate the efficiency losses in the U.S. capital facilities industry resulting from inadequate interoperability. This study includes design, engineering, facilities management and business processes software systems, and redundant paper records management across all facility life-cycle phases. Based on interviews and survey responses, $15.8 billion in annual interoperability costs were quantified for the capital facilities industry in 2002. Of these costs, two-thirds are borne by owners and operators, which incur most of these costs during ongoing facility operation and maintenance (O&M). In addition to the costs quantified, respondents indicated that there are additional significant inefficiency and lost opportunity costs associated with interoperability problems that were beyond the scope of our analysis. Thus, the $15.8 billion cost estimate developed in this study is likely to be a conservative figure.

OECD (2005). Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data. 3rd E. Commission, Oslo, Norway**:** 1-166.

Abstract: The ability to determine the scale of innovation activities, the characteristics of innovation firms and the internal and systemic factors that can influence innovation is a prerequisite for the pursuit and analysis of policies aimed at fostering innovation. The *Oslo Manual* is the foremost international source of guidelines for the collection and use of data on innovation activities in industry. This third edition, published in October 2005, has been updated to take into account the progress made in understanding the innovation process and its economic impact, and the experience gained from recent rounds of innovation surveys in OECD member and non-member countries. For the first time, the Manual investigates the field of non-technological innovation and the linkages between different innovation types. It also includes an annex on the implementation of innovation surveys in developing countries.

Thompson, L.L. (2001). Life Cycle Assessment Tools to Measure Environmental Impacts: Assessing their Applicability to the Homebuilding Industry. US Department of Housing and Urban Development, Washington D.C.**:** 1-49.

Abstract: On April 20, 2001, a group of international experts met in Baltimore for a full-day workshop to discuss life cycle assessment (LCA) issues and the current state of LCA tools. In particular, the discussion focused on the ways in which LCA tools affect and concern the home building industry. The tools thus far have been used primarily by architects, designers, product manufacturers, builders and engineers in the commercial building industry; the workshop was an opportunity to examine their usefulness for the residential building sector. The workshop included a mix of participants of varied backgrounds. The goal was to have in the same room, not only LCA tool developers and LCA experts, but also professionals who are well versed in the environmental indicators (impact categories) that LCA tools attempt to profile via their algorithms.

In general, LCA tools take data and assumptions and produce an environmental rating for building products or systems. Five LCA tools developed around the world were

highlighted at the workshop. Each tool has its own unique approach, design, and set of outputs. Tool developers briefly presented information on each tool to help forum participants understand each tool's breadth and idiosyncrasies. Once details of each tool were presented, the forum participants had the opportunity to ask questions and express concerns about the tools in particular, and LCA in general. The day was split into four facilitated sessions, each focusing on a different topic area. The first session addressed data needs; the second concerned LCA methodologies; the third tried to determine the audience for the tools; and the fourth session concentrated on creating a list of recommendations to help make LCA tools more useful for the home building industry.

Overall, the group felt that LCA tools are not useful to home builders in their current form. Information produced by the tools, however, might be useful to some people in the home building industry if its accuracy can be reasonably assured, and if results can be presented in a simple format, such as an eco-rating or a group of ratings. The usefulness of LCA tools to other groups that affect the product selection process was also examined.

Tucker, Robert (2004). "Innovation Network." Innovation Metrics: Embedding Innovation in an Organization's Systems. ThinkSmart, www.thinksmart.com, 29 May 2006.

Turrell, Mark (2004). "Show me the Numbers: A look at Innovation Metrics." Innovation Tools, www.innovationtools.com/Articles/EnterpriseDetails, 29 May 2006.

Abstract: It's an old adage: What gets measured, gets done. Our research at Imaginatik has found that innovation groups that adopt measurable targets are significantly better supported by management than groups without targets. Moreover, groups without targets are rarely considered as serious by management, and the lack of metrics can imperil the very survival of innovation activities within an organization. Several firms studied by Imaginatik Research reported that metrics were not necessary, but then proceeded to describe the problems they have had attracting resources and management attention to further their cause. Occasionally we found innovation groups supported by a visionary executive, but it is rare that an executive can continuously protect an initiative from more skeptical colleagues.

Diffusion

Bernstein, H.M., Kissinger, J.P., and Kirksey, W. (1998). "Moving Innovation into Practice." *Civil Engineering in the Asia Region: Proceedings of the First International Civil Engineering Conference,* Downey, E.A., ASCE, 250-259.

Conover, D. (2002). Getting Building Technology Accepted. National Evaluation Service**:** 1-36.

Abstract: The Partnership for Advancing Technology in Housing (PATH) is a public-private partnership created to add value to and increase the affordability of housing through technology. PATH examines the issues and institutional problems related to technology development in the housing industry and creates viable, cost-effective solutions to improve the rate of change. PATH partners include the major research and

housing agencies in the Federal Government; leaders in the manufacturing of homebuilding products; innovators in the homebuilding and contracting industry; researchers from diverse backgrounds; and officials from insurance, financial, and regulatory groups in housing and construction. PATH has adopted far-reaching goals for the quality, durability, environmental impact, energy efficiency, affordability, and disaster risk of America's homes. PATH's partners contribute to this vision by:

- Developing new housing technologies (research and development).
- Disseminating information about new and existing housing technologies (information and outreach).
- Studying and establishing programs for sustained housing technology development and market acceptance (planning and barriers analysis).

Dick, J. and Payne, D. (2005). "Regional Sectoral Support: A Review of the Construction Industry, SMES and Regional Innovation Strategies across Europe." *International Journal of Strategic Property Management*, 9: 55-63.

Abstract: The performance of the EU construction industry in total makes a major impact on the European Community's economy, particularly on capital formation and employment. Small and Micro Enterprises account for 97% of businesses across the construction sector in the EU, a profile broadly reflected in the individual national and regional business base of members. This paper reviews the state of regional support for innovation and technology transfer in the Small Medium and Micro-sized Enterprises (SME) sector of the Construction industry in the European Community. Results show that at the regional level, where most construction SMEs operate, there is a marked absence of focus on construction in either innovation support initiatives or business development services. Data on the construction industry at national and regional levels across Europe is not available in sufficient quality or detail for strategic decisions concerning this economically significant sector.

Koebel, C.T., Papadakis, M., Hudson, E., and Cavell, M. (2004). The Diffusion of Innovation in the Residential Building Industry. Center for Housing Research, Virginia Polytechnic Institute, Blacksburg, VA and U.S. Department of Housing and Urban Development, Blacksburg, VA**:** 3-95.

Abstract: At the early stage of diffusion, national and regional firms, multifamily and modular builders, and custom builders are more likely to adopt innovations than are single-family production builders. Although sales and supplier representatives, subcontractors, and trade shows are important sources of information about new products and materials for all builders, early-stage adopters rely on technology transfer programs and universities more than middle or late-stage adopters do. Although small, less established manufacturers often are the first to introduce new products, residential building construction relies heavily on established manufacturers who stand behind their products. This behavior likely reflects the substantial financial and market risks associated with innovation in residential building. Product failures can cost builders dearly, both in direct losses and in damage to the firm's reputation. Establishing a

reputation for high quality and durable homes, and for quickly addressing problems in new homes, was a key business strategy for over two-thirds of the builders in this survey.

Labay, D.G. and Kinnear, T.C. (1981). "Exploring the Consumer Decision Process in the Adoption of Solar Energy Systems." *Journal of Consumer Research*, 8(3): 271-278.

Abstract: This study examines residential solar energy systems within an adoption and diffusion of innovations framework. The findings indicate considerable differences between adopters and nonadopters on many measures. Multivariate nominal scale analysis is used to develop classification models based on both attribute perceptions of solar energy systems and demographic characteristics.

Leonard-Barton, D. (1985). "Experts as Negative Opinion Leaders in the Diffusion of a Technological Innovation." *Journal of Consumer Research*, 11(4): 914-926.

Abstract: In the diffusion of controversial technological innovations, experts influence the rate and extent of acceptance by serving as negative or positive opinion leaders. This study of prosthodontists and their choice of opinion leaders draws data from both national and local samples of professionals to explain the use of nonprecious alloys as a gold substitute in dental restorations. The role of innovation discontinuers is also explored.

Rogers, E.M. (1995). *Diffusion of Innovations*, 4th Edition. Free Press, New York, NY.

Ryan, B. and Gross, N.C. (1943). "The Diffusion of Hybrid Seed Corn in Two Iowa Communities." *Rural Sociology*, 8(1): 15–24.

Saha, A., Love, A., et al. (1994). "Adoption of Emerging Technologies under Output Uncertainty." *American Journal of Agricultural Economics*, 76: 836-846.

Abstract: A model of divisible technology adoption under incomplete information dissemination and output uncertainty is developed. We identify economic and subjective factors affecting technology adoption and its intensity. Empirical estimation employs a mixed dichotomous-continuous framework with nonrandom sample selection. Producers' adoption intensity is conditional on their knowing about and deciding to adopt the new technology. Using survey data on bST (bovine somatotropin) adoption among Texas dairy producers, we find that larger and more educated operators are likely to adopt more intensively. Traditional dichotomous adoption models without sample selection significantly overestimate the adoption rate.

Steel, J. (2001). "Planning and Managing Innovation and Diffusion in Construction" *Perspectives on Innovation in Architecture, Engineering and Construction*. C.J. Anumba, C. Egbu, and A. Thorpe, Eds., Centre for Innovative Construction Engineering, Loughborough University, Loughborough, Leicestershire, U.K.

Toole, T.M. (2001). "Technological Trajectories of Construction Innovation." *Journal of Architectural Engineering*, ASCE, 7(4): 107-114.

Abstract: This paper analyzes four streams of building products to show that successful innovative building products are those that offer cost, time, and performance advantages through progress along four technological trajectories: location of the work, means of production, materials used, and incorporation of system design principles. Market and production factors that hinder progress along these trajectories are identified. The future success of innovative products can be predicted by evaluating their progress along the four trajectories.

Information Technology in Construction

Ekstrom, M.K. and Bjornsson, H.C. (2005). "Valuing Flexibility in Architecture, Engineering and Construction Information Technology Investments." *Journal of Construction Engineering and Management*, ASCE, 131(4): 431-438.

Abstract: When investing in information technology applications, construction managers implicitly account for the value of adding future applications to the original investment as the business and technical environment changes. A real option model links uncertainty to the value of an underlying traded asset, providing an objective measure of this managerial flexibility. A case study that investigated the value of options to extend a general contractor's software platform showed that it is possible to construct a real option model which measures the value of this flexibility, since the major risk ~the architect's adoption rate! is external to the investing organization. In another case study, a contractor evaluated the value of the pilot project in view of the information it is expected to generate. Since the risks are internal, a decision analysis model is used instead of a binary option model. The results show that it is possible to quantify the value of managerial flexibility for IT investments in the architecture, engineering, and construction industry, but that the proper method to use is contingent on the nature of the investment project.

El-Mashaleh, M., O'Brien, W.J., and Minchin, R.E., Jr. (2006). "Firm Performance and Information technology Utilization in the Construction Industry." *Journal of Construction Engineering and Management*, ASCE, 132(5): 499-507.

Abstract: This paper, which is written to both researchers and practitioners, examines the impact of information technology on construction firm performance. Based on data collected from 74 construction firms, regression analysis is used to test the relationship between performance and IT. Analysis provides empirical evidence that IT is positively associated with firm performance, schedule performance, and cost performance. Firm performance is a composite score of several metrics of performance: schedule performance, cost performance, customer satisfaction, safety performance, and profit. The regression analysis shows that for every 1 unit increase in IT utilization, there is an increase of about 2, 5, and 3% in firm performance, schedule performance, and cost performance, respectively. No relationship is found between IT use and customer satisfaction, safety performance, and profitability.

Toole, T.M. (2002). Information Technology Innovation: A View of Large Contractors. Construction Research Congress, ASCE, Honolulu, HI.

> **Abstract:** This paper presents the views of ten large construction contractors on two sets of issues relating to the impact of IT innovation on construction. Large contractors believe that web-based software that facilities electronic collaboration between project participants will have a large impact on the industry, but requires overcoming substantial barriers involving clients, subcontractors and architects. Large contractors also believe that mobile computing devices that can capture and transmit digital files and job costing data will eventually also have a large impact on the industry. Data-mining using company historical databases will continue to improve companies' estimating, marketing and project management capabilities.

Veshosky, D. (1998). "Managing Innovation Information in Engineering and Construction Firms." *Journal of Management in Engineering*, ASCE, 14(1): 58-66.

> **Abstract:** This paper presents the results of a study of the ways in which project managers in the U.S. engineering and construction industry attempt to obtain information about relevant innovations, and the ways in which industry firms attempt to facilitate their project managers' abilities to obtain such information. The study determined that project managers rely heavily on trade magazines and conversations with internal colleagues for information about innovations, and that firms' efforts to facilitate information seeking by their project managers focus primarily on information from internal sources, through reports of "lessons learned" and other means. Project managers are often unaware of their firms' policies or programs intended to assist them in obtaining innovation information, or do not use available assistance.

Williams, T.P. (2003). "Applying Handheld Computers in the Construction Industry." *Practice Periodical on Structural Design and Construction*, ASCE, 8(4): 226-231.

> **Abstract:** Handheld computers are becoming more powerful and their application to construction projects is becoming increasingly feasible. Wireless connectivity allows handheld computers to access the Internet for Web-browsing and data transfer. Potential construction handheld computer applications include data collection, electronic books and reference materials, access to computer-aided design drawings, estimating, and scheduling applications. Mobile construction applications can be differentiated into two categories. They are general applications that can be used on many projects, and project-specific applications that must be tailored to a specific project. The capabilities of the two most popular handheld devices, the Palm and Pocket PC devices, are discussed and compared. The potential and costs of using handheld devices for Web access are discussed. A prototype Palm Web-clipping application is described. The capabilities of commercially available software packages and several prototype construction applications are discussed.

Issues in Residential and Small-Scale Construction

Hammad, A.A., Hastak, M., and Syal, M. (2004). "Comparative Study of Manufactured Housing Production Systems." *Journal of Architectural Engineering*, ASCE, 10(4): 136-142.

Abstract: This paper illustrates the production process of a manufactured housing factory and potential bottlenecks that could affect the system efficiency. To investigate ways for improving the performance of the U-shaped flow pattern layouts, a comparative study between two case study factories was conducted to realize their relative efficiencies and drawbacks. Process maps were prepared to establish the subactivity relationship at every assembly and subassembly station. Time data were collected for the station process time and the subactivity process time at the two factories to realize a generic (streamlined) system. The efficient criteria of the two systems were joined to develop a streamlined generic system.

Sexton, M. and Barrett, P. (2003). "Appropriate Innovation in Small Construction Firms." *Construction Management and Economics*, 21: 623-633.

Abstract: Innovation-led performance improvement in the construction industry is significantly influenced by the innovation performance of small firms. There is a dearth of research investigating innovation from the perspective of the small construction firm. This paper contributes to this underdeveloped area by offering relevant empirically based results. The findings stress the important role that owners of firms play in successful innovation. The type of innovation undertaken, and the different organizational factors which are brought into play, is shown to depend on the characteristics of the interaction environment in which the firm is operating. Small construction firms need to incrementally nurture, or identify and move into, supportive enabling interaction environments. This is achieved through an integrated development of a firm's business strategy and market positioning, organization of work, technology and people. The process of innovation is demonstrated to be subject to cyclical peaks and troughs as the progress of the innovation competes with day-to-day pressures. Small construction firms have their own distinctive characteristics, which are profoundly different from those of large construction firms. The implication for policy is that any initiatives geared toward improving appropriate innovation need to appreciate these differences.

Sexton, M. and Barrett, P. (2003). "A Literature Synthesis of Innovation in Small Construction Firms: Insights, Ambiguities and Questions." *Construction Management and Economics*, 21: 613-622.

Abstract: Construction firms are being challenged to be more adept at successful innovation to better meet client needs and to enhance business competitiveness. The substantial contribution that small construction firms make to the output of the industry signifies the importance for this body of firms to improve their innovation performance if the performance of the industry as a whole is to move forward. The literature on innovation in small construction firms is synthesized and structured around a generic model to provide a holistic picture of our current knowledge. Significant gaps in the

understanding and practice of innovation in small construction literature are identified, which severely hamper understanding of the myriad complex and systemically interactive issues embodied within the theory and practice of innovation. The gaps identified by this literature synthesis are the basis for a number of important questions that, the authors propose, form an integrating agenda for future research.

Toole, T.M. (1998). "Uncertainty and Home Builders' Adoption of Technological Innovations." *Journal of Construction Engineering and Management*, ASCE, 124(4): 323-332.

Abstract: An empirical investigation pertaining to the adoption of technological innovations by small- and medium-sized home building firms was conducted by multiple regression analysis of data collected from interviewing over 100 home builders across the country. The research shows that home builders who are more apt to adopt nondiffused technological innovations tap into more sources of information about new products from portions of their organizational environments than do nonadopters. The data also indicate that relatively early adopters of high uncertainty innovations differ from those more apt to be relatively early adopters of low uncertainty innovations in the characteristics of the individuals involved in innovation-related activities. The empirical findings support the general hypothesis that uncertainty reduction plays a key role in the adoption of technological innovations in residential construction.

Innovation Organizations

Abbott, C. and Allen, S. (2005). "Facilitating Innovation: The Role of the Centre for Construction Innovation." *International Journal of Strategic Property Management*, 9: 79-89.

Abstract: The concepts underlying innovation and standardisation presents an apparent divergence in what each strives to achieve. In the view of the authors, this has contributed in no small measure to the low take-up of standardisation within the construction sector as organisations strive to be innovative to improve on their performance and attain continuous improvement in their processes and operations as well as design solutions. The paper presents as a case, how one major public sector outfit is striving to achieve innovation within an agenda that involves a widespread adoption of standardisation. It presents the motivations for adopting an organisation-wide agenda on innovation and standardisation, identifies the elements of apparent incongruity between the concepts, and outlines how the case organisation has resolved the divergences.

Modeling

Park, M., Nepal, M., and Dulaimi, M. (2004). "Dynamic Modeling for Construction Innovation" *Journal of Management in Engineering*, ASCE, 20(4): 170-177.

Abstract: Previous research on construction innovation has commonly recognized the importance of the organizational climate and key individuals, often called "champions," for the success of innovation. However, it rarely focuses on the role of participants at the project level and addresses the dynamics of construction innovation. This paper therefore

presents a dynamic innovation model that has been developed using the concept of system dynamics. The model incorporates the influence of several individual and situational factors and highlights two critical elements that drive construction innovations: (1) normative pressure created by project managers through their championing behavior, and (2) instrumental motivation of team members facilitated by a supportive organizational climate. The model is qualified empirically, using the results of a survey of project managers and their project team members working for general contractors in Singapore, by assessing casual relationships for key model variables. Finally, the paper discusses the implications of the model structure for fostering construction innovations.

Sachs, H., Nadal, S., Amann, J.T., Tuazon, M., and Mendelsohn, E. (2004). Emerging Energy-Saving Technologies and Practices for the Building Sector as of 2004, ACCEE**:** 1-246.

Abstract: Adopting new energy-efficient technologies and practices is a key for reducing energy consumption while maintaining economic growth. Fortunately, innovators introduce new T&Ps more rapidly than the market can assimilate them. Some have great potential and some have less, so periodic, systematic evaluations of emerging T&Ps serve to identify the best candidates for program development. Comparing findings over time gives additional insights into the efficiency industry's health, allowing investigation of questions like, "Is the conservation well going to run dry?" This analysis, the third in a decade, began with reconnaissance of 200 T&Ps, which were screened to select those which promise to (1) save at least 0.25% nationally when mature and accepted, (2) avoid large "lost opportunities" in new construction, or (3) capture important regional opportunities. The findings are encouraging: there are still many promising technologies and practices that will save large amounts of energy. On the other hand, the number of "pure" technologies that emerged from the screening process was smaller than before. However, this was compensated by increasing numbers of "practices" that reflect new systems views of older issues. Overall, technologies and practices have the potential to make a major impact on future energy use.

Slaughter, S. (1998). "Models of Construction Innovation." *Journal of Construction Engineering and Management*, ASCE, 124(3): 226-231.

Abstract: Construction innovation offers the potential for significant company, industry, and societal benefits. The objective of this paper is to present five models of construction innovation, which can provide a basis upon which companies can select and implement the innovations. Based upon current management and economic theories of innovations, the models reflect the unique conditions of constructed facilities, including the scale, complexity, and longevity of the facilities, as well as their organizational and social contexts. The innovations are differentiated by their degree of change from current practice, and their links to other components and systems. The five models are incremental, modular, architectural, system, and radical innovations. Using this categorization of innovations, companies can plan their implementation activities with respect to timing of commitment, coordination among the project team, special resources,

and level of supervisory activity. Examples of construction innovations in each category are discussed.

Tatum, C.B. (1986). "Potential Mechanisms for Construction Innovation." *Journal of Construction Engineering and Management*, ASCE, 112(2), 178-191.

Other Innovation Topics

Arditi, D., Kate, S., and Tangkar, M. (1997). "Innovation in Construction Equipment and its Flow into the Construction Industry." *Journal of Construction Engineering and Management*, ASCE, 123(4): 371-378.

Abstract: The rate of innovation in construction equipment is measured by using two variables over a 30-year period, 1962–92: The number of new models introduced every year and the technological life of eight earthmoving equipments are considered in this study. The findings indicate that the rate of innovation in the construction equipment industry increased in the 30-year study period. The findings also suggest that these innovations are incremental in nature, stimulated by technological advances in other industries, but primarily driven by market forces. Technological advances are not confined to the industry that produces innovations. The mapping of the interindustry flow of innovations highlights that while construction companies play a predominant role in generating their own technological innovations, they are also heavily dependent on other industries, such as the construction equipment industry for the flow of technical system innovations. As such, the continuous and incremental innovations in the construction equipment industry are bound to act as a catalyst for the generation of technological advances in the construction industry.

Christensen, C.M. (1997). The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail. Harvard Business School Press, Boston, MA, 225 pp.

Christensen, C.M. and Raynor, M.E. (2003). The Innovator's Solution: Creating and Sustaining Successful Growth. Harvard Business School Press, Boston, MA, 320 pages.

CII/NSF (1997). "How Do We Use Research to Improve the Engineering and Construction Industry?" Final Report, NSF Contract #9700436 CMS, Workshop Co-sponsored by CII and NSF, Austin, TX, May 13-14, 1997.

Dulaimi, M. (1995). "The Challenge of Innovation in Construction." *Building Research and Information*, Taylor & Francis, 23(2), 106-109.

ENR (2006). "Who Will Pay for Project Delivery Process Innovation?" *Engineering News-Record*, McGraw-Hill, Inc., New York, NY, Nov. 27, 2006.

Gann, D.M. (2003). "Guest Editorial: Innovation in the Built Environment." *Construction Management and Economics*, 21: 553-555.

Halim, A. and Haas, R. (2004). "Process and Case Illustration of Construction Innovation." *Journal of Construction Engineering and Management*, ASCE, 130(4): 570-575.

Abstract: This paper describes the major stages and component steps leading to the realization of the technical and commercial potential of a new construction technology. It encompasses a process of innovation and invention, which is generically applicable to any construction innovation. A case illustration of a new asphalt compaction technology is also described within each stage to provide a "real life" example. Motivation for the new technology came from the fact that existing, conventional rollers can cause serious damage to the compacted asphalt mat at the time of construction. This damage is in the form of construction cracks, often termed "roller checking," which can result in accelerated, in-service deterioration. The new technology originally termed the "Asphalt Multi Integrated Roller" (AMIR), overcomes the problems of current rollers through stiffness compatibility with the asphalt mix and a different geometry than conventional rollers. Commercial realization of the technology has been achieved through a new generation of AMIR, termed "HIPAC." The paper also provides background on the issues of concern to pavement engineers, including limitations of current compaction methods. It explains in functional terms the unique difference provided by the new technology. As well, it describes the major hurdles that were overcome to achieve commercial realization.

Harty, C. (2005). "Innovation in Construction: Sociology of Technology Approach." *Building Research and Information*, 33(6): 512-522.

Abstract: An alternative approach to understanding innovation is made using two intersecting ideas. The first is that successful innovation requires consideration of the social and organizational contexts in which it is located. The complex context of construction work is characterized by inter-organizational collaboration, a project-based approach and power distributed amongst collaborating organizations. The second is that innovations can be divided into two modes: 'bounded', where the implications of innovation are restricted within a single, coherent sphere of influence, and 'unbounded', where the effects of implementation spill over beyond this. Bounded innovations are adequately explained within the construction literature. However, less discussed are unbounded innovations, where many firms' collaboration is required for successful implementation, even though many innovations can be considered unbounded within construction's inter-organizational context. It is argued that unbounded innovations require an approach to understand and facilitate the interactions both within a range of actors and between the actors and technological artifacts. The insights from a sociology of technology approach can be applied to the multiplicity of negotiations and alignments that constitute the implementation of unbounded innovation. The utility of concepts from the sociology of technology, including 'system building' and 'heterogeneous engineering', is demonstrated by applying them to an empirical study of an unbounded innovation on a major construction project (the new terminal at Heathrow Airport, London, UK). This study suggests that 'system building' contains outcomes that are not only transformations of practices, processes and systems, but also the potential transformation of technologies themselves.

Henry, D. (2006). "Creativity Pays. Here's How Much." *BusinessWeek Online*, <http://biz.yahoo.com/special/innovation06_article2.html>, April 28, 2006.

Hofstede, G. and Hofstede, G.J. (2005). Cultures and Organizations: Software of the Mind. McGraw-Hill, Inc., New York, NY.

Kelley, T. (2005). The Ten Faces of Innovation. Doubleday, New York, NY.

Loosemore, M., Choo, H., and Koh, J. (2002). "Encouraging Research and Development in Construction Companies." *Journal of Professional Issues in Engineering Education and Practice*, ASCE, 128(1): 25-29.

> **Abstract:** Governments around the world are seeking to transfer their traditional responsibility for research and development to the private sector. This paper investigates the factors that will impede the effectiveness of privately funded research and development in the construction industry. It concludes that the construction industry is skeptical of the process and ill-equipped to undertake it. Recommendations are made to help private firms adapt to their new role and benefit from it. These relate to issues of strategy, organizational culture, procurement, contractual practices, and interorganizational alliances.

Michel, H.L. (1998). "The Next 25 Years: The Future of the Construction Industry." *Journal of Management in Engineering*, ASCE, 14, 26-31.

Midgley, D.F. and Dowling, G.R. (1993). "A Longitudinal Study of Product Form Innovation: The Interaction between Predispositions and Social Messages." *Journal of Consumer Research*, 19(4): 611-625.

> **Abstract:** In this article we simplify and apply our 1978 contingency model of adoption, in the simplified model, an individual's predisposition to innovate is modified by socially transmitted messages about the innovation, as well as by other situation specific factors. This model is used to make predictions about the future behavior of a sample of consumers that are tested with data collected during the diffusion of six innovations. While our findings support the model, especially with respect to the role of innovative individuals, they also demonstrate the need to develop explanations of rejection.

Salter, A. and Torbett, R. (2003). "Innovation and Performance in Engineering Design." *Construction Management and Economics*, 21: 573-580.

> **Abstract:** This paper explores the experiences of engineering, design and construction organizations (EDOs) in developing innovative approaches to performance measurement in their design activities. It contrasts experiences of these firms with those of manufacturing organizations. It finds that performance measurement of engineering design activities is poorly understood in many industries, including construction. The development of new performance measures can provide a new opportunity for innovation

in engineering, design and construction firms. At present, the measures used to assess design in construction are based on the financial performance of a project rather than other important objectives of the design process, such as quality and buildability. In manufacturing industries, firms rely on measures of new product development, but these indicators also say little about the measurement of engineering design activities, that is, those on-going and continuous. To realize the innovative potential of design and performance measures, EDOs need to take a broader perspective on the nature of design activities, and to look to the experiences of leading manufacturing firms to find new ways of measuring and understanding their design activities.

Salwen, P. (2003). "Fostering Innovation and Entrepreneurialism in a Value-Driven Organization." *Journal of Leadership and Management in Engineering*, ASCE, 3: 153-158.

Abstract: In this interview with the founder and chief executive officer of BEM Systems, Inc., an environmental science and engineering firm, attention is given to the approach that has enabled a small company to go beyond the narrow scope of an assignment and develop creative solutions that support the long-term business goals of its clients. In being entrepreneurial, the employees of the firm look for connections between disparate sectors of the industry and draw on latent talents and relationships in an effort to turn any opportunity first into a strategy and then into a concrete, revenue-generating project. The key role that innovation played during the company's formative stages is recounted. The company's hiring and compensation practices are then discussed, and the importance of creating a culture that respects and rewards innovation is stressed. Attention is also given to the company's project management quality control system.

Schein, E. (1999). The Corporate Culture Survival Guide: Sense and Nonsense about Culture Change. Jossey-Bass, New York, NY.

Slaughter, S. (1993). "Builders as Sources of Construction Innovation." *Journal of Construction Engineering and Management*, ASCE, 119(3): 532-549.

Abstract: Innovation in the construction industry occurs to a much greater extent than is usually recognized, and the sources of these innovations are more likely to be people working on-site rather than manufacturers or research laboratories. Thirty-four innovations to a single technology, the stressed-skin panel, are examined; and it is found that the vast majority of these innovations were developed by builders rather than manufacturers. In addition, these builder innovations were significantly different from those produced by the manufacturers. The builders' innovations explicitly integrate the panel into the total building system; the manufacturers' innovations are confined to the panels themselves. A third finding is that manufacturers commercialized few of the builders' innovations—particularly avoiding those that involved connection of the panels to other systems—despite their potential for substantial improvement in the performance of the panel overall. The implications of these results is that users of technologies can be important sources of technological innovations and improvements, and the design of products can explicitly accommodate the need for changes and innovations on-site.

Waterman, R. Jr., Peters, T., and Phillips, J.R. (1980). “Structure is not Organization.” *Business Horizons*, Edward Elgar Publishing, 23(3), June 1980, 14-26.

Winch, G. (2003). “How Innovative is Construction? Comparing Aggregated Data on Construction Innovation and Other Sectors - A Case of Apples and Pears.” *Construction Management and Economics*, 21: 651-654.

Abstract: This research note addresses the widespread perception that construction performs badly compared to other industrial sectors. The evidence for this perception is usually based on comparative industrial performance data. However, due to technical problems with the Standard Industrial Classifications used, like is not compared with like in these analyses, to the systematic disadvantage of the construction industry’s comparative performance. In an effort to improve the performance of the industry, the auto industry is often held up as an exemplar. However, when that industry is compared on a like-for-like basis with construction, it proves to have a poor record of performance.

ADDITIONAL RESOURCES

Points of Contact

Dr. John A. Gambatese
School of Civil and Construction Engineering
Oregon State University
220 Owen Hall
Corvallis, OR 97333
Tel.: (541) 737-8913
E-mail: john.gambatese@oregonstate.edu

Robert K. Tener, Executive Director
Charles Pankow Foundation
223 West Foothill Blvd., 2nd Floor
Claremont, CA 91711
Tel.: (909) 634-8595
E-mail: info@pankowfoundation.org

Walker Lee Evey, President
Design Build Institute of America
1100 H Street, NW, Suite 500
Washington, DC 20005-5476
Tel.: (202) 682-0110
E-mail: info@dbia.org

Other Resources

Listed below are additional resources created from the Energizing Innovation in Integrated Project Delivery research study. Copies of the resources can be obtained on the Pankow Reports webpage under Publications on the SPUR (San Francisco Planning & Urban Research Association) website (www.spur.org/pankowreports/).

Innovation Manual of Practice
The Innovation Manual of Practice addresses innovation and specifically how firms can work to make innovation a significant part of project delivery. The manual, a product of research funded by the Foundation for Integrated Services and the Charles Pankow Foundation and conducted by Oregon State University, is intended to serve as a guide for practitioners when contemplating innovation on their projects. Best practices that research has shown to be the most effective are provided, with other methods also detailed so that the reader has a good understanding of all of the components involved in pursuing innovation. The goal is to energize innovation within the construction industry and help owners, designers, and contractors collaborate more effectively to deliver successful projects. The manual is intended for use by owners, architects, engineers, and constructors and on all types of construction projects. The manual contains several components to assist with implementation. An implementation flowchart is provided that indicates steps to

take to enhance and maintain innovation. Best practices that appear to be the most effective in spurring on innovation are provided as well.

Energizing Innovation in Integrated Project Delivery Monograph
A monograph is available which presents the salient results of the Energizing Innovation in Integrated Project Delivery research study. The monograph contains a description of the research study along with the findings, conclusions, and recommendations. It also presents detailed descriptions of best practices and guidelines for enhancing innovation on construction projects. The monograph is designed to be used by integrated project delivery practitioners in developing the means and methods to encourage innovation in their projects.

Energizing Innovation in Integrated Project Delivery Slide Presentation
A PowerPoint slide presentation is available that describes the research study, results, conclusions, and recommendations. The presentation is helpful for on-line learning of best practices to enhance innovation on projects. Practitioners may also find the presentation of interest for educating others on a project or within a firm about innovation.