Design/Construction Integration thru Virtual Construction for Improved Constructability

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Executive Summary: Changing industry needs have take big leaps in the past two decades. Design and construction practices and project delivery systems have moved into the direction of integration. This has strongly encouraged many practitioners to consider design processes and construction processes concurrently in consecutive phases. By narrowing the gap between design and construction, thru integration, project constructability can be greatly improved. This white paper attempts to present the author's views on how the design process can be further enhanced thru direct integration with the construction process. The paper first presents a brief summary of several recent research efforts that address this issue. The paper then presents a model for integrating the design and construction processes during the pre-construction stage for improved constructability. The model proposes a user-interactive virtual construction sessions that allow the user (design and/or builder) to construct and criticize the proposed facility using a 3D virtual environment. The model is part of a broader research effort at Virginia Tech to develop virtual construction environments for improved design and planning of construction facilities.

Introduction: From start to completion, construction projects undergo a number of phases characterized by many tasks aimed at identifying, planning, designing, and constructing the proposed facility. Such phases and tasks may be grouped into two main stages as shown in Figure 1; a Pre-construction Stage and a Construction Stage.

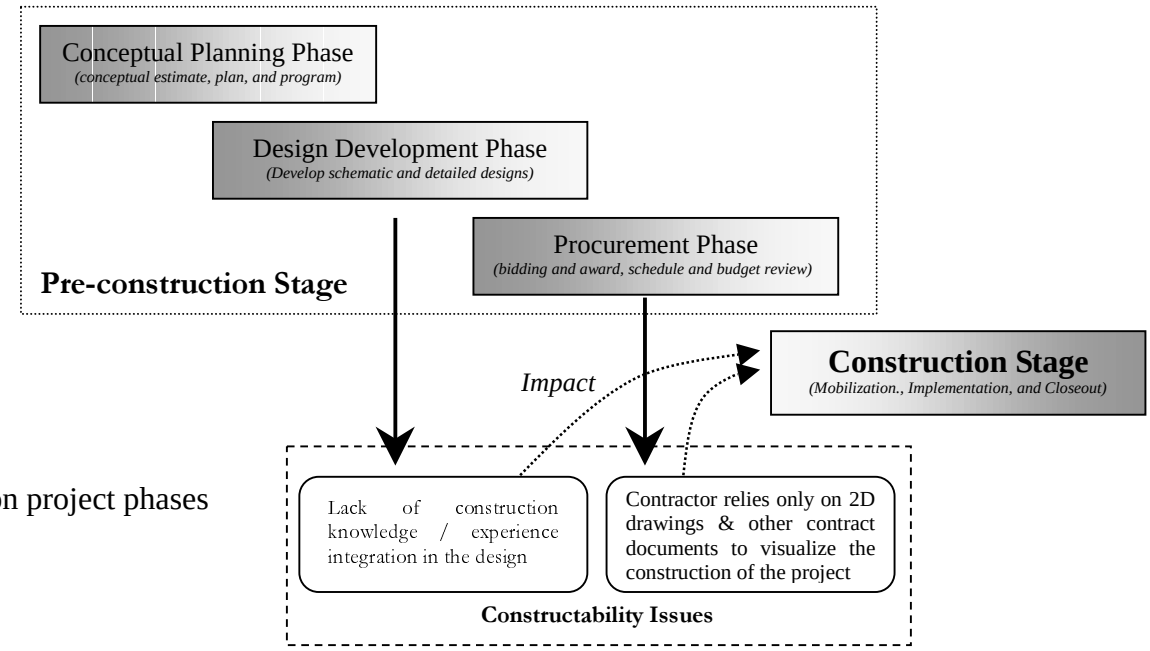

Figure 1: Construction project phases

During *the conceptual planning phase*, the owner hires key consultants to begin selecting the project site, and developing a conceptual estimate, plan, and program. In this phase, the owner, after gathering information about the project, makes a decision whether or not to proceed with the project. *The design*

development phase comprises of: (1) the schematic designs where the design team investigates alternate design solutions and alternate materials and systems, and (2) the detailed design where the design team evaluates, selects, and finalizes the major systems and components of the project. The design phase also includes the preparation of technical documents, specifications, as well as the general conditions. The project's schedule and budget continue to be developed and monitored during this phase. *The project procurement phase* is the time when the project formally transitions from design preparation into construction preparation. This phase includes the bidding and award process. The project's schedule and budget are finalized in this phase. *The construction phase* presents the actual physical construction of the project. This phase begins with the mobilization to the site, then the implementation, and finally ends by the project closeout.

The successful completion of a construction project requires a thorough understanding of all stages and phases of the project, and can be enhanced through integration of design and construction during the pre-construction stage. Constructability, or buildability (UK), is a major factor in measuring the success or failure of construction projects. Several constructability problems or barriers to accomplish a successful project may be addressed during the pre-construction stage, as well as the construction stage. During the pre-construction stage, lack of construction knowledge/experience integration in the planning and design processes is a major factor that leads to constructability problems during the construction stage. This is because many design professionals have little experience in construction practices, local considerations, the availability of different resources, and are not necessarily experts in construction means and methods. During the procurement phase, contractor reliance on contract documents to visualize the construction process and decide on appropriate construction methods is limited to 2D drawings. This approach limits the contractor's ability to be more familiar with the project at this early stage and prior to the start of actual construction. During the construction stage, constructability issues such as safety, storage access, security, quality, and schedule updating are major factors that influence the accomplishment of a successful project.

Constructability improvement strategies: Several strategies and concepts have been presented to improve the project constructability during the different phases of the pre-construction stage. Tatum [87] recommended the use of the "backward pass" approach to planning to ensure that the schedule is driven by the construction needs. Glavinich [95] described two methods for improving constructability and decreasing design-related problems during the construction process: (1) Design Phase Scheduling,

and (2) In-House Design-Phase Constructability Review. O'Connor et al. [87] identified seven concepts for improving constructability during the design/procurement phases of a project: (1) a Construction-Driven schedule, (2) Simplified Design, (3) standardization of design, (4) Pre-assembly work should be scoped in advance and pre-assembly designs should be prepared to facilitate fabrication, transport, and installation, and thus to enhance project constructability. (5) Accessibility, (6) Adverse Weather, (7) Specifications.

Constructability improvement solution models: Different solution models for constructability improvement were implemented to assist the project team in integrating construction knowledge/experience during the pre-construction stage. Fischer [93] presented a Construction Knowledge Expert (COKE) that guides designers towards designing structures that are more constructable. Patty et al. [95] presented a computer tool that utilizes a multimedia to give the designer the capability of accessing constructability information at the point of design. Moore and Tunnicliffe [95] described aspects of the production of an Automated Design Aid (ADA) that provides the designer with useful decision support regarding design corrections and adaptations. Kupernas et al. [95] introduced a methodology to use a computer aided drafting (CAD) 3D model of a project to review design layouts and to identify design conflicts as part of a pre-construction constructability review. Within this methodology two reviews are performed.

Proposed Solution Model: The author suggests a model for design/construction integration using virtual construction. As depicted in Figure 2, the model is based on a design review process through virtual construction of the developed design. This review process can be applied to partial or completed designs based on the size and complexity of the facility under consideration.

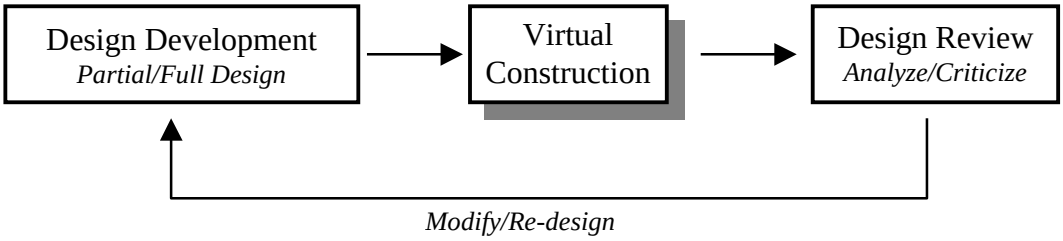

Figure 2: Design/construction integration

With reference to Figure 3, the proposed model will utilize user-interactive construction sessions that will allow the user (designer and/or builder) to virtually construct 3D models of the project from pre-

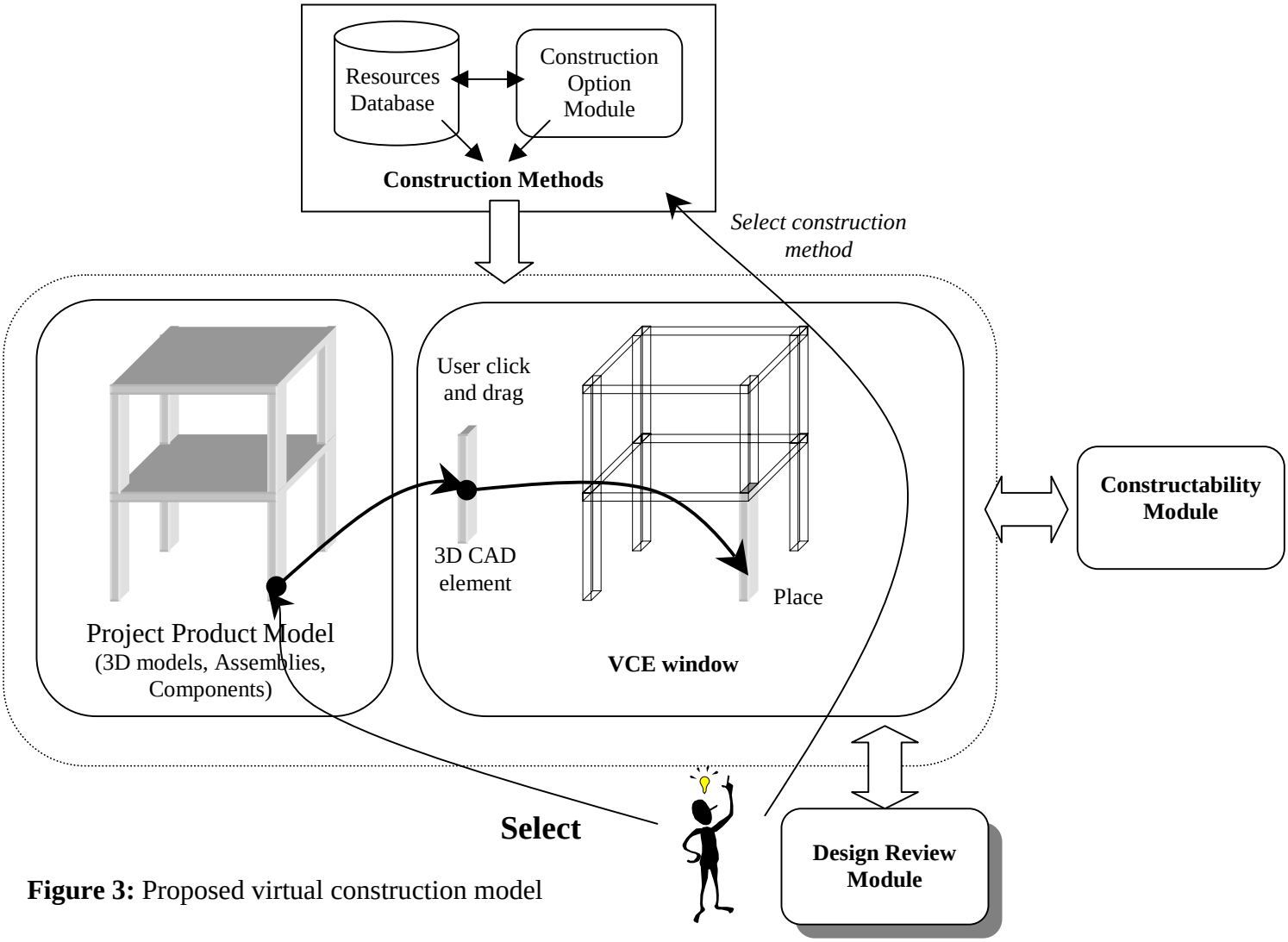

Figure 3: Proposed virtual construction model

defined construction CAD assemblies or components. The virtual construction process will be guided by the facility's 3D product model generated during design development. By performing virtual construction during the project's pre-construction stage, the user will be able to undertake rehearsals of the construction process allowing them to analyze and criticize designs as well as perform what-if scenarios for selection of different construction methods. A knowledge base, comprising primarily of construction options module and resources module, will assist the user in decision making. The construction options module consists of different construction alternatives available for the execution of the work item. The resources module consists of information on available resources such as crew, equipment, space. Using pre-defined assemblies, the user selects the construction method associated with each construction assembly. The construction method is the combination of the construction option selected for the execution of the work item, and the associated resources required to perform the construction option. A Constructability Module will check the capability of applying the selected construction option and the selected resources with the selected order of construction. A Design Review module will allow the user to modify/re-design the assembly.

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