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OPTIMAL CONSTRUCTION PROJECT PLANNING

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ABSTRACT

The nature of the construction industry combined with the lack of appropriate techniques and technologies suitable for construction work are among the main reasons for inadequate industry performance. Researchers need to develop a better understanding of the construction industry and develop approaches and technologies that will enable construction companies to do a better job in estimating, planning, and control. A production-based framework is proposed in this paper to address some of the challenges in managing construction projects. The framework is based on a number of components, which collectively represent an integrated approach for planning and execution of construction projects. This paper focuses on the simulation component of the framework and highlights the features currently available in Simphony as a leading construction simulation platform. It also addresses the main challenges and requirements for extending its capabilities to fit within the envisioned framework.

1 INTRODUCTION

Construction projects are complex dynamic systems that are subject to a multitude of random external processes. When viewed as such, they represent a challenge for existing planning and control techniques.

A radical shift in the way construction projects evolve from inception to completion is required in order to address the challenges of the future construction environment. The most recent transformation of construction took place in the late 1950's with the introduction of planning techniques based on bar charts and scheduling networks (CPM, PERT, Precedence, etc.). Those techniques have become prevalent in construction, although their effectiveness in modeling the construction process has been limited. Most of the construction companies carry out some form of CPM project planning and scheduling. However, in most cases, these plans are of limited use once the project proceeds. This observation is supported by many researchers, for example, International Group for Lean Construction (1999) and Tommelein (1998).

Construction companies still lack the ability to properly plan, estimate, and execute projects in a consistent, efficient, and reliable manner. Statistics on cost and schedule overruns demonstrating our inability to accurately plan and estimate were summarized in Abd Majid and McCaffer (1998). A recent study of 213 projects conducted by the City of Edmonton on estimating accuracy for capital construction projects (AbouRizk 1998) showed that estimates are not as accurate as generally believed, with only a small portion of projects actually falling within the desirable accuracy range. Similar observations can be made (although no statistical analyses were carried out), regarding inaccurate costs and poor delivery times resulting from planning or execution, for a multitude of construction mega-projects. This is partly due to the nature of the construction industry and partly due to the lack of appropriate techniques and technologies suitable for construction work.

This paper discusses the challenges and requirements for an envisioned production-based modeling and analysis framework for use in construction. The aim of this framework is to produce *ideal (or perfect) project execution plans.* The framework aims at producing a new generation of planning and analysis tools and providing the foundation upon which solutions to common construction problems can be developed. Simulation tools represent a core component of such a framework and will be the main focus of the paper.

2 THE SIMULATION COMPONENT

A production-based modeling and analysis framework represents the integration of various processes required for the successful delivery of a project, as shown in Figure 1. The framework is based on a number of components, which collectively represent an integrated approach for the planning and execution of construction projects in a man-

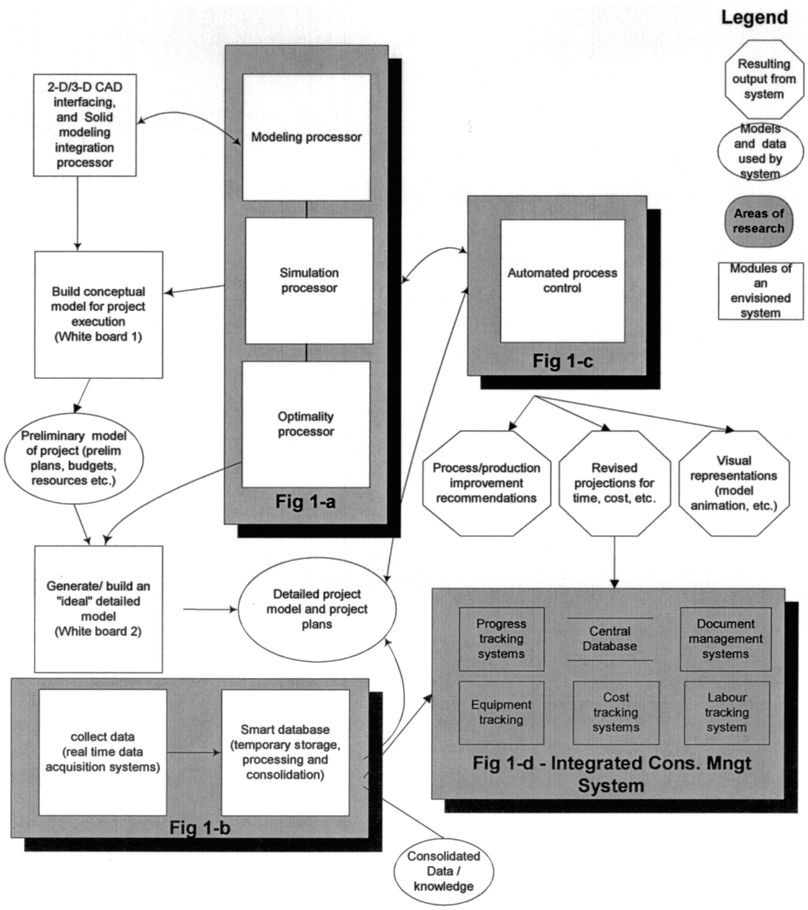

Figure 1: Conceptual Model of the Production-Based Environment

ner that drives the system towards optimum productivity. The "engine" that drives this framework is composed of the modeling, simulation, and optimality processors (see Figure 1-a). The approach is supplemented with automated data acquisition, smart databases, and automated process control (Figure 1-b and 1-c).

The simulation processor represents a key component within the framework and needs to be flexible and powerful enough to accommodate the complexity and diversity of construction operations. Hajjar and AbouRizk (2000) developed a simulation development environment called Simphony that combined power and flexibility enabling to create simulation tools in a cost-effective manner. In addition to being able to use the simulation tools for their intended purposes, the end user can extend the resulting tools, integrate them with other Simphony templates, and modify the behavior of their elements. This flexibility is achieved through the open environment illustrated in Figure 2: Figure 2-a provides an overview of the system components, Figure 2-b shows the application framework view of the system, Figure 2-c provides an overview of how modeling and simulation elements are formed by the developer of a special purpose simulation tool, Figure 2-d shows an end-result model developed by the user for an aggregate production operation, and Figure 2-e shows the Simphony object model illustrating the structure of the system.

However, Simphony is limited in its functionality to modeling and simulating processes that lend themselves to discrete event process interaction simulation and constraint modeling simulation (mathematical function-based modeling). Advancements are needed in the modeling phase of simulation as well as in the experimentation (computer processing) phase. Other forms of systems modeling need to be developed in the area of modeling. Theories need to be extended to enable solving of large-scale models within the simulation experimentation area. This requires revisiting of the experimentation phase to take advantage of parallel and distributed processing approaches in computing science.

3 CHALLENGES IN MODELING CONSTRUCTION PROCESSES AND METHODS

The modeling and simulation approaches completed to date for modeling construction processes have their roots in process interaction discrete-event simulation, which only represents one of the "world-views" of simulation modeling. This modeling approach was fully deployed in the *Simphony*

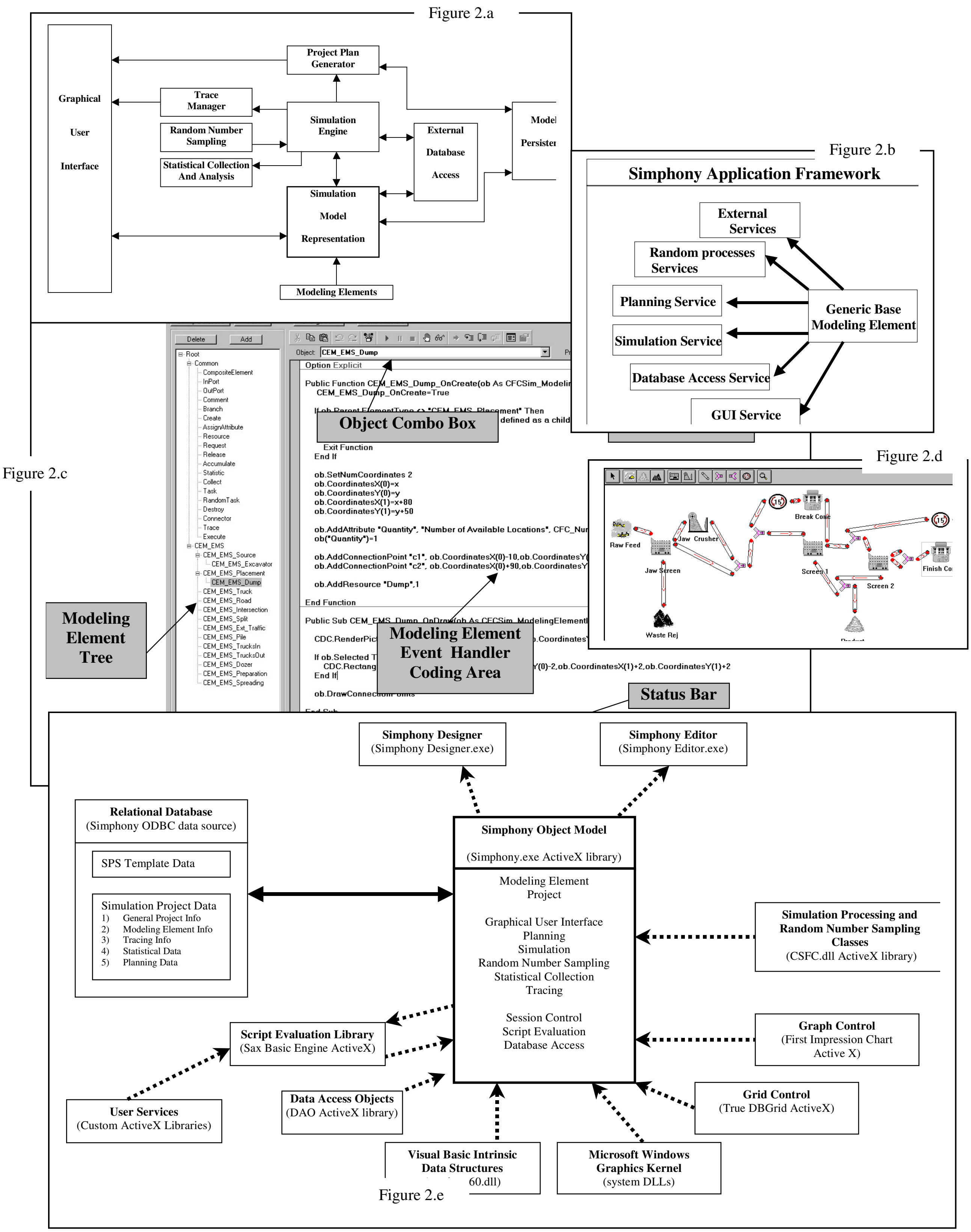

Figure 2: Architecture of Simphony Environment

simulation environment. The complexity and diversity of processes on a construction project calls for an extended suite of modeling and simulation ideas to cover other "world-views" of simulation, including subjective modeling, state-based modeling, and continuous process modeling. The envisioned requirements for extending the modeling capabilities of Simphony are illustrated in Figure 3.

3.1 Modeling Subjective Information

A study of fuzzy set theory, artificial neural networks, Bayesian statistics, and other fields needs to be conducted together with the possibility of integration with the current modeling strategies. This area has numerous applications within construction systems modeling, including estimating (Fayek 1996); decision making and its impact on system performance; estimating missing or unavailable data for duration, cost, and quality; and impact of external factors on construction operations (e.g. work hours, learning improvement, etc.).

3.2 State-Based Modeling

Transition state modeling is frequently encountered in construction projects (e.g. tunnel excavation transition from a state of good soil to poor soil, or weather transition from dry to rain) yet it is not readily integrated within the current simulation modeling frameworks. Markovian models are promising but limited in their current state. One of the main limitations is that the modeler has to specifically enumerate all state-to-state transitions. Although acceptable for some applications, it does not lend itself to dynamic process interaction models where states may be generated during the simulation and transition probabilities are updated based on various factors encountered during the simulation. A further limitation of these models is their dependence on past historical data to derive the transition probabilities. In many situations encountered while simulating construction systems data is not always available or complete. In this context, knowledge in data modeling (see for example AbouRizk 1994), fuzzy set theory (see Sawhney 1994, Fayek 1996), and Bayesian statistics (see McCabe and AbouRizk 1998, Lu 2000) can be used to derive and implement techniques that enable the development of more powerful state-based modeling constructs.

3.3 Constraint Modeling

Many components of construction systems are continuous processes yet are generally treated as discrete-event processes for the purpose of simulation modeling. Processes of this nature include dewatering construction sites, weather and its impacts, and a number of others. Many of these processes can be represented with mathematical formulations of the system. A better understanding of these concepts and further developments of its theory will greatly enhance its applicability to the construction field.

3.4 Simulation Integration Issues

In addition to the modeling strategies discussed above, effort needs to be spent devising better approaches to multi-modeling. Most construction projects are aggregates of different sub-models and processes. Integrating sub-models of different natures (e.g. discrete-event, continuous, state-based, etc.) in a harmonious model has numerous challenges, including the synchronization of interactions between the sub-models, directing the simulation process to ensure that the model is executing appropriately, and providing the tools and utilities to trace the simulation process.

4 CONCLUSIONS

The nature of construction projects and the lack of effective planning and control tools require the creation of a new set of modeling and analysis tools for construction management. These tools should work together within a production-based framework that enables the construction engineer to drive a project towards optimality. Simulation tools are a key component within such a framework. This paper discussed an envisioned structure for a production-based framework. The different components were identified with a focus on the simulation component. The capabilities available within the existing Simphony' simulation platform were highlighted. The requirements and challenges for extending these capabilities were also discussed and outlined.

REFERENCES

Abd Majid, M.Z.A, and R. McCaffer. 1998. "Factors of Non-Excusable Delays that Influence Contractors' Performance." *Journal of Management in Engineering*, 14(3), 42-48.

AbouRizk, S. M., D. W. Halpin, and J. R. Wilson. 1994. "Fitting Beta Distributions Based on Sample Data.", Journal of Construction Engineering and Management, ASCE, 120(2) 288-305.

AbouRizk, S. M. 1998. "Value for Money Audit: Project Management –Cost Estimating." Report to City of Edmonton, Office of the Auditor General.

AbouRizk, S., and Y. Mohamed. 2000. "Simphony—An Integrated Environment for Construction Simulation." Proceedings of the WSC 2000, Orlando, Florida

Fayek, A. 1996. A Competitive Estimating and Tendering Strategy Model for Use in the Civil Engineering Construction Industry. Ph.D. Thesis, University of Melbourne, Melbourne, Australia.

Hajjar, D., and S. M. AbouRizk. 2000. "An Application Framework for the Development of Simulation

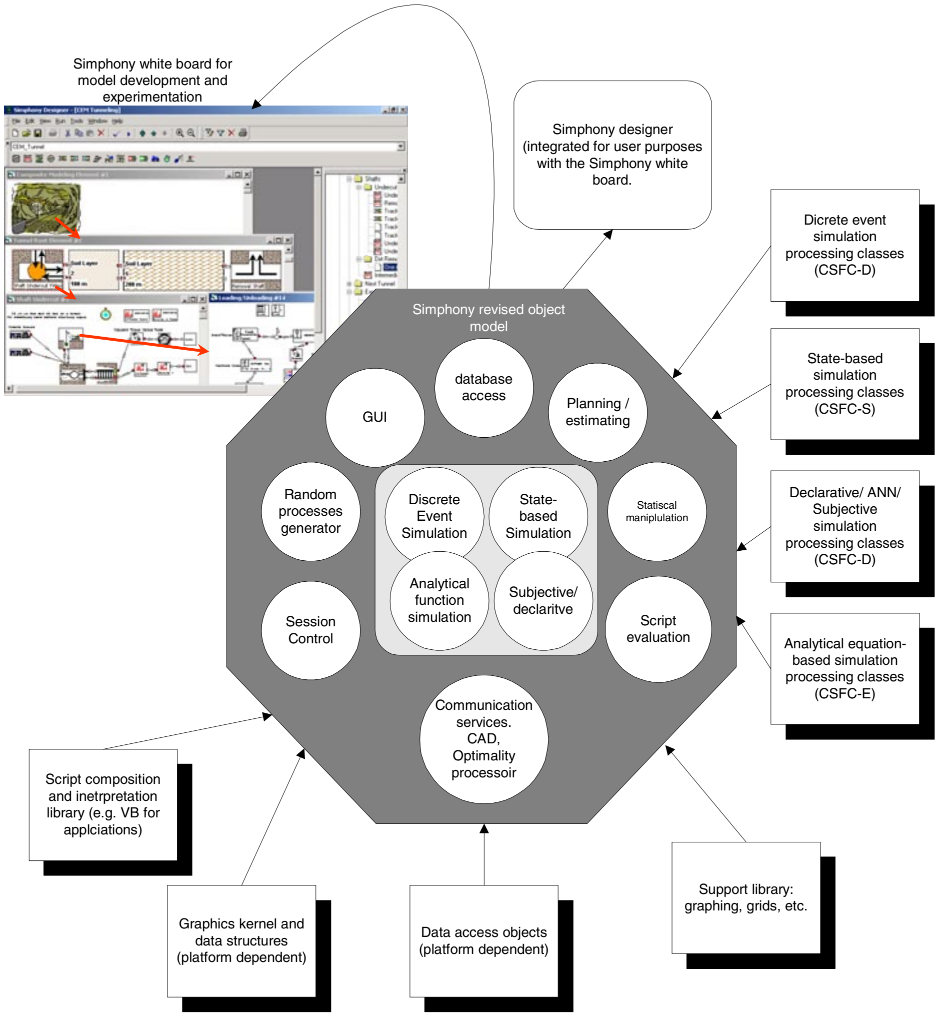

Figure 3: Simphony Platform Revised

Tools." Journal of Computing in Civil Engineering, ASCE, 14(3), 160-167.

International Group for Lean Construction. 1999. <http://cic.vtt.fi/lean/index.htm> [accessed on August 27, 2001].

Lu, M. (2000). Productivity Studies using Advanced Artificial Neural Network Models. Ph.D. thesis, University of Alberta, Edmonton, Alberta.

McCabe, B., S. M. AbouRizk, and R. Goebel. 1998. "Belief Networks for Construction Performance Diagnostics." Journal of Computing in Civil Engineering, ASCE, 12(2), 93-100.

Sawhney. 1994. Simulation-based planning for Construction. Ph.D. thesis, University of Alberta, Edmonton, Alberta.

Tommelein, I.D. 1998. "Pull-driven Scheduling for Pipe-Spool Installation: Simulation of Lean Construction Technique.", Journal of Construction Engineering and Management, ASCE, 124 (4) 279-288.

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