Construction Engineering and Management Workshop

NSF Research Agenda on Product/Process Development

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I. Introduction

Taking a somewhat philosophical approach to the topic, I first consider the objectives of the field of Construction Engineering and Management, and from that derive the ways in which research could realize those objectives.

As a general definition, Construction Engineering and Management is the creation, maintenance, and renewal of the built environment, in accordance with the natural environment and social objectives, within economic constraints. Design and construction only constitute a small portion of the total life of a facility, but are critical processes to establish the attributes of the facility for its long-term performance. To the public, the act of creating a facility is a single massive undertaking. This perceived unity of function requires a specific party willing to take responsibility and exercise control over the realization of the facility as a whole. The built environment establishes the nature and quality of life, from clean potable water and basic shelter to public museums and extensive communication networks. The social objectives concerning the built environment shift by cultural, political, and economic trends, reflecting the concerns and requirements of the people. Current primary trends throughout the world are for environmental protection (both near and long term) and the need for economic development.

The built environment provides the context for economic activity, and reflects both the sources (e.g., manufacturing, services) and locus (e.g., urban, suburban, rural) of value-added activities. Investments in the built environment are considered with respect to both the contribution to the public good and the private appropriation of benefits. Choices made with respect to the nature of the facilities within the built environment, their configuration, and their location are evaluated with respect to expected value within a defined service life, including the opportunity costs associated with pursuing alternative investments.

II. Research Agenda

The objective of research in the field of Construction Engineering and Management is to improve the efficiency and effectiveness of adapting the built and natural environment to meet the objectives of the owners (private and public) and society.

The research approaches to fulfill this objective must be responsive to the nature of the built environment. The built environment consists of many complex, multi-system facilities which must adapt to dynamic conditions and requirements. The research approach must explicitly

address the system and inter-system attributes and factors that affect immediate (i.e., during creation) and long-term performance. The research approach must also explicitly incorporate the full expected service life of the facilities rather than concentrating primarily on the creation process (i.e., design and construction).

III. Research Areas

Several specific research areas can be developed from the general objective and the general research approaches.

The objective of the first area of research is to incorporate and use system-specific knowledge and developments to improve the performance (immediate and long-term) of the facility as a whole. The constructed facility can be seen to be composed of four general systems (i.e., structural, exterior enclosure, services, and interior finish). Significant theoretical and technological developments exist and are emerging related to these systems, both within the field of Civil and Environmental Engineering, and in other fields, such as materials science, mechanical engineering, chemical/biochemical engineering, and computer science. While it would be counter-productive to attempt to duplicate research and development activities from those fields, the application area of constructed facilities requires specific and directed activities to adapt and appropriately implement the developments from related fields. In addition, the multi-system characteristics and interactions involved in construction facilities requires a set of research programs that can particularly explore the inter-system dynamics and performance attributes. Potential significant benefits from these activities could be enhanced complementary interactions among systems, reduced spatial and functional conflicts, and improved facility-level performance.

The objective of the second area of research is to develop the understanding and use of processes to enhance the link between the completed facility and the objectives of the owners and society. Specifically, this area would involve the development of informed decision-making theories, methodologies, and tools. Informed design, for instance, could include the immediate analysis and feedback during design development on the costs to construct, operate, renovate, and decommission a facility, as well as the time to build, renovate and demolish it. In addition, the design and its alternatives could be directly assessed with respect to the construction processes which could be employed, the ease with which the construction can be performed, and the impact on worker safety. Long-term performance of the facility could be analyzed with respect to both operational criteria (e.g., comfort, noise, light, energy use) as well as the ability to accommodate changes over the long term. New designs, processes, and technologies could be analyzed with respect to the specific facility being considered, providing both system and inter-system level results with respect to the project's multiple objectives.

Informed construction could consider the range of processes available to realize the design most effectively, given a particular balance among the project's objectives. Planning for the project could include specific consideration of the supply chain, and the relation between off-site and on-site activities to expedite construction, improve safety, reduce environmental impacts, and improve the overall facility performance. Direct consideration of new components, systems, and processes, and their potential impact on both the construction process and the facility's final performance can be incorporated with the management of the construction dynamics.

Informed facility management explicitly considers both the initial, emerging, and expected future requirements for the facility, with respect to the detailed information about the existing facility. Knowledge of the system and inter-system spatial and functional interactions could significantly improve the capacity of the facility to accommodate the dynamic conditions and requirements over time, and reduce the potential for facility obsolescence. In addition, innovative designs and technologies can be assessed with respect to the existing facility for their appropriateness to effectively meet the changing facility requirements.

The objective of the third area of research is to extend knowledge of the interaction between the built and natural environment, during the creation, operation, and decommissioning of different facilities. As certain built facilities become functionally obsolete and redundant (e.g., small dams on local rivers and streams), they are being removed. Certain impacts are expected from this decommissioning, but the long-term and inter-system impacts are not well understood. Certain areas, such as micro-climate analysis, have provided a means to analyze the localized impacts of built facilities on the nearby neighborhood, but the current development of large scale models for the interactions between the natural environments (e.g., land, sea, air) could be extended to include the built environment.

The objective of the fourth area of research is to improve the performance of the facilities within the built environment as interlinking infrastructures. For example, the current approach to deliver social services (e.g., water and waste treatment, energy generation, communication, transportation) through large, centralized systems may be in the process of significant shifts towards smaller, more decentralized systems. The interactions among these infrastructures, and the means through which the quality of service provision remains high and the public safety is preserved while the technologies change radically and quickly will be a concern for all professionals associated with Construction Engineering and Management.

IV. My Background

I have been researching innovation in the built environment, specifically associated with construction, for approximately 15 years. Over the past 4 years, I and my research team have been developing dynamic process simulation models of construction activities. The models provide a means to analyze the cost, duration, and worker safety impacts of system and inter-system changes in construction facilities and processes in project-specific scenarios. Other current projects include analysis of inter-organizational collaboration mechanisms for the development and use of construction innovations, and the development of design strategies to increase the capacity of facilities to accommodate change over the long-term.