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Measuring Construction Innovation

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Abstract
Innovation is a complex and multidimensional process that has received the attention of researchers in all fields due to its contribution to economic growth and competitiveness. Innovation in general terms is the creation and adoption of new knowledge to improve the value of products, processes, and services. Although there are numerous studies investigating the implementation and management of innovation in construction, more research is required to develop appropriate metrics for different types of innovative activities that are carried out throughout the lifecycle of a construction project and at different sectors of the construction industry. Innovation in construction generally tend to be process and organization-based; construction companies invest less in R&D but rather adopt new technology and new ideas to improve their operations. Therefore, such innovations are difficult to capture with the standard indicators used for technology-intense sectors. The major objective of this study is to discuss the difficulties associated with measuring innovation in construction and provide recommendations to overcome the limitations for developing relevant metrics. In this respect, the appropriateness of metrics used for construction innovations will be investigated and how these metrics can be improved will be discussed.

Keywords
Innovation measurement, Construction industry, Built environment

1. Introduction

Innovation is regarded as one of the key factors contributing to national economic growth, competitiveness, and higher living standards. As far as the strategic role of intangible assets is concerned, innovation is at the heart of the knowledge-based economy of the countries as well (OECD and Eurostat, 2005). There is not a single and complete definition of innovation, however it may be defined as creation and adoption of new knowledge to improve the value of products, processes, and services. Innovation can be technological as well as non-technological including organizational and marketing aspects. Patterns and types of innovation differ both at sector level and firm level. The characteristics of innovation in the service industries are different from those in manufacturing industries (OECD and Eurostat, 2005).

Innovation can be a key source of competitive advantage for construction companies, offering the means through which a firm can achieve a client's objectives in a specific project, or its own objectives over a range of projects (Slaughter, 2000). As Barrett *et al.* (2001) have suggested, specific research into innovation in construction must be undertaken and all generic innovation research be "envisioned, embedded and evaluated in a construction context to form a robust body of construction innovation knowledge in its own right".

Innovation measurement tended to focus on products and related production systems that is based on measuring inputs to innovation (R&D expenditures, education expenditures, capital investment) and intermediate outputs (publications, patents, workforce size and experience, innovative products) (Milbergs and Vonortas, 2004). As NESTA (2006) stated, traditional indicators of innovation performance are heavily biased toward investments in scientific and technological invention and so do not capture innovation in non-research intensive industries and there is a gap between actual innovative activity and the conventional measures that are intended to represent it. The construction industry provides an example of a sector within which traditional measures do not reflect the true extent of the innovative activity that is taking place (NESTA, 2006; Barrett *et al.*, 2007). As much of this innovation is process and organization-based and hidden at the project level; construction companies tend to invest less in R&D and rarely create new patents (NESTA, 2007; BERR, 2008), therefore such innovations are difficult to capture with the standard indicators used for technology-intense sectors. Sound policy analysis and decision-making requires relevant indicators in order to remove this gap and capture the hidden innovation in construction (Barrett *et al.*, 2007).

The major objective of this study is to discuss the difficulties associated with measuring different types of innovation activity in construction and to propose relevant metrics to measure these innovations. In this respect, studies dealing with innovation in the construction industry are reviewed, indicators that are used to measure dimensions of innovation are highlighted, a framework for analysing construction innovation is presented and how these indicators can be improved and revised to capture construction innovations is discussed. Finally, it is suggested that specific metrics should be developed to assess the inputs, implementation (processes/activities), contextual (institutional) factors, outputs, and impacts of innovation and different indicators should apply to different sectors of construction industry for an accurate analysis.

2. Innovation in Construction

Innovation is "*the adoption of an idea or behaviour, whether a system, policy, program, device, process, product or service, that is new to the adopting organization*" (Damanpour, 1992). It is a complex and multidimensional process having a number of outcomes including the renewal and enlargement of products and services, and their associated market; new methods of production, supply and distribution; and new organisational and work forms and practices (Barrett and Sexton, 1998).

According to DTI (2007), innovation can take several forms including product innovation (changes in the products/services) which an organisation offers; process innovation (changes in the ways in which they are created and delivered); position innovation (changes in the context in which the products/services are introduced); paradigm innovation (changes in the underlying mental models which frame what the organisation does). Phillips (1997) distinguishes between technological innovation and non-technological (including organizational and marketing) innovation. Technological innovations comprise implemented technologically new products and processes and significant technological improvements in products and processes. Organisational innovation in the firm includes significant changes in organisational structures; the implementation of advanced management techniques; and the implementation of new or substantially changed corporate strategic orientations. Marketing innovation, on the other hand, is the implementation of a new marketing method involving significant changes in product, price, and promotion strategy (OECD and Eurostat, 2005).

Innovation can be observed at three different levels namely the 'sector-level', 'business-level' and 'project level'. Among these, sector-level is the most visible type of innovation and project level is the most hidden (Barrett *et al.*, 2007). Being project-based, construction is known to be among the low innovative industries. In addition, the organizational context of construction innovations differs significantly from a great portion of manufacturing innovations (Slaughter, 1998). Construction is a very diverse sector and there is not one single way in which innovation occurs. According to Lansley (1996) the occurrence of innovation within the construction industry is often characterised by the widespread adoption of new practices as a result of advances in technological and business processes. Slaughter (1998) presented five models of construction innovation categorised as incremental, modular, architectural, system and radical, which can provide a basis upon which companies can select and implement the innovations. Incremental innovation is a small change, based upon current knowledge and experience, whereas a radical innovation is a breakthrough in science or technology that often changes the character and nature of an industry.

Many studies on how innovation could be implemented in construction projects have been undertaken (Tatum, 1987; Slaughter, 1993, 1998, 2000; Winch, 2003). There have been a number of case studies of how successful firms have been able to make a range of different organizational, managerial or technological innovations to overcome the limits of their environment (Slaughter, 1993; 1998; Veshosky, 1998; Koskela and Vrijhoef, 2001; Sexton and Barrett, 2003; Cleasby, 2004); yet there have been relatively few large-scale surveys of innovation in construction and what role these processes of innovation are having in reshaping practices. Seaden and Manseau (2001) developed a conceptual model for the analysis of innovation in construction to describe the linkages between the business environment, business strategy, innovative practices and business outcomes. Dikmen *et al.* (2005) developed a conceptual framework to investigate value innovations within construction companies in Turkish construction industry, where the elements of the model are objectives, strategies, environmental barriers/drivers, and organizational factors. Yitmen's (2007) study focused on the investigation of the challenge of change for innovation in North Cyprus construction industry. These studies usually focused on how innovation is managed within one firm and there is a lack of focus on specific project stages as well as a lack of specific focus on different construction sectors. Only a small minority of the research articles have considered innovation at a specific stage of the project lifecycle or from the point of view of the project lifecycle in general (Dickinson *et al.*, 2005). Moreover, none of these studies discussed the accurate measurement and proper indicators for construction innovation.

3. Innovation Measurement

As a significant economic variable, the measurement of innovation has attracted a lot of attention. However, due to the complexities inherent in the whole process, measuring innovation is not an easy task. One of the major limitations is related to the definition of innovation. Innovation may be regarded as development of new products/services/technologies/strategies or the implementation of new processes (adoption) or the continuous improvement within the organizations. Innovation can be technological and/or non-technological. Innovative activities and effects of innovation depend extensively on the why innovation takes place (drivers) and who innovates (actors) as well as the external environment the innovation takes place. Several surveys have been conducted to measure the innovativeness of firms and countries. Connecting enterprise level indicators to macro economic performance is difficult. Therefore, proper indicators are necessary to link the outputs of innovation at firm level to the impacts at national level.

3.1 Measuring the Inputs and Outputs of Innovation

Innovation is a complicated phenomenon having inputs and outputs as well as the impacts on several aspects of performance of companies and nations. Historically, organizations and public bodies have tended to measure innovation in terms of inputs (e.g. R&D expenditure) and outputs (e.g. patent or

trademark applications) (Archibugi and Pianta, 1996). Although extensively used, these two indicators are not sufficient to measure innovation process as a whole. No single measure is able to capture innovation's multiplicity of features. In addition, metrics for inputs and outputs of innovation should be distinguished at the firm, sector and national levels. The following paragraphs present the input and output metrics to measure innovation.

Input metrics of innovation: Several metrics are proposed in the literature for measuring the inputs of innovation. R&D expenditures can be measured as the percentage of the gross value added of all industrial firms spent on R&D, whereas the total innovation expenditures (R&D and non-R&D) are measured as the percentage of the total turnover of industrial firms spent on innovations (Hesen, 2001). The European Innovation Scoreboard (EIS) has three dimensions of innovation inputs including innovation drivers (e.g. number of graduates, broadband penetration rate), which measure the structural conditions required for innovation potential; knowledge creation (e.g. R&D expenditures, share of enterprises receiving public funding), which measure the investments in R&D activities; and innovation & entrepreneurship (e.g. number of SMEs cooperating with others and SMEs using organizational innovation ICT expenditures), which measure the efforts towards innovation at firm level (European Commission, 2006). Based on Milberg's (2004) classification, innovation input factors are listed as R&D (funding, intellectual property, patents, scientific publications), talent (human capital, education, competencies, experience), capital, and networks (knowledge communities, linkages, collaborations, public/private partnerships). The knowledge produced in industry, universities and government research institutes is clearly another key input for any innovation ecosystem (Turville, 2007).

Output metrics of innovation: A traditional indicator as an output measure of technological innovation is the number of patents granted. New products commercialized, market penetration and growth, cost reduction, profits, revenues and value to customers are among the output indicators of innovation (Milbergs, 2004). Output metrics used by the European Commission (2006) focus on two dimensions such as applications that measure the performance, expressed in terms of labour and business activities, and their value added in innovative sectors and intellectual property that measure the achieved results in terms of successful know-how.

3.2 Measuring Innovation as a System

An economy's rate of innovation depends on a range of activities and the links between them. Companies may take the lead, but do not innovate in isolation. Most innovations involve a multitude of organizations. This is especially the case for the most knowledge-intensive, complex technologies (Milbergs and Vonortas, 2004). Systemic innovation metrics are necessary to capture the context in which organizations form and match expectations and capabilities to innovate. Besides measuring the inputs and outputs of innovation, the process and contextual variables should be investigated as well as the impacts in order to fully realize the benefits of innovation.

Process variables comprise sources of information available to firms; cooperation between firms on R&D; difficulties encountered by firms during innovation projects (Hesen, 2001); management issues (strategies, practices, organizational factors, internal barriers); product development activities (design, engineering, marketing, distribution); and absorptive capacity (Milbergs, 2004).

According to Milbergs (2004), four contextual domains are distinguished that influence the rate and direction of innovative activity. These include the macro-economic conditions such as fiscal/monetary environment, interest rates, global economic growth rates, demographics; public policy conditions such as R&D funding policy, taxes, intellectual property, regulations, standards and market access policies; innovation infrastructure conditions such as university research infrastructure, federal labs, capital markets, power and transportation systems, regional clusters; and national mindset such as public attitudes to science, cultural factors, and political issues related innovation. More research should be done

to explore knowledge production and utilization, technology transfer, standards, entrepreneurship, services innovation, general purpose technologies, public policy impact, innovation infrastructure and relating these factors to the impacts at national level (Milbergs, 2004).

Various indicators can be used to measure the impact of innovations on the performance of the firms. Among these are the proportion of sales due to technologically new or improved products; the results of innovation effort; the impact of innovation on the use of factors of production (OECD and Eurostat, 2005). Economic impact factors such as growth, employment, productivity, standard of living, competitiveness and global market share are among the national impacts of innovation (Milbergs, 2004).

3.3 Indicators for Measuring Construction Innovation

Modern construction companies largely function and innovate by the quality of their processes, the people operating them and the way in which they change and adapt to suit the changing business environment. Much construction innovation is project-based and unrelated to formal R&D expenditure and many innovations, particularly organizational or process innovations are neither patented nor trademarked (Slaughter, 1993). Therefore, traditional indicators poorly reflect the true level of innovative activity in construction. This gulf between practice and measurement is the real innovation gap (NESTA, 2006).

Based on the analysis of construction innovation literature by Dickinson *et al.* (2005), studies on construction innovation so far lack specific focus on level of analysis, stage of lifecycle, and sector. The levels of analysis involve the product, project, firm, industry and national levels. The firm level has received most attention in the analysed literature; this might be because the principal drivers for innovation are often created at the firm level (Seaden and Manseau, 2001). Innovation could be investigated in different stages of the lifecycle including the design, preparation, construction, and maintenance. As Winch (2003) argues, most product innovation in construction is excluded from the analysis in industry-based surveys. Furthermore, different sectors in the construction industry should be included in the analysis. Architectural and engineering consulting firms that carry out most of the design work in construction are excluded from the standard construction industry classification. This point is developed further by Barrett *et al.* (2007) who point out that the standard definition of construction does not include much of the value-adding construction activity such as manufacturing, architectural and technical consultancy, business services, and real estate activities. The built environment cluster analysis provides a wider approach to analyse the operations and functions of the construction sector within the overall economy of a country (Carassus *et al.*, 2006). Adopting a built environment view helps analyse the major economic activities of manufacturing, production, asset management, project management, distribution, and services. A similar approach was adopted in one of the studies (Reichstein *et al.*, 2005) that included all firms in traditional construction as well as the firms involved in architectural activities, urban planning and landscape design, quantity surveying and engineering consultancy and design activities in the variable broad construction sector.

According to the Oslo Manual (OECD and Eurostat, 2005), the minimum set of data that would need to be collected in an innovation survey consists of the type of innovation; the economic benefits flowing from the innovation activity; the expenditure on innovation activity; the purpose of the innovation activity; and the source of ideas/information for the innovation activity. In this respect, a framework approach is necessary to establish proper innovation indicators. Such a framework should consist of the key elements regarding the whole innovative process. Figure 1 shows the proposed innovation framework where innovation in construction is analysed within a framework that links the inputs, implementation (processes/activities) factors and contextual (institutional) variables to intermediate outputs that finally lead to impacts.

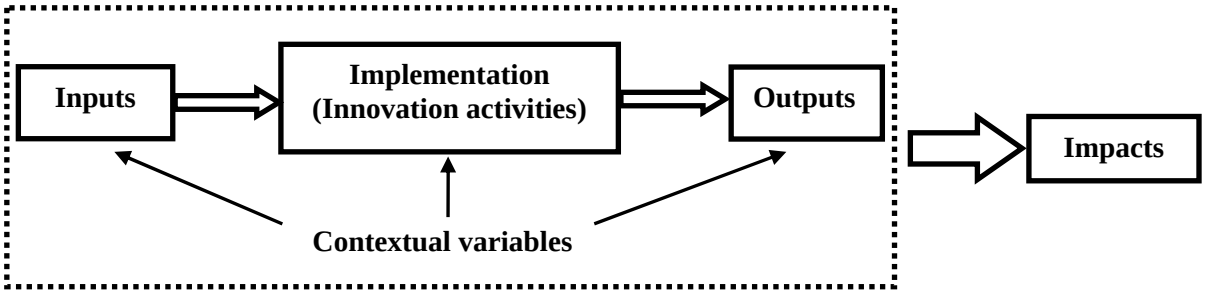

Figure 1: Framework for Analysing Innovation in Construction

Table 1 shows the identified metrics for firm-level innovation that are derived from the literature. However, relevant metrics should be developed to distinguish the components of innovation at the project, firm, sectoral, and national levels. Besides, innovation measurement surveys should identify the areas of construction industry such as construction, engineering, surveying, architecture and design, facilities management, legal, education, and consultancy as suggested Chartered Institute of Building (CIOB, 2007).

Table 1: Measures of Innovation at Firm Level

Inputs	R&D spending Number of R&D projects Number of ideas or concepts Number of people actively devoted to innovation Sources of information (internal and external) Capital (investment in ICT, purchase of software and equipment) Networks (technology alliances)
Contextual (institutional variables)	Organizational factors (company structure, culture, organizational learning, resources) Country related factors (political, economic, regulations, public policies, socio-cultural conditions) Industry-related factors (fragmentation, competitiveness, technological advancement, project-based, lack of an agenda, no of parties, legal issues)
Implementation (processes/activities)	Tools, techniques, strategies (knowledge management, human resources, IT and R&D, design, marketing, distribution, business process reengineering)
Outputs	Number of new products introduced/commercialized/exported Number of new processes/services introduced Intellectual property (patents, trademarks, designs)
Impacts	Revenue growth due to new products or services Short and long-term profitability Increase in organizational effectiveness Increase in technical capability Improvement of service/product quality/processes Improvement of organizational structure Improvement of human resources Market penetration and growth Better company image Innovation collaborations Improvement of client satisfaction

4. Conclusions

Innovation is a dynamic, interactive, open, global, and a multidimensional activity that increases competitiveness, generates economic benefits, and improves the quality of living standards through the successful exploitation of new ideas and technologies. Due to its contribution to several performance indicators at firm and national level, accurate measurement of innovative activities in all industries are becoming more important. Patterns of innovation in construction industry are different in many ways from those of others. Since construction innovation tends to focus more on changes in organizations and processes rather than technological basis, it is difficult to capture such innovations using the traditional indicators (R&D and patents) that are mainly developed to measure technological innovations. In this respect, the major objective of this study was to discuss the appropriateness of metrics reported in the literature for the construction industry. Indicators for inputs, processes, outputs, and impacts of innovation are reviewed. In addition, contextual factors related to the environment where the innovation takes place are mentioned.

A framework is presented to analyse the whole innovation process within the construction industry and some metrics are proposed to assess dimensions of innovation at firm level. It is suggested that subsectors of construction should be included in the innovation surveys in order to capture the hidden innovation in construction. Companies operating in building, infrastructure, housing, industrial, etc. sectors could be surveyed individually in order to explore different patterns of innovation. Investigation within the broader built environment cluster rather than focusing on the construction process alone can be better way of understanding and measuring innovation in different phases including the production, construction, and marketing. Analysis of distinct project stages and development of proper indicators will allow effectively measuring the different types of innovative activities. Finally, components of innovation should be investigated at the project, firm, industry, and country levels and relevant metrics should be developed to explore the innovation activities and impacts.

5. References

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