ITcon

www.itcon.org - Journal of Information Technology in Construction - ISSN 1874-4753

STRATEGIC ROADMAPS FOR CONSTRUCTION INNOVATION: ASSESSING THE STATE OF RESEARCH

PUBLISHED: August 2009 at http://www.itcon.org/2009/26

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SUMMARY: *A strategic planning initiative was undertaken to advance innovation in the Canadian construction industry. A preliminary step in this strategic planning process was to carry out an inventory of the current state of research relating to the construction process that was conducted within Canadian Universities. It was found that this type of current research inventory was not often included in strategic planning initiatives, but has proven to be a valuable contribution to the process.*

The paper describes the research inventory initiative and briefly summarizes the resulting picture of the construction research landscape in Canada. This methodology involved collecting summaries of over 100 individual research projects, mainly through direct interviews, and deriving a series of research classifications through a clustering analysis of the results. The projects were classified according to the three dimensions of application area, technology, and innovation lifecycle phase forming a framework for analysis (resulting in three distinct roadmaps of current Canadian construction research). Further dimensions of scale, drivers, and time are then added to further assist the ongoing strategic planning process.

Two examples of opportunities and activities underway to improve the innovation climate are discussed as they relate to the use of the framework. The scope of the strategic planning process is expanding in scope to include other stakeholders in the process (e.g., industrial research, users of technology). The results are expected to provide an underlying planning, coordination, and dissemination foundation to improve the ability for the research community to contribute to innovation in the Canadian construction industry.

Key beneficiaries of this paper are individuals involved in creating and using industry-level strategic plans for construction innovation. The timeframe for the discussed roadmap is 0-2 years.

KEYWORDS: *Construction Research, roadmap, strategic planning, Canada*

REFERENCE: *Froese T, Rankin J (2009) Strategic roadmaps for construction innovation: assessing the state of research, Journal of Information Technology in Construction (ITcon), Vol. 14, Special Issue Next Generation Construction IT: Technology Foresight, Future Studies, Roadmapping, and Scenario Planning, pg. 400-411, http://www.itcon.org/2009/26*

1. INTRODUCTION

1.1 The Innovation process

Innovation is the process through which new ideas enter practice. It is the mechanism at the centre of the key strategic objective of continuous improvement. A successful innovation life cycle turns something new into something that is standard practice. Like other organizational processes, innovation is greatly enhanced by effective management.

This paper examines planning and management processes to improve the innovation processes within the construction industry, with a particular focus on information and communication technologies (ICT). The approach is to present conceptual models that help to understand these processes and support analysis techniques. These models are structured into a single, multi-dimensional framework for the innovation processes in construction ICT, ranging in scale from individual construction projects to international construction sectors.

This paper follows, in part, from a strategic planning initiative focussing on construction process technologies in Canada. This initiative was sponsored by the Institute for Research in Construction of the National Research Council of Canada. As a preliminary step in this strategic process, a survey was conducted to assess the state of Canadian university-based construction research (Froese 2009). Not only did this study produce an overview of the research topics under active investigation in Canada, but it also yielded results in survey and analysis methodology. In particular, each research project studied (over one hundred) was categorized and plotted on three different roadmaps—a first describing the application area, a second describing the technology area, and a third describing the innovation life-cycle phase. These three roadmaps can be thought of as axes that define a three dimensional “construction innovation space”, within which any technology innovation activity can be located. Subsequent to this study, we have expanded upon this approach of a multi-dimensional construction innovation space as an integrative structure that can incorporate a wider range of innovation issues to provide a cohesive framework for innovation within the construction industry.

After introducing the framework, this paper discusses the application of the framework to support the innovation process, and links this to other ongoing research activities by the authors. For example, a first step in employing the framework is to support an analysis of where the industry stands and where opportunities for improvement might exist for the construction industry. A benchmarking study that explores these questions is introduced, and we believe that this identification of gaps in the innovation process will better enable researchers and practitioners to direct efforts in quickening the pace of innovation within the industry. At a different scale, the innovation process applied to individual construction projects is less about creating new ideas and more about introducing new techniques into projects and managing them effectively. We introduce the topic of project information management as a response to this need.

2. POINTS OF DEPARTURE

2.1 Principles of innovation in construction

There is an extensive body of knowledge surrounding the general topic of innovation in construction. The efforts of several successive CIB task groups (TGs) have established a somewhat common view of many of the issues surrounding the process of innovation in the construction industry. Results from TG35 Innovation Systems in Construction (Manseau 2001) provide a definition for innovation within the context of the construction industry and a policy level understanding of the issues involved. Upon an examination of the public policy from 15 different countries, it was determined that an impact on innovation was achieved through: promotion of long term value and performance; emphasis on performance versus prescription; local programs based on access to technologies; promotion of collaborations; and pre-market evaluations of products and processes. There was also recognition that innovation within the construction industry is not a linear model but closer to the concept of complex products and systems (CoPS) which is highly reliant on knowledge transfer and the flow of information.

With an emphasis on the flow of information, TG47 Innovation Brokerage in Construction (Winch 2007) examined the mechanisms that make innovation happen at an organizational level and the catalyst role of brokers which provide the necessary information to support knowledgeable decisions surrounding adoption and implementation. One of the primary issues identified is the ability to effectively manage the information that is required for a new process to succeed in practice. Most recently, TG58 Clients and Construction Innovation (Brandon 2008) identified how the client can impact innovation within the construction industry and acknowledge some of the basic mechanisms required to facilitate the flow of information, such as establishing and measuring performance metrics and the subsequent encapsulation and dissemination through best practices.

2.2 Innovation in the construction process

There are several things to note with respect to information and communication technologies (ICT). We are talking for the most part about a change in design and management practices through implementation of technology and therefore categorize the change as a process-type innovation versus an innovation arising from a new product. From an information flow perspective, the essentials that must exist for change (innovation) to happen includes information (in the form of know how) and standards of practice. Relating this back to the policy level (Manseau and Seaden 2001), the industry requires information that provides assessment of long term value and performance from an unbiased source. A key feature to reduce bias is the availability of an agreed upon standard—in this case, a standard of practice.

It is worth contrasting ICT innovation with other process and product innovations. For product innovations, we may consider how a new construction material and its associated method of installation (on-site activities) gets introduced and is adopted for use in the industry. For example, the use of insulated concrete forms for foundation walls is a relatively new approach in the Canadian construction industry for both commercial and residential construction. At the time of its early adoption (1999), this innovation had the necessary conditions in place where the National Research Council of Canada developed an initial opinion from NRC Institute for Research in Construction Canadian Construction Materials Centre (CCMC) that it meets National Building Code of Canada (NBCC) and, by extension, it satisfies Canada Mortgage and Housing with respect to aspects of financing and insurance. In addition, there was a plethora of information from suppliers on how to properly use the technology. There is also support for a limited set of process innovations. For example, quality management may rely on the ISO 9000 series of standards and safety management may rely on a variety of legislated acts and regulations as well as standards of implementation (e.g., CAN/CSA Z1000-06). In addition to these pseudo-standards of practice, there are also mechanisms for assessing their implementation and use, through certification or compliance with legislation.

However, we do not have the same types and detail of information from suppliers of process technologies (practices) and there is no equivalent standard or code nor method of validating conformance for construction practices. From this perspective, we are missing two key ingredients. We suggest that innovation in the area of process technologies is no different then other areas in that it requires knowledge of previous experiences represented as standards of practice. These standards of practice are unlikely to take the form of formal standards issued and certified by a standards organization, but rather well-structured knowledge and best practices that are widely known and followed throughout the industry. The work described in this paper relating to frameworks for innovation, as well as the more specific techniques of performance benchmarking and project information management presented in Section 4, are examples of such standards of practice.

2.3 Classifying Construction Innovation

Efforts to manage the innovation process occur at many different levels within the construction industry—for example, processes for international R&D strategic planning, for corporate innovation management, or for introducing new technologies on individual construction projects. While these different processes will vary widely, a common feature is that they will explicitly identify the technical innovations being considered, and will often organize these innovations into some type of classification structure. For example, the FIATECH (2004) organization (a North American industry organization dedicated to advancing technology for capital projects) has developed a Capital Projects Technology Roadmap (CPTR) that positions emerging technologies into an overall vision for the construction industry (FIATECH 2004). At its highest level, the FIATECH CPTR is organized into a guiding model showing an integrated structure composed of nine critical elements that represent a virtual enterprise for the future:

- Scenario-based project planning
- Automated design
- Integrated, automated procurement and supply network
- Intelligent and automated construction job site
- Intelligent self-maintaining and repairing operational facility
- Real-time project and facility management, coordination and control

- New materials, methods, products and equipment
- Technology and knowledge-enabled workforce
- Lifecycle data management and information integration

The elements are organized according to the primary lifecycle phases of projects (planning, design, procurement, construction operations, and facility operations and maintenance). An overarching project management element spans across all of these, while the supporting elements of materials, workforce, and information provide an underlying foundation. Each element is expressed in terms of a future technology vision for the element. Within the body of the roadmap itself, each of these elements in decomposed into a comprehensive listing of the technological innovations required to reach the vision for the future.

Within a series of technology platform initiatives associated with the European 7th Framework Program, a European Construction Technology Platform (ECTP) project is currently underway (ECTP 2009). The ECTP is structured around seven focus areas:

- Underground Construction
- Cities and Building
- Networks
- Cultural Heritage
- Quality of Life
- Materials
- Processes & ICT

The first four are vertical focus areas that address specific segments of the industry, while the last three are cross-cutting, or horizontal, themes that integrate these topic areas across industry segments. The outputs of the activities related to these focus areas include contributions to a Vision 2030 plan, a strategic research agenda, and priorities to be implemented by national and European R&D programmes.

The FIATECH CPTR and the ECTP are both examples of conceptual frameworks for innovation in the construction sector that organize innovative technologies according to a single classification structure. Conceptual frameworks provide mental models that represent, simplify, and clarify complex real-world issues. They assist understanding and reasoning about the complex issues associated with the topic of innovation throughout the construction industry. For many purposes, these single classification systems provide simple, useful, and very appropriate frameworks, which help those involved to better identify and pursue the set of innovations being considered. However, such frameworks do nothing to enhance understanding or support improvements to the innovation process. Our approach is to incorporate several more factors into the framework—extending the single dimensional model to a multi-dimensional model—in order to support a more comprehensive and richer understanding of the innovation process. We will briefly introduce these dimensions here, then expand on each one of them in the following sections of this paper.

3. A MULTI-DIMENSIONAL FRAMEWORK FOR CONSTRUCTION INNOVATION

In the Canadian construction research survey introduced previously, we applied a three dimensional approach to produce three distinct roadmaps of construction-related research projects in Canada—namely, a roadmap of application areas for the research (i.e., the construction issue being addressed by the research), a roadmap of the technology used, and a roadmap of the innovation lifecycle phase addressed by the research (e.g. from early-stage development of the underlying technologies to later-stage application of existing, established technologies). Here, we have further developed this structure into a multi-dimensional framework for supporting construction innovation.

A framework based on these three classification facets defines a three-dimensional space (the "construction innovation space"). Any innovation activity (e.g., an R&D project) can be positioned within this three dimensional space to give a more complete understanding of the coverage of topics, etc., than is provided by a single dimension framework. The framework also supports analysis and management activities: for example, starting by defining the areas within the construction innovation space that require activity and then initiating action in these areas; or defining performance indicators for each important area within the three-dimensional space (applications of the framework are addressed later in this paper).

A three-dimensional framework has the distinct advantage of reasonable visualization through the analogy to 3D physical space. For example, innovation activities can be plotted on a three-dimensional graph. Although we forgo this advantage by adding additional dimensions, we have found that several other issues are also significant in understanding construction innovation and are orthogonal to the previous perspectives, and they therefore fit within the approach of additional dimensions added to the framework. These additional dimensions are the organization scale at which the innovation occurs, the objectives or drivers of the innovation, and the time dimension. These dimensions, six in total, are illustrated in Figure 1 and discussed in the following sections.

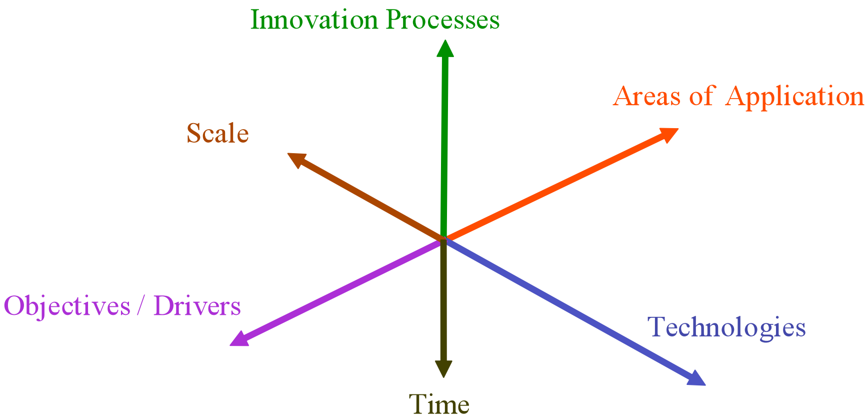

FIG. 1: The six dimensions of the proposed framework for construction innovation.

3.1 Dimension 1: Applications Areas

Construction innovations apply new techniques or technologies to some aspect of construction practice. The first dimension of the innovation framework classifies the application area—the field of activity within the construction industry to which the innovation is targeted. The application areas could be products or things within the construction industry (e.g., a new type of material), or they could be construction processes. The Canadian construction research survey, adopting the approach based on the FIATECH Capital Projects Technology Roadmap, expanded the application area dimension into a series of sequential life-cycle processes (e.g., design, procurement, production, maintenance, etc.) along with management processes that span the entire project lifecycle, and supporting processes that are considered to provide underlying foundation for all activities, such as collaboration processes, sustainability, etc. The application area dimension could also differentiate different sectors within the industry (which can have very different needs and different innovation mechanisms).

The application area dimension emphasises the industry's viewpoint of problems (pain points) within current practice, or the opportunities seen for improving practice. An example of how the application area dimension could be useful in supporting innovation planning is to look for differences between the application areas of current research efforts with those identified by industry as their most pressing needs: these would indicate gaps that would warrant consideration in strategic planning efforts.

3.2 Dimension 2: Technology Areas

The second dimension classifies innovation by technology area, which emphasizes the opportunities created by advances in technologies such as ICT. Within this dimension, the Canadian construction research survey classified research projects as being either computational or non-computational, with the majority of current research efforts falling within one of ten computational sub-categories. Whereas the application area dimension emphasized industry problem areas, the technology area dimension emphasizes the opportunities created by improved technologies and techniques.

3.3 Dimension 3: Innovation Process

While the first two dimensions describe the innovation itself, the third dimension, the innovation process, explicitly models the various lifecycle stages that move innovations from a new idea to a new standard practice. Whereas the application area dimension included consideration of the construction process, this dimension can be considered to be a "meta-process"—the innovation process that can act bring about advances in the construction processes. We have found that this explicit representation of the innovation process adds significant value, for example, in helping to highlight gaps in the process, as we will discuss later in this paper.

Figure 2 depicts a basic model of the innovation process. In progressing from an idea that is new to one that is standard practice, the steps include those that are more often attributed to the supply side: research, development, and deploy, to steps on the demand side: adopt, implement, and accept. It is worth noting that although presented as a linear model, the process of innovation cab be quite complex and has many iterative steps. The line between push and pull in Figure 2 is intended to be representative of a barrier that frequently exists in the flow of information regarding an innovation, a general disconnect or gap between the supply and demand.

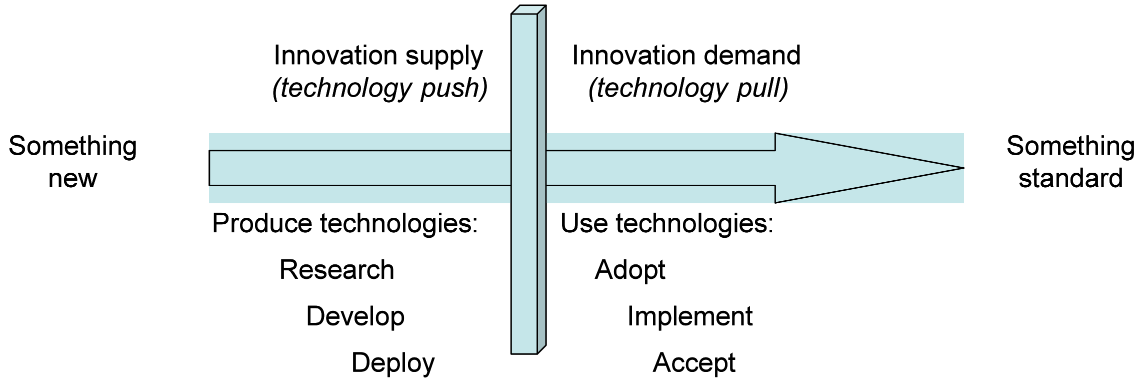

FIG. 2: A generic innovation process.

In the Canadian construction research survey, this dimension provides a perspective of the areas of emphasis with respect to the current research. As is the nature of construction engineering and management researchers, there are instances from purely research-research (so called white coat research) to implementation and acceptance research (analyses of impact though use in practice).

3.4 Dimension 4: Scale

The first three dimensions—application area, technology area, and innovation process—comprise primary views that were developed in the Canadian construction research survey. In this paper, we have extended this with three additional dimensions. The first extension to the framework is the dimension of scale that defines the level of granularity for a given innovation (or the level at which the process of innovation is examined). As we have previously mentioned, this can rage from across the international construction sector, to national or regional initiatives, to corporate processes, to individual construct projects and even individual practitioners. This dimension is significant both because the innovation processes are quite different at different scales, and because the interfaces between the scales is an important issue. For example, at the international industry-wide level, the focus is on large-scale research and development efforts to bring new technologies to market. At the national level, examples of innovation processes include strategic planning efforts such as the Canadian construction research survey, or the national productivity benchmarking studies described later in this paper. At the level of individual construction projects, the focus is less on bringing new ideas into the marketplace, and more on applying newer, emerging technologies to the project at hand (e.g., the focus of the project information management work described later in this paper).

3.5 Dimension 5: Objectives and Drivers for Innovation

A fifth dimension focuses on the objectives or drivers of innovation. Again, different objectives lead to different innovation processes. For example, national initiatives will differ if the drivers are a sagging economy than if the drivers are environmental sustainability issues; corporate innovation programs will differ if the strategy is technological leadership than if the strategy is competition based on price alone. This dimension is also important for linking together the different scales, since the objectives at one level of scale drive actions at the lower. More clearly defined objectives for innovation support efforts in assessing the success in adoption and implementation, as well as provide a means of measuring performance. Attaining clarity in objectives also goes to the heart of breaking through the common barrier between innovation supply and innovation demand, as illustrated in Figure 2, since this is the common ground that must unite the two segments of the innovation process.

3.6 Dimension 6: Time, The Dynamic Perspective

Finally, a sixth dimension is time. A static view of the previous dimensions provides a useful snapshot in time of the innovation processes. However, additional insight is gained by adding the time dimension and considering the dynamics of how these processes change over time. For example, an understanding of the changes to technology areas from year to year provides insight into technical trends, rates of change, and fads.

4. APPLYING THE FRAMEWORK

The innovation process framework provides a high-level conceptual model. This section discusses examples of how the framework can support users that are engaged in understanding, analysing, and managing construction innovation. At the most fundamental level, the framework provides a mental checklist that prompts users to consider the range of topics and perspectives associated with construction innovation. It illustrates how these different topics relate to each other, and can be useful in structuring gap analysis (identifying the gaps between the current situation and some desired future state, as a strategic tool for identifying objectives). By decomposing each of the six dimensions into greater range and detail of issues, the framework is able to support a spectrum of different activities related to the innovation process, a few of which are highlighted in this section. Specifically, this section discusses several initiatives previously undertaken by the authors relating to construction innovation. These initiatives pre-date this framework and did not benefit from its use, but here we describe each initiative in terms of the framework dimensions to illustrate how the framework might be applied and, where possible, how the framework could offer improvements to the initiatives. These initiatives include an assessment of the current state of innovation research and development, considerations of a national innovation strategy, and an assessment of current practice.

As previously noted, and a caveat to the description of the application of the framework that follows, to date only data from university-based researchers has been collected and analyzed. For a true application of the framework, a more comprehensive view of innovation related activities is required (i.e., data collection on the current status from other stakeholders in the industry). So, although we are exploring the application of the current roadmaps as a more robust framework, we do not yet have the full picture.

4.1 Using Dimensions 1 to 3 to Assess the Current status of Research and Development

We have shown that the innovation framework originated out of the Canadian construction research survey, which was carried out as input to a strategic planning effort that was intended to assess the needs and opportunities for a national initiative to promote innovation in the construction industry. To this end, the use of the first three dimensions was found to provide a valuable structure for organizing and analyzing the results of the research survey. To further demonstrate the opportunity for considering the relationships between the dimensions, we have here combined all three of these dimensions' classification of the research projects into a single figure. Figure 3 plots each of the 106 research projects included in the research survey. Each research project is located in a row according to the application area dimension, and in a column according to the technology area, and is indicated by an icon that illustrates the innovation phase dimension. The result not only gives a visual indication of the amount of activity within each category, but it conveys the inter-relationships between the dimensions. For example, clusters of research activity can be seen in the conceptual development of decision support systems for infrastructure, and in the conceptual development and application of 3D/4D systems to support traditional and emerging construction management tasks. It can also be seen that the computation research includes a large amount of conceptual development (i.e., research focussed on the development the basic approaches for applying some technology to some application area), whereas non-computational research is weighted more heavily on either data collection tasks, or on developing solutions that can be applied at a industrial production scale.

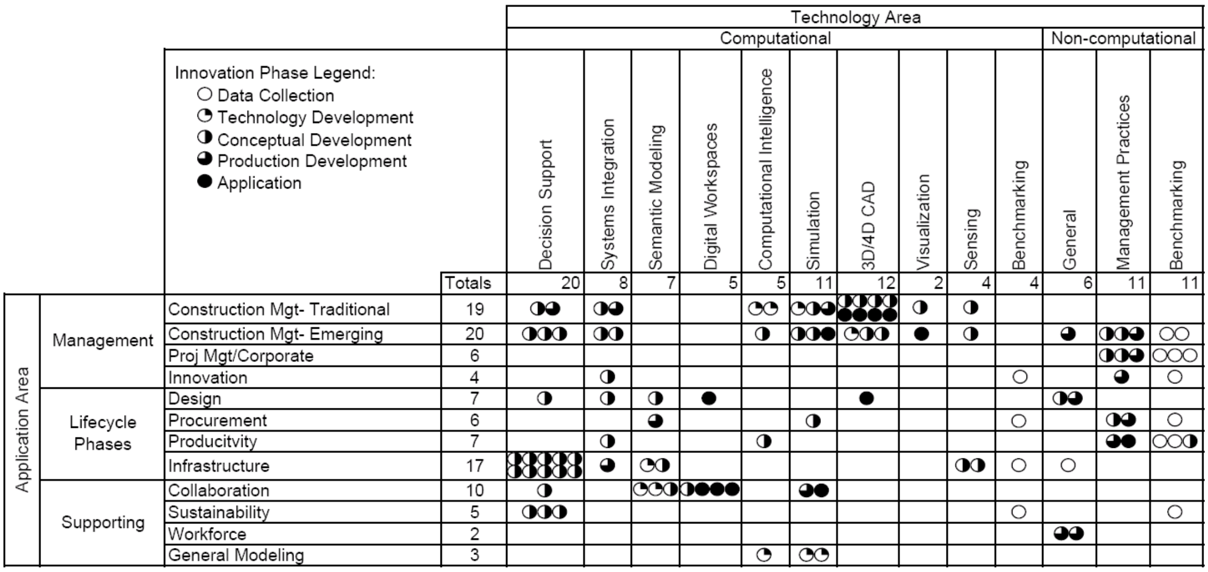

FIG. 3: Results of the Canadian construction research survey, combining the dimensions of application area, technology area, and innovation phase into a single figure.

4.2 Considering Dimensions 4 to 6 to Analyze Barriers and Opportunities to Advance Innovation at a National Level

As previously indicated, a primary motivation behind the Canadian construction research survey was to contribute to a better understanding of the current status of innovation in construction process technologies within the industry. As applied to the development of a national innovation strategy, the results of the survey (summarized in Figure 3) do provide insight with respect to the current focus of application areas, technology areas, and innovation phase. This section discusses these results further with respect to the additional dimensions of scale, objectives, and time, to better understand the barriers and opportunities for advancing construction innovation.

In support of a national innovation strategy, we desire additional insight on the scale dimension and perhaps more emphasis on the innovation process (innovation phase) dimension. An examination of the distribution of research projects based on the innovation phase (data collection—15, technology development—10, conceptual development—53, production development—15, application development—13) indicates a peak at the conceptual development phase. We could interpret this as demonstrating an expected focus of construction engineering and management research, or alternatively it could indicate a deficiency in front-end research activities (such as data collection) or downstream research topics such as those understanding the application of technologies. This is not to say that the focus of research projects undertaken by universities should have equal balance across the phases of innovation, but if we expect innovation to happen at an acceptable rate, then support should be offered by someone throughout the process. The survey results raise the question as to whether this type of support is in place.

Although we did not collect data or explicitly classify the research projects based on the dimension of scale, we observe that the majority of the research projects were aimed at developing systems that would be applied at an organizational or project level. Examples of work that may be aimed more at the industry scale level include the supporting application areas (e.g., sustainability, workforce issues, or general modelling); the technology areas of benchmarking; and the innovation phases of data collection or fundamental technology development.

Using the dimension of "objectives/drivers" of innovation provides additional insight with respect to what is being supported at a national level. Specifically, each research project would need to define this. Part of the answer lies in the "application area" which we would presume would align well with research objectives but might not always be stated well with respect to industry objectives. In the case of "technology area" (i.e., computational) there are multiple objectives driving innovation activities.

Finally, with respect to the sixth dimension of time, the Canadian construction research survey and the few additional relevant data sets available all represent specific instances in time. We have no data sets that have been repeated over some time interval. To fully understand the current state of innovation and to carry out strategic planning at all scale levels, it may be just as important to know how the objectives, application areas, technology areas, and gaps in each of these areas are trending over time. The time dimension of the framework emphasizes this "first derivative" of the other dimensions, and suggests that data collection, analysis, and planning activities should attempt to incorporate a consideration of changes over time.

4.3 Understanding the Innovation Gap 1: The Lack of Industry-wide Organizations to Support Innovation

To consider the perceived gap in the innovation process also requires a review of current status. The most recent comprehensive assessment of the Canadian Construction Industry was conducted by Statistics Canada in 1999 and reported as Innovation, Advanced Technologies and Practices in the Construction and Related Industries: National Estimates (Anderson and Schaan 2001). Among the data collected in this survey are the industry's sources of information in support of innovation, which include the following (with % of respondents): suppliers (72%), trade journals (55%), universities (12%), research organizations (9%). There is no distinction made between the type of innovation (i.e., their classifications along any of the framework dimensions). Again, this is an indication of a disconnect in the dissemination of information/knowledge between the innovation supply and innovation demand sectors of the industry

Upon further examination, Rankin and Lendzion (2001) identified a lack of broad-based industry organizations in Canada that identify best practices, establishes industry networks, and aligns objectives. These types of organizations exist in other countries, such as the European Construction Institute and the Construction Industry Institute in the USA. In Canada, existing entities have a dual focus on research and development, and dissemination, with no single sponsor that focuses on dissemination. The general conclusion was that guidance is required in technology development and mechanisms of dissemination need improvement. The establishment of honest brokers for practices was recommended.

This gap in information flow between innovation supply and innovation demand can be clearly positioned along the innovation process dimension of the framework. Relating this to the other framework dimensions could add additional insight into the issue. For example, comparisons of both application areas and technical areas being pursued by the innovation suppliers (as in the Canadian construction research survey) with those of the innovation users (e.g., the priority problem and opportunity areas identified by industry) would be invaluable in better understanding the innovation gap. Analysis of the innovation gap at different levels of scale is also insightful.

4.4 Understanding the Innovation Gap 2: Identifying Appropriate Innovations

Figure 4 illustrates a generic systems model of construction processes, along with inputs and outputs. Relative to this model, innovation typically takes the form of changes to the construction practices (D). Several issues arise in considering how these practices can improve through innovation. First, success in the adoption and implementation of new technologies requires knowledge (i.e., interpreted information in the proper format). Industry cannot make the proper decisions if it does not have the right kind of information regarding the existence and suitability of potential innovations. Second, we are interested in assessing the ability of potential innovations to meet the constraints (B and C) on a process for a given set of practices (D). Third, for those potential innovations that satisfy the constraints on the construction processes, we must assess their influence on the process's overall productivity (the increase in the ratio of Outputs per Inputs). All of these considerations require access to information about potential innovations.

Relative to the framework, the technology areas dimension suggests the range of potential innovations (new technologies and techniques). A classification of these potential technologies according to the innovation process dimension would suggest which potential innovations are sufficiently well-developed to use in pilot or production applications. Classification according to the dimensions of application area, scale, and objectives would help to narrow down potential innovations to those that met the condition and objective constraints of a particular project.

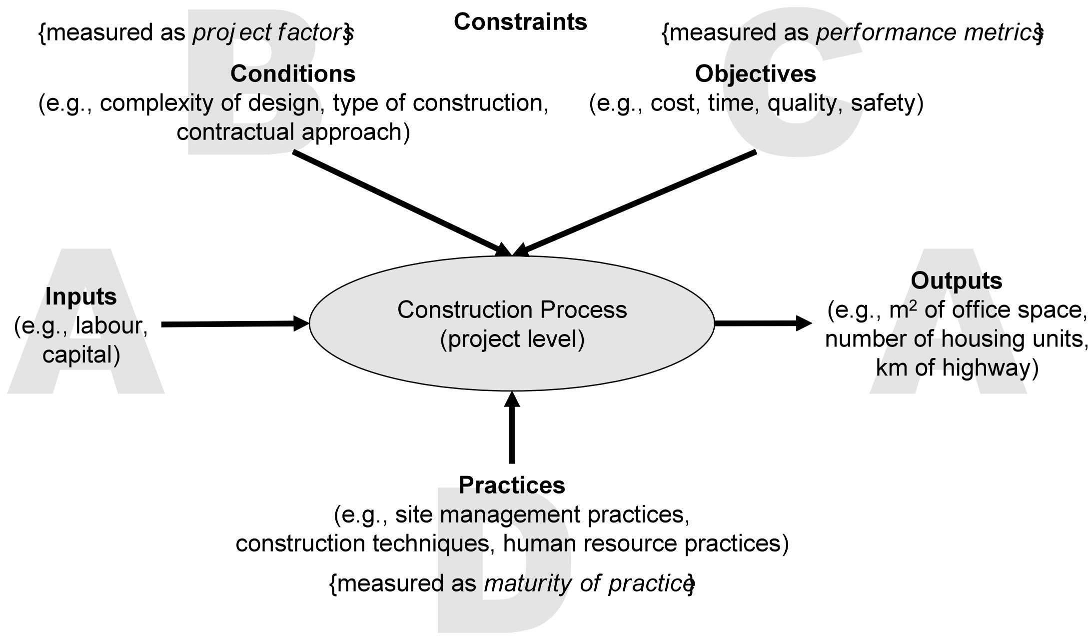

FIG. 4: The generic conceptual components of a construction process.

4.5 Potential Solution to Innovation Gap 1

The mechanisms to address the barriers between innovation supply and demand are known. As depicted in Figure 5, we need a combination of the solutions that answer the questions of information flow. Examples of how to approach this include: benchmarking process performance and complimentary capture and dissemination of best practices. Similar to other countries, Canada is currently undertaking a performance and productivity benchmarking program under the leadership of the Canadian Construction Sector Council (Fayek et al. 2008). This program has a significant emphasis on going beyond the standard approach of capturing performance metrics of cost, time, quality, and safety, to also account for a comprehensive set of constraints under which metrics are achieved and most importantly the practices that are employed. This is accomplished by first establishing a set of industry best practices (e.g., information management practices) and then assessing their implementation as a level of management maturity. Ultimately, the results will contribute to the solutions noted in Figure 5, where the information captured is readily available in a format that is usable for practitioners.

As noted, the framework would be valuable in support of analyzing the types (based on the various dimensions) of information flowing (or not flowing) and how this might be changing over time. However, with respect to the data collected surrounding innovation activities, the framework must be expanded in its scope to include all those involved in the process (i.e., beyond university based researchers).

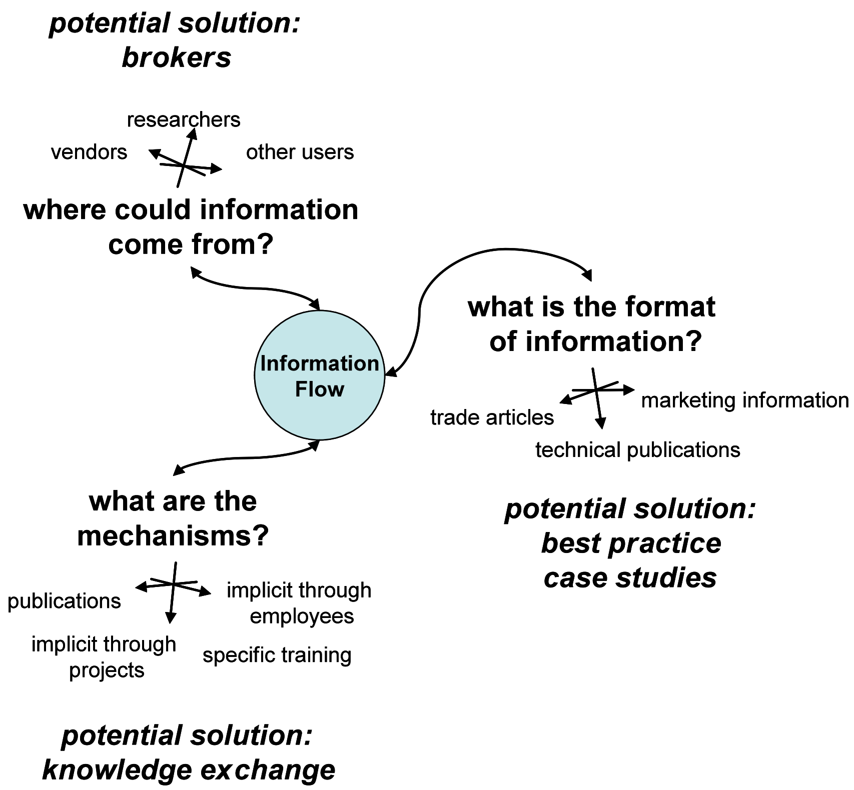

FIG. 5: Solutions to the information flow requirements.

4.6 Potential Solution to Innovation Gap 2

At the level of individual projects on the framework dimension of scale, the focus of innovation is less about bringing new ideas into standard practice, and is rather about how best to apply new ideas that are emerging in the surrounding marketplace to the project at hand. This becomes a process of managing innovation at the project level. We have been considering this issue for information technology innovations in particular. Information systems are becoming increasingly complex and important to project success, and a well-developed practice of project information management is required to take full advantage of their potential. Yet information management remains a much less-well-developed sub-discipline of project management than many other areas such as time management, cost management, risk management, quality management, or safety management. We have proposed a more formal development of the practice of project information management (Froese 2006). Not only would well-developed project information management practices improve the management of information technology innovations on construction projects, but it could also address the gap between innovation supply and demand, since it is the discipline that addresses how new technologies should be used.

The discipline of project information management is scoped by the project level on the framework scale dimension, and the information technologies category of the technology areas dimension. Moreover, we have based our framework for project information management on the same basic multi-dimensional model as the innovation framework: a dimension that defines the project elements to which the information system will be applied, a dimension that defines the elements that make up the elements of the information systems themselves, a dimension that defines the processes that make up project information management, and (like the innovation framework) dimensions for objectives, scale, and time.

5. CONCLUSIONS

At the core of the strategic planning process in Canadian construction process technologies is to understand what is required to make innovation happen at a quicker pace. The framework that has been developed to analyze the inventory of university-based research projects contains three dimensions of application, technology and innovation stage. This has been extended to include dimensions of scale, drivers, and time. The innovation framework provides an important mental checklist of what needs to be considered and the ability to identify gaps in the innovation process from multiple perspectives. To date, the strategic planning process has benefited greatly from the cooperation of the Canadian university construction researchers community (through the

Construction Division of the Canadian Society for Civil Engineering) and the National Research Council of Canada's Institute for Research in Construction. The initiative will now rely on a broader industry community.

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