RESEARCH PLANNING METHODOLOGY FOR TECHNOLOGY FUSION IN CONSTRUCTION

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Abstract: Interdisciplinary (multidisciplinary) research has recently become the main strategy by which the current construction technology can be raised to the level of next generation. Combination of knowledge from different departments has the potential to generate new kinds of technology, which can make a breakthrough in the regular course of technology development. However, it has not yet been clear as to how an interdisciplinary research program can be effectively planned and conducted. Without an effective research planning methodology, ambitious programs with interdisciplinary features may end up in failure. To address the issue, this paper presents various research planning methodologies for “technology fusion”-based research in construction. The expression, “technology fusion,” is here used to refer to the truly interdisciplinary approach of technology development. Research planning methodologies, including technology foresight and planning, are reviewed, and the criteria for selecting the methodology appropriate for a particular project are described. Finally, a case study is presented to show how the identified research planning methodology is applied in identifying an important research area in construction.

Keywords: Construction Research, Technology Fusion, Technology Foresight and Planning.

1. INTRODUCTION

Those in the same department are accustomed to their traditional ways of conducting business. They lack the knowledge of other disciplines that might assist them in developing better ways of running their business. Thus, a consensus has been formed that people with the same expertise in the same scientific and technological discipline have their limit in developing new ideas and new technologies in their area. However, when they get in contact with people in other scientific disciplines, they get exposed to different types of knowledge and technology. They also get chances to learn new ways of reasoning and problem solving. This positive influence of other disciplines generally inspires people to significantly improve the way they conduct their business. This is why the importance of so-called interdisciplinary or multidisciplinary research is increasingly recognized. Multidisciplinary (or interdisciplinary) research is defined as a study that relies on the knowledge of more than one traditional scientific and technological discipline. The knowledge that has been available for a long time in one discipline may be a breakthrough technology that can revolutionize the business practices of another discipline. A technique that has been being developed in a department, with a tremendous amount of time, money, and other efforts, may be what has been regarded as common knowledge for a long time in another department. Multidisciplinary approach clearly opens the new possibility of effective technology development.

To distinguish highly multidisciplinary approach from relatively low-level multidisciplinary approach, the term, “technology fusion” is here used. Technology fusion denotes combination of different types of knowledge from different departments, in order to have a breakthrough in the regular course of technology development. In other words, technology fusion means the truly interdisciplinary approach that from the beginning, tries to makes the best use of the knowledge from other departments, for the purpose of identifying or developing innovative technologies in the particular domain. However, for the success of technology fusion-based research, the research program needs to be strategically planned from its research topic generation to the full deployment of the final results. Without an effective and systematic research planning methodology, a tremendous amount of investments on the research can easily be wasted producing nothing valuable. This applies well to the development of new construction technology based on the approach of technology fusion. It is not easy to combine the traditional construction knowledge with the technology of other disciplines. The difficulty partially comes from the intrinsic characteristics of construction that most activities take place in an outdoor environment, where labors, equipments, and materials are exposed to uncontrollable external conditions, such as hot or cold temperature, rain or snow, day and night, differing subsoil conditions, and so on. The traditional construction process needs to be clearly understood and analyzed to identify the technology of other disciplines that can be successfully applied to the construction process, in order to produce significant improvements in the management of cost, time, quality, and safety.

This paper reviews research planning methodologies for the systematic and effective development of technology fusion-based research in construction. First, methodologies for technology foresight and planning are discussed. Then, the criteria for selecting the methodology appropriate for a particular project are described. Finally, a case study is presented to show how the identified research planning methodology is applied in identifying an important research area in construction.

2. THE REVIEW OF THE METHODOLOGIES FOR TECHNOLOGY STRATEGY

In general, the main part of research planning methodologies can be divided into two steps: technology foresight and technology planning. The following two sections discuss how these two concepts are defined and what the existing methodologies of each concept are.

2.1 Technology foresight

Technology foresight is in general defined as follows: “Foresight involves systematic attempts to look into the future of science, technology, society and the economy, and their interactions, in order to promote social, economic and environmental benefit (APEC center for technology foresight 1998).” Various methods are commonly used to make technology foresight to be systematic and long-term oriented, based on a wide-range of factors. The methodologies for technology foresight could be classified into two categories: quantitative data-based methodology and expert knowledge-based judgmental forecasting. Quantitative data-based technology forecasting mainly extrapolates history by generating statistical fits to the historical data. Trend extrapolation, simulation modeling, cross impact analysis, and system dynamics are included in this category. On the other hand, judgmental forecasting mainly depends on the subjective judgments of experts. This category includes Delphi survey, expert panel discussion, brainstorming, and scenario analysis. Since in many cases, little statistical data is available for research planning, this paper focuses on the judgmental methodologies based on expert knowledge.

Delphi survey is a structured group interaction process that is directed in rounds of opinion collection and feedback. Opinion collection is achieved by conducting a series of surveys using questionnaires. The result of each survey will be presented to the group of people participating in the Delphi survey and the questionnaire used in the next round is built upon the result of the previous round. Delphi survey is useful to obtain subjective judgment and identify important issues in the interested field, in case there is few empirical and quantitative data. Another merit of Delphi survey is the ability to gather opinions from experts who has diverse backgrounds. The disadvantages of Delphi survey, on the other hand, are that the minor opinions are easily neglected and that it takes a long time to complete the survey due to the iterative and repetitive nature of the rounds of survey. Note that the key features of Delphi survey that are different from other methodologies are structuring of information flow, regular feedback from and to the survey participants, and anonymity of the participants (Turoff et al. 1996).

Expert panel discussion is the methodology that consists of experts with diverse backgrounds. Information of the interested issues and the questionnaire are presented to the expert panel and they are allowed to freely discuss the issues to forecast what is likely to happen. It is recommended that the number of panel should be between 12 and 15. If the number of experts in a panel is two low, it is hard to draw proper number of significant ideas. On the flip side, if the number is too high, the facilitation of the panel discussion could be extremely challenging. Expert panel discussion has strong abilities to forecast based on wide-range of information, to be easily combined with other methodologies, and to easily facilitate interactions among the individual experts (KSTEP 2006).

Brainstorming is a group technique for generating new, useful ideas and promoting creative thinking to solve a problem (Osborn 1953). A main principle of brainstorming is that the participants are discouraged from being too critical on the opinions of other participants. Brainstorming can be applied to virtually any application that requires the generation of a list of idea, including project risk management, team building, business planning, and so on. Thus, it is an effective tool to predict what is likely to happen in the future from many different perspectives.

Futures wheel is a type of brainstorming methodology for identifying and packaging secondary and tertiary consequences of trends and events (Jerome 1971). Futures wheel makes use of a visual tool that places a future event in a circle in the center of a document. Consequences from the event of interest are placed in the second order ring of circles, then the third, and so on. Futures wheel identifies expanding consequences as shown in Fig. 1.

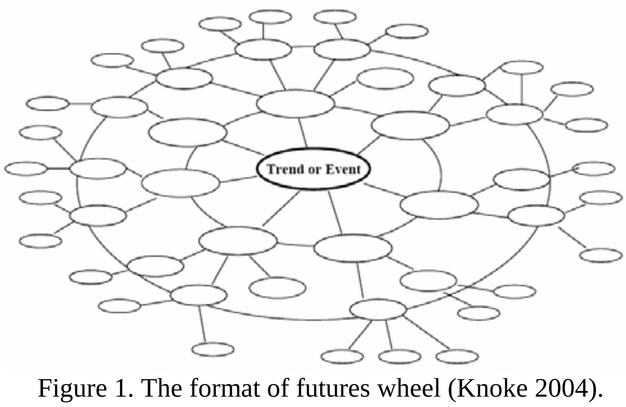

Figure 1. The format of futures wheel (Knoke 2004).

Futures wheel is currently used by corporate planners and public policymakers to identify potential problems and opportunities, new markets, products, and services, and to assess alternative tactics and strategies. General procedure of futures wheel is as follows: At the first step, the central trend or event is determined by the organizer based on the interested topic. At the second step, participants come up with the primary effects stemming from the central trend. At the third step, each primary effect produces secondary effects. Finally, participants explore the effects of the primary and secondary effects on their industry. It is recommended that one of the effect circle should be at least one negative idea. Though it is a very simple technique, requiring only blank paper, a pen, and one or more fertile mind, many fertile ideas on future foresight will be produced in a short time (Knoke 2004).

Another useful methodology for technology foresight is scenario analysis. Scenario analysis is a tool for ordering one's perceptions about alternative future environments in which one's decisions might be played out (Peter 1992). That is, scenario analysis is a process of analyzing possible future events by considering alternative possible outcomes. The analysis is designed to allow for improved decision-making by enabling more complete consideration of outcomes and their implications. Scenario analysis is an appropriate tool to evaluate the determined key assumptions on foresight. If the scenario analysis is to be successful, the following guideline should be kept in mind: first, the scenario should describe the possible future changes in a particular system, domain, environment, and society. Second, the scenario should be written in the past or present tense as if the visualized trends and events had already happened. Third, the scenario should indicate the "causes and consequences" of the key developments. Finally, the scenario developed in this way assist people in creating and evaluating alternative policies, strategies, and actions (Linneman 1977).

There are some criteria for selecting the proper methodology for technology foresight such as organizational context, quantitative/qualitative data requirements, time horizon, and visualization requirement. It is also possible to combine one methodology with other methodologies to have better results of technology foresight. It is worth noting that careful evaluation of the issue under consideration is essential in ensuring the selection of the most proper methodology because more often than not, the intrinsic nature of the issue itself determines what methodology is the most appropriate.

2.2 Technology planning

Whereas technology foresight only deals with identifying the future conditions, technology planning, in a broad sense, covers the whole process of technology development, including vision setup, technology foresight, specific research strategy, and evaluation. However, technology planning here is defined in a narrower sense, meaning the planning for concrete research strategy. There are various methodologies for technology planning, such as technology road map, technology tree, value curve, quality function development, theory of inventive problem solving, and design of experiments.

Technology road map is a needs-driven technology planning process to help identify, select, and develop technology alternatives to satisfy a set of product needs. The main benefit of technology road map is that it provides information to make better decisions for technology investment. Technology roadmap is the document which is generated by the technology roadmapping process. For a set of product needs, a technology roadmap identifies the system requirements, the product and process performance targets, and the technology alternatives and milestones for meeting those targets. Under different circumstances with uncertainty or risk, one or multiple paths can be selected and pursued for achieving those objectives. In order to construct a roadmap, it is required to identify the nodes, the links between nodes and specify al the node and link attributes as well as the directions and magnitudes of the links (Sandia National Laboratories 2005).

Technology tree is a hierarchical visual representation of the possible paths to classify the market demand and expected performance, identify core technology to satisfy the demand and expected performance, and realize the core technology. The general process of technology tress is as follows: 1) target definition 2) analysis of target's characteristics, 3) identification of elementary technologies, and 4) index allocation (KSTEP 2006).

Quality function deployment is a comprehensive quality design method that identifies customer needs, uncovers positive quality that charms the customer, translates these into designs characteristics and deliverable actions, and builds and delivers a quality product or service by focusing the various business functions toward achieving customer satisfaction (KISTEP 2006).

Theory of Inventive Problem Solving, which is abbreviated as the acronym, "TRIZ" was developed in Russia. TRIZ research began with the hypothesis that there are universal principles of invention that are the basis for creative innovations that advance technology, and that if these principles could be identified and codified, they could be taught to people to make the process of invention more predictable. The research has proceeded in several stages over the last 50 years. Over 2 million patents have been examined, classified by level of inventiveness, and analyzed to look for principles of innovation. The three findings of this research are as follows: 1) Problems and solutions were repeated across industries and sciences. 2) Patterns of technical evolution were repeated across industries and sciences. 3) Innovations used scientific effects outside the field where they were developed. In the application of TRIZ all three of these findings are applied to create and to improve products, services, and systems (triz-journal 2002).

There are other methodologies for technology planning. Design of experiments is a structured, organized method for determining the relationship between factors affecting a process and the output of that process (isixsigma 2002). Value curve is a curve representing the value of company or industry and it can be used to create the innovative service and product (KSTEP 2006). In practice, these methodologies are combined to supplement defects of one another and to produce synergy effects.

3. CASE STUDY: PROMOTION OF PILOT FUSION TECHNOLOGY LABORATORY

Complex for Technology Fusion (C4TF) in Construction is the research center in Korea to establish innovative construction technology plan based on the technology fusion strategy. C4TF introduces a unique planning strategy for a systematic fusion research of construction technologies and other technologies such as nano technology, image processing technology, robotics, database technology, communication technology, and sensing technology. These six technological areas were identified based on the needs of construction industry by an expert panel discussion to make the technology fusion to be more systematic. One of the roles that C4TF plays was to identify an innovative research area based on the technology fusion approach. For this purpose, C4TF took steps as follows: 1) the needs of construction industry and market were identified by an expert panel discussion, and then the results were presented to the researchers in the six technological areas; 2) in order to understand which area has the most positive influence on improving traditional construction processes, Simple MultiAttribute Rating Technique(SMART) was used. The survey was conducted by e-mailing questionnaires to 150 experts in multidisciplinary areas including civil engineering, architectural engineering, electronic engineering, mechanical engineering, material science, and computer science. They consist of university professors, researchers in government supported research institutes, and industry practitioners. As a result of the SMART, the order of importance was determined for the six technological areas, designating robot technology as the most needed research area with top priority, as shown in Table 2.

4. CONCLUSIONS

It is crucial to have an effective construction research planning methodology, especially when technology fusion-based research is planned. This paper reviewed available research planning methodologies, including technology foresight methodologies and technology planning methodologies. Technology foresight methodologies include Delphi survey, expert panel discussion, brainstorming, and scenario analysis while technology planning methodologies include technology road map, technology tree, value curve, quality function development, theory of inventive problem solving, and design of experiments. As seen in the case study presented in this paper, these methodologies can be combined to maximize their usefulness in identifying an innovative construction research area.

Table 1. Criteria for selecting the most needed research area

No.	Criteria	Description
1	Technology demand	Needs
		Innovation
2	Research capacity	Research ability
		Global competitiveness
3	Business	Possibility to generate new business
4	Education	Improvement of training system
5	Policy	Advanced infrastructure
		Enhancement of living status
		Economic growth engine

Table 2. The result of the SMART Method

Criteria (weight) / Technology	1 (22)	2 (19)	3 (21)	4 (18)	5 (20)	Total	Priority
Communication	73.7	67.1	66.5	63.2	72.1	68.5	3
Nano	68.4	62.1	65.2	60.8	63.0	63.9	6
Image processing	68.2	66.8	66.8	62.4	66.7	66.2	5
Robot	**73.3**	**73.1**	**76.5**	**72.0**	**74.2**	**73.8**	**1**
Database	70.3	69.43	66.8	64.2	66.8	67.5	4
Sensing	70.5	69.0	71.4	64.8	67.5	68.6	2

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