PRODUCT MODELING FOR CONSTRUCTION MANAGEMENT

Product modeling for construction management

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Durability of Building Materials and Components 8. (1999) *Edited by M.A. Lacasse and D.J. Vanier*. Institute for Research in Construction, Ottawa ON, K1A 0R6, Canada, pp. 2747-2757.

Abstract

With the ever-increasing use of computer technologies for managing the information involved in business processes, information standardization has been identified as an important step towards improving the efficiency and effectiveness of these processes. Over the past two decades, many research and development projects have worked towards standardizing existing information in the architecture, engineering, and construction (AEC) industry. Many information models at different levels have been proposed and many prototypes have been developed. The major part of this effort has focused on modeling product information in AEC projects (as opposed to process, organizational, or other project information), and has concentrated on the designer's perspective. Our interest, however, is from the perspective of project managers. Although project management introduces a spectrum of process information that governs the act of constructing a project, the product information that describes the facility itself is still central. Yet this product information is not explicitly represented in existing project management software such as estimating and scheduling software. This paper outlines the dimensions of a research project aimed at product modeling for project management. It discusses some of the specific requirements of product models for the purpose of supporting project management functionality. The paper also describes a framework that has been devised for categorizing project management functions.

Keywords: Construction Management, Construction Management Information Systems, Information Models, Process Models, Product Models, Project Management

1 Introduction

Management of product information is attributed as a strategic action for achieving "process efficiency" [Leslie 1996]. Any architecture, engineering, and construction (AEC) project starts and ends with a product; i.e. starting with recognition of a need (for a physical object, as a product) and ending with the constructed product. In the evolution process of the product, from conceptualization to realization, information about each stage of the product becomes a stimulator and reference for subsequent processes. Therefore, defining, representing, and presenting this information in a shareable and exchangeable form is crucial to the smooth progress of projects.

The existing commercial project management systems, despite their coverage of many application areas, do not support a full range of construction management (CM) functions. Moreover, product data, despite its centrality for operations of CM functions, is not explicitly represented in the current systems. Human interpretation usually is a part of the processes of these functions. Thus a higher level modeling of such information has been sought. However, there seems to be different approaches to the development of such models [Fischer et al. 1995]. Moreover, the proposed product models tend to portray a designer's view in some specific aspects of the product and thus they are not as appropriate for supporting CM processes. There is a question of how to model product information in a way that the resulting models could be shareable among CM functions.

This paper provides an overview of our research, aimed at product modeling for project and construction management. First, a background is presented. A brief outline of the objectives and methodology of our research follows. The rest of the paper gives some of the visions of the research and a framework developed for classification of PM functions.

2 Background

2.1 Project and construction management

Grouping *works* performed by organizations into operations and projects, the Project Management Institute (PMI) defines the term *project* as: "a *temporary* endeavor undertaken to create a *unique* product or service." It then defines *Project Management* (PM) as "the application of knowledge, skill, tools, and techniques to project activities in order to meet stakeholder needs and expectations from a project" [PMI 1996]. More specifically, the term *Construction Management* has been defined as "*the composite of all modern project management methodologies having as their objective the control of time, cost, and quality in the design and construction of a new facility*" [Kavanagh et. al 1978].

For the purpose of this paper, we apply the term 'CM functions' to refer to the activities that take place in the delivery of a construction project. We relate these functions to those performed by the constructor of the facility, from preparation for construction to construction and hand-over of the product to the stakeholder (or owner). However, in some occasions, due to inheritance of the functions of PM by CM, we use these two terms interchangeably.

2.2 Product, product model, and process model

Though tightly interwoven, the totality of *project data* can be divided into *product data* and *process data*. The term *product*, in a materialized sense, is defined as: “thing or substance produced by a natural or manufacturing process” [Oxford Dictionary 1989]. This definition matches with the definition given in a data modeling sense, by ISO: "a thing or substance produced by a natural or artificial process" [ISO 1992].

Product data is also defined as: "a representation of facts, concepts, or instructions about a product or set of products in a formal manner suitable for communication, interpretation, or processing by human beings or by automatic means" [ISO 1992]. Some examples of product data are 3.00, large, SouthEast, and acceptable; representing the height (in metres), size, orientation, and finishing quality of a wall (i.e. product) respectively. Product data gives information about different characteristics of the physical product, irregardless of how it is built. A *Product model* describes such information. Examples of product-oriented models are RATAS [Bjork 1989], COMBINE [Augenbroe 1995], and STEP standards [ISO 1992].

Process data, on the other hand, is data about processes in a system; i.e. data about the actions taken in order to construct a building, for instance. It includes data on construction methods, resources, organization, etc. Process models describe such information. Examples of proposed process models are IRMA [Luiten et. al 1993], and ICON [Aouad et. al 1994].

The concept of *project models* [Fischer and Froese, 1996] is a response to the need for integration of product and process information. One of the major on-going standardization effort is the activities of the IAI (Industry Alliance for Interoperability), which is similar to the STEP project and has aimed at definition of building industry object classes called the Industry Foundation Classes (IFC’s). IFC’s are considered to be a library of commonly defined objects, creating project data, and supporting the whole life cycle of building development [IAI 1997]. Nevertheless, so far, the focus of this project has been more towards modeling design and facility management application areas, and defining those objects supporting construction management functions has been limited to estimating and scheduling.

3 Objectives and research methodology

The scope of this research is product modeling for Construction Management. The basic question of *how product model information can be useful for CM processes* has been split into the following four research issues:

1. What are the information ingredients of products, and how are they modeled in existing product models?
2. What are CM functions, and how do the existing systems support these functions?

3. How do CM functions use product information?
4. What should CM-oriented product models look like?

The above questions have led to a research methodology illustrated in figure 1. The methodology involves three major steps. As a first step, to conceptually map types of product information, a very high-level classification of the information is investigated. Existing product models are reviewed for these information ingredients from a CM perspective, with an eye towards improving the support for CM functions in these models.

The second step involves the classification of CM functions and systems. A framework has been developed for top-down classification of the functions. The resulting classification would help in identifying potential CM information systems. A review of the existing commercial CM systems has helped verify the results of the framework and identify the missing areas for systems modeling and development.

The answer to the third and fourth questions above will be sought in the third phase of the research, by exploring a specific CM application area, and examining the exact role of product model data relative to that application. The output from the second phase will lead to the selection of a CM function and development of product models for that function.

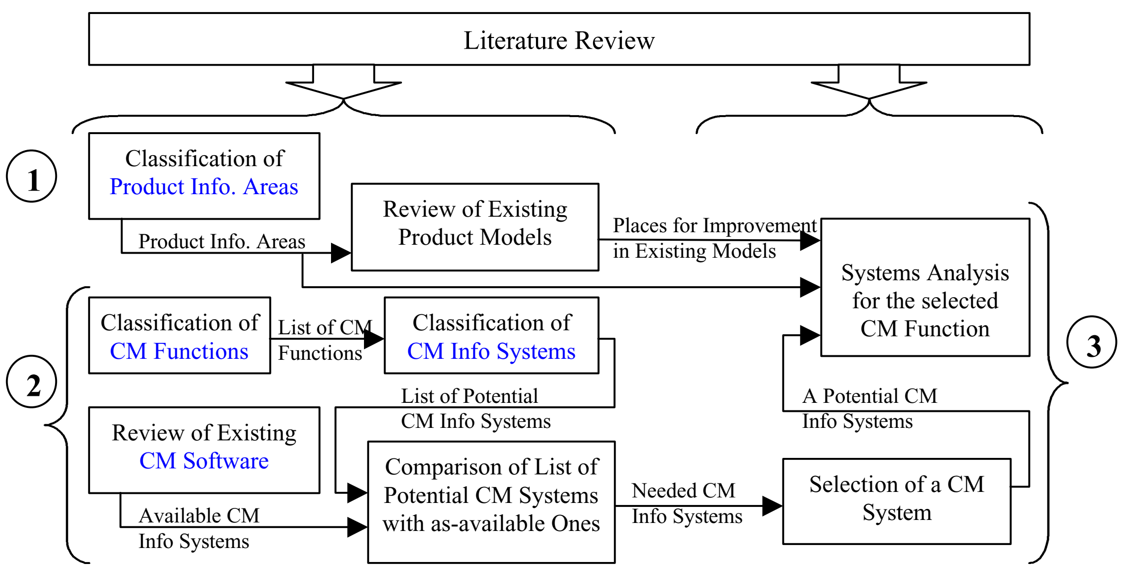

Fig. 1: The research methodology

The methodology of the research demonstrates a coupling of both top-down and bottom-up approaches, complementing each other. Development of our conceptual frameworks and analyses are top-down while review of the literature and the existing CM software systems and product models are bottom-up.

4 Product data and construction management

Defining basic inter-related product concepts, this section discusses on how product data may be viewed and used by CM functions.

4.1 Product, space, and material

A product can be conceptually classified according to the nature of its constituent elements and the type of product data that is used in the product development processes. A product (e.g. a building) that becomes the subject of a construction contract is comprised of two major elements: 1) *tangible product* (i.e. what is visible and can be touched), and 2) *space* (e.g. zone, floor, room, etc.). The tangible product, in turn, encompasses two elements: 1) physical product, which we call *target product* (e.g. walls, doors, technical equipment such as a heat generator, etc.), and 2) *material* from which that target product is developed (e.g. concrete, brick, pipe, insulation, etc.). We refer to material as is needed and used by CM functions (e.g. materials management and quality control); i.e. the physical material.

4.2 Product and its data in different views

The data that describes the form or shape of a product is perhaps some of the most important references regularly used by processes of CM functions. Shape-related product information is comprised of topological and geometrical information. *Topology* refers to the physical structure (or configuration) of components, while *geometry* encompasses dimensionality of components. Inclusion and intersection are two examples of topological concepts. Size, height, and length, on the other hand, are geometrical concepts.

The product's form data is used by the processes of PM functions and becomes an integral part of the input data used to evaluate and analyze process elements. A typical example is the use of size (e.g. length, width, and height), numbers, and location (e.g. zone, block, floor, etc.) of product items for estimating purpose. Not only do such data help in the preparation of product bills of quantities, but they are also used for CM engineering purposes. The shape and size of a concrete foundation or wall specified in drawings, for instance, are used for formwork design. This means that there is a relationship between shape characteristics of (tangible) products and that of the resource used for their construction.

Progress reports prepared during construction are another example of a CM function that references the geometrical information of products. The *square meter of walls* completed in a particular day, the *length of road* paved in a day, and the *cubic meter of concrete* (i.e. material) placed in *foundation walls* are some instances in which geometrical data about product plays an important role in the definition of the concepts used in CM processes. A major use of this as-built data about products is further made for productivity analyses and control as well as cost control purposes.

Selection of a construction method for a particular job is heavily dependent on the size of the job. Resource selection is a process that usually requires the (target) product's shape data. Compatibility of size of equipment with size of the product is a major criterion in this selection (e.g. considering shape and size of a building for selecting and locating cranes and scaffoldings).

Spatial information is an essential and integral part of product models of AEC projects, especially building projects. Arranging spaces is at the heart of the architectural design process (i.e. translating required functions into spaces, containing physical components; e.g. a set of rooms containing shared walls, columns, windows, door, etc.).

However, spatial and physical component information may play different roles in different project views. Each functional view of design (e.g. architecture, HVAC, structure, etc.) and construction (e.g. procurement, scheduling, etc.) may look at space differently. The perception that a project participant may have of a space and the information in which they are interested is dependent on the type of manipulation that that may perform on the space and its data. For instance, to the construction manager, space is a something of which he can temporarily use during construction (e.g. for storing materials, housing construction office personnel and laborers, etc.). This view of space is in contrast to that drawn by an architect: a fully furnished and decorated room, for example, with no sign of construction activity.

Nonetheless, not all data generated during design may be used as input to CM systems. For example, a construction manager may not need to know about the required energy, solar heat gain, internal heat gain, etc. which are used for energy analysis of spaces during design. Quality management (QM) might rather be interested to know the final specification of the product, such as heat power of the technical system required to be installed (i.e. what gives the total required heat for a space). The result of such analyses is transferred to CM functions in the form of as-required performance data. QM functions are a major user of performance data.

4.3 Material information

How does a project manager look at construction material and its information? Material is defined as: "substance or things from which something else is or can be made" [Oxford Dictionary 1989]. In construction, material may be used not only for constructing a target "product" (e.g. constructing a column from bulk concrete) but also for assembling a "resource" (e.g. making a ladder or concrete formwork from pieces of woods received on the site). This is the view of the construction and facility manager. However, in the existing models, material is not usually modeled as "physical material", but as "material properties", which may be enough for engineering analysis and design but not for construction. This appears as a bottleneck in transferring material information electronically from design to construction. The same problem would exist during operation and facility management.

The quality control function, for example, looks for information describing the quality—both as required and as-constructed—of items, such as the finish of a column, slump of the concrete received on the site, or strength of a concrete test sample block. Some of this information may have been provided during the design, however, other information may not be provided, or at most, may be fragmentally scattered throughout the design documents and specifications in text form with no linkage between them.

The material management function is another example which needs some form-and-performance-related information about materials and some association between this and the physical product for materials space handling. Materials information together with shape characteristics of space is a basic input to both the processes of space management for activity scheduling and material handling. Avoiding congestion and interference in construction processes is highly dependent on the size of space available to the crew [Riley and Sanvido 1995].

Consideration of *space*, *target product*, and *material* as three closely interrelated product elements in a product model would enhance the integrity and effectiveness of the models. Topological and geometrical characteristics then must be modeled as they relate to any form of product (i.e. space, target product, and material).

5 Classification of construction management functions: A framework

The literature on general project management and construction management elaborate the processes involved in the management of construction projects. Some of the literature has attempted to classifying the functions and processes involved. Based on a literature review, we have developed a framework that helps provide a comprehensive list of CM functions. Such listing can be used for classifying and developing CM information systems.

5.1 The PMBOK

In "the Project Management Body of Knowledge" (PMBOK), the Project Management Institute (PMI) divides project processes into two groups: "PM processes" (i.e. those concerned with describing and organizing the work of the project); and "product-oriented processes" (i.e. those concerned with specifying and creating the project product) [PMI 1996]. Concentrating on PM processes, the PMBOK groups the processes into nine knowledge areas.

The PMBOK describes project management in general. It covers the major areas and processes of project management common to all types of projects. However, some processes common in construction management are not covered, such as equipment management, materials management, and safety management. Materials handling and distribution plays a significant role in the progress of many types of projects (including construction) as does materials procurement, which is considered in the PMBOK in the form of acquiring goods and services. Overall, the PMBOK provides a good reference for identifying PM functions, but modifications and extensions are needed in order to cover a full range of construction management functionality.

5.2 Dimensions of project management

Three basic dimensions can be defined for construction management: project objectives, project elements, and basic CM functions. We use these dimensions to devise a framework to classify CM functions.

5.2.1 Project objectives

The goals of every construction project are to be completed with the right scope, within a reasonable time, cost, and quality, without injury and accident, and at minimal risk. Thus, at the very highest level of importance, the objectives of management of a project are summarized into control of *scope, time, cost, quality, safety,* and *Risk*. These objectives govern all the processes involved in the development of the project. We have considered PM objectives as one of the basic dimensions of our PM framework.

5.2.2 Project elements

Construction management involves the use of resources to create a targeted product in an environment. We call these resources, product, and environment "*project elements,"* specifically: *human resources*, *equipment and tools*, *materials*, *money/financial* resources, *information*, target *product*, and project *context and externals* (e.g. vendors, customers, competitors, environment, etc.). The progress of a project is dependent on these elements.

5.2.3 Basic construction management functions

Regardless of types or phases of projects, there are a number of basic functions which are performed in managing a project. Kavanagh et. al [1978], list five basic functions from which scientific management is comprised: *planning*, *control*, *organization*, *coordination*, and *direction*. PMI, in another approach, groups PM processes into five "process groups": *Initiating, planning*, *executing*, *controlling*, and *closing* [PMI 1996].

There are major overlaps and similarities among these proposed classifications. We draw from these to classify basic PM functions into seven groups:

1. *Initiating*: recognition of a need for a project and commitment to carry it out,
2. *Planning*: developing and maintaining project plans,
3. *Organizing*: selecting and arranging project resources,
4. *Executing*: implementing the project plan,
5. *Controlling*: tracking of execution of project plans to ensure project objectives,
6. *Closing-out*: formalizing acceptance of the product and closing the project, and
7. *Following-up and Redirecting*: providing warranty services and learning from project processes.

The basic CM functions are those generic and conceptual activities that are usually performed in the progress of a typical project. These functions are generic in the sense that they may be exerted at any specific phase (e.g. design, construction, operation and maintenance) or the total life cycle of a construction project (i.e. from inception to operation and demolition of the facility).

5.3 The framework

Figure 2 illustrates a three dimensional rectilinear grid representing the three major conceptual PM dimensions on its three axes. Each grid cell in a coordinate plane would identify a function, holding a number of processes, relating to the two corresponding dimensions concepts (e.g. cost control for cost and controlling extending vertically throughout project elements).

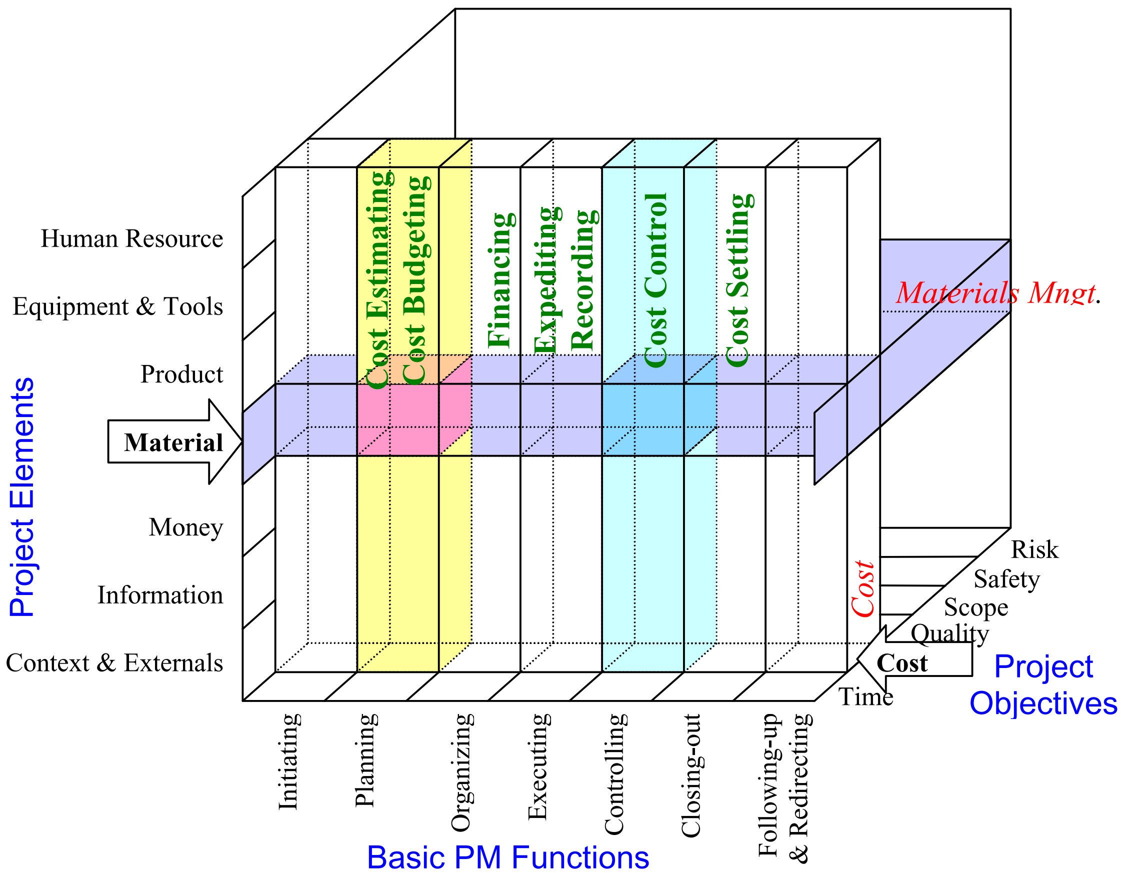

Fig. 2: Dimensions and functions of project management

Each three-dimensional grid coordinate (i.e. cube) would represent a conceptual process, holding a number of sub-processes, originating from the three corresponding dimensions concepts (e.g. materials cost control at intersection of material, cost, and controlling). The figure illustrates how the three dimensional rectilinear grid can be used to identify processes, here relating to how materials management may interact with cost management. This framework is flexible, and the coordinates would help us identify any possible functions of CM from different perspectives (e.g. project *planning*, *cost* management, and *materials* management).

6 Conclusions

This paper presented some of the dimensions and visions of an on-going research project aimed at product modeling for construction management. This includes the objectives and overall methodology of the research, and some of the visions and conceptualization stages of the research.

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