Enabling Technologies for Project Supply Chain Collaboration

NSF/ICIS Infrastructure and Information Technology Workshop

June 25-27, 2001
Arlington, VA

Dr. William O'Brien[1]
University of Florida

Introduction

This paper describes a research agenda for enabling technologies to support supply chain collaboration in the construction industry. Its intention is not to provide a broad-based survey of research needs in construction for infrastructure applications; papers by others in this workshop perform that role admirably. Rather, the purpose of this paper is to set an agenda for technologies that will enable effective, computer supported sharing of knowledge among the many members of the project supply chain. It is the view of this author that improving the cost and time performance of infrastructure projects will necessarily come through improvements in supply chain performance. And while today there exist various tools and paradigms to effect performance improvements, implementation of these require data from the diverse members of the project supply chain. Obtaining this data is one of the most difficult challenges on projects due to dual challenges of heterogeneous information systems and knowledge that is not currently represented on-line. Thus this paper outlines enabling technologies including mechanisms to automate extraction of data and knowledge and mechanisms to enable local knowledge to be formalized and represented on-line so it can be shared. While specific in scope, the recommended research agenda is not narrow. Collectively, the technologies envisaged in this paper provide the basis to enable the next generation of supply chain collaboration tools.

[1] Assistant Professor, Dept. of Civil & Coastal Engineering, 345 Weil Hall/PO Box 116580, University of Florida, Gainesville, FL 32611-6580, 352-392-7213, wjob@ce.ufl.edu

Why the Supply Chain?

It is this author's view that performance improvements in the supply chain are central to making timely and cost effective investments in civil infrastructure. Projects must become less expensive, faster, and, just as important, more predictable in their schedule and scope.

Figure 1 shows a conceptual model of a project supply chain. Several subcontractors work on a project. Each subcontractor is served by one or more suppliers. Suppliers in turn can be served by one or more sub-suppliers, and so on. While supply chain composition will vary from project-to-project, any given project may have hundreds of firms involved in the supply chain.

It is clear that much of the design and production knowledge on projects resides in the supply chain. Consider that on any given project, cost may break down as follows:

- Supply-chain operations and detailed design: 80%
- Traditional design and project management: 5%
- Insurance and related service costs: 15%

Of course, these numbers will vary across projects, but supply chain operations account for the largest share of project costs. It is through supply chain improvement that some of largest gains in construction cost and schedule are to be made. Examples of 25-50% reduction in time and cost are not uncommon in manufacturing supply chain applications, and the construction industry FIATECH initiative (www.fiatech.org) has similar goals of 30-40% reduction in cost and time through improved supply chain management and concurrent engineering.

In general, improved supply chain methods are dependent on leveraging knowledge resident in the firms that comprise the supply chain. Extracting this knowledge from potentially hundreds of firms is a fundamental problem in implementing supply chain improvements. A central issue for information technology research is: ***How do we share supply chain knowledge so it can be leveraged?***

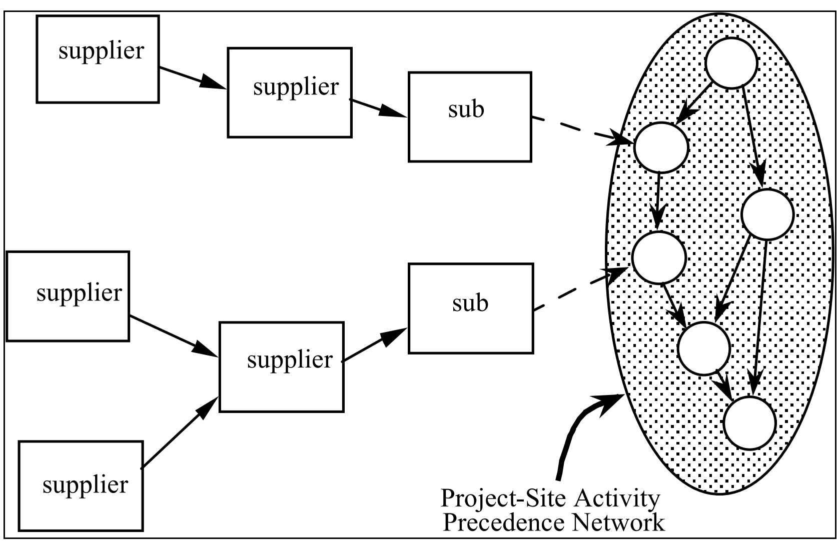

Figure 1: Conceptual representation of the construction project supply chain. Project supply chains are composed of hundreds of firms.

Ubiquitous Problems in Sharing Knowledge

With increasing use of computers in construction over the past few decades, we have become increasingly sophisticated in our understanding of the problems of sharing data and knowledge on project teams, including members of the supply chain. There appears to be an emerging consensus that the principal difficulties in sharing information are:

1. *Too many sources of information*: It is difficult for professionals to assemble information pertinent to business decisions. Information exists in many locations and is often in a raw form not useful for decision making. More time is expended gathering and transmitting information on projects than in evaluating it.
2. *Local knowledge is not formalized*: While increasing amounts of design and construction information is represented on-line, considerable local and tacit knowledge is not formalized. Information that is represented on-line is often in point solutions for individuals and is difficult to share and/or re-use. Much knowledge is in idiosyncratic mental models that are difficult to share with others involved in decision making. This leads to long meetings and miscommunication.
3. *Limited shared visualizations*: Partly due to points one and two, there exists little knowledge about how to visualize process-related information for individual tasks let alone tasks that require input from several professionals. It is all but impossible for professionals to visualize and understand the full magnitude of relationships and constraints in design and corresponding schedule alternatives, leading to unanticipated consequences such as errors and omissions, rework, and misallocated resources.

Limitations of Current Approaches

The principal research and practical approaches to overcome difficulties in sharing information have been based on the development of semantic data standards such as the IFC (iaiweb.lbl.org) and AECXML (www.aecxml.org). These standards facilitate automated sharing of data by applications designed to operate on those standards. Much of this effort has been directed to represent product data, i.e., the geometry and physical properties of construction products. These data standards have been extended to include process data such as cost, resources, productivity, etc. Data standards represent a significant advance, particularly in terms of providing a common language for product modeling. Applications build from data standards will probably usher in the first significant computer IT revolution in construction.

However, standards are not a panacea to all the problems of sharing data. Data standards may speed the collection of data across sources, at least partially addressing point one (above). It is less clear that data standards developed by a committee will be able to represent relevant local and tacit knowledge. And by themselves, data standards do not provide shared visualizations.

Moreover, given the large number of firms on projects, and given differences in size and sophistication of those firms, it seems implausible that all the firms in a project supply chain will uniformly subscribe to a single data standard. It is more likely that there will be multiple standards developed for use by small groups of firms or trades, such as the CIMsteel standards (www.cis2.org). Moreover, as much process information in the supply chain relates to cost, time and production capabilities (i.e., much of firms' core operational and competitive information), it is likely that many firms will prefer to use legacy applications to manage this information, avoiding the expensive transition to new applications.

Research Agenda in Enabling Technologies

The challenges in sharing knowledge described above suggest three difficulties that must be overcome. First, extracting data resident in the supply chain. Second, enabling formalization of local and tacit knowledge. Third, development of shared visualizations of product/process knowledge. Existing technologies cannot adequately address any of these difficulties. Collectively, they suggest a research agenda in enabling technologies to support effective project supply chain collaboration.

Enabling technology one: Extracting supply chain data. Extracting data in the supply chain is a challenge as it will likely be stored in information systems with a high degree of semantic and physical heterogeneity. The only way to currently extract data from such systems is to write code for each link to each system. This is untenable given both the number of firms on projects and the transient nature of firms' participation on projects. We need to develop technology with the requisite intelligence to (semi-)automatically link to firms' information systems, discover knowledge resident in those systems, and translate it to a form needed for subsequent analysis. This is a difficult challenge that calls for research both in Computer Science and Civil Engineering. Fortunately, it is unlikely that general-purpose extraction tools are needed. Supply chain analysis generally calls for specific types of inputs, thus it is possible to generate specialized tools to discover specific and limited forms of knowledge.

Enabling technology two: Formalizing local knowledge. How can we help firms capture local knowledge so it can be represented in computer interpretable form? Construction research has a strong tradition of knowledge formalization by researchers. More broadly, computer science has a history of formalizing knowledge in expert systems. Neither approach has made significant impacts on practice outside of limited applications. We need a more general approach that allows practitioners to interact with the computer to develop useful formalisms. One such approach would be to provide graphical modeling tools of core firm processes. As these are customized, the formalisms would be developed almost in the background. In such an approach, core technologies to be developed are dynamic links between graphic models such as scene graphs and process models such as simulations.

Enabling technology three: Shared product/process visualizations. In many respects, the challenges here are similar to those of formalizing local knowledge. While it is likely that some standard shared visualizations will be developed, we must allow practitioners to customize these as needed. We must also provide them with the tools to generate new visualizations appropriate to the needs of individual projects. Visual modeling tools developed to enable formalization of local knowledge would be useful in the manipulation of shared models. However, shared models imply development and manipulation by multiple professionals. Enabling such sharing in computer interpretable form requires that the underlying languages of local formalisms be made compatible (in computer science terminology, we must provide mechanisms to develop shared ontologies). Shared models, if dynamic, must also be updated. The ability to continuously synchronize product and processes data based on events and changes requires extraction of data using technologies like those envisaged above.

Acknowledgements

The author would like to thank the NSF for funding under grant CMS-0075407 that has provided time and resources to develop research needs concerning extraction of supply chain knowledge.