A Top-Down Approach to Integrating the Building Process

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Abstract. Many computer-aided tools have been developed to assist designers, engineers, and managers with specific well-defined functions, yet they are not well integrated. This paper develops the need for an information architecture to integrate the processes and subsequent software used throughout the life of a building. It then defines a process model of the functions required to provide a facility to the end user, namely, managing, planning, designing, constructing, and operating the facility. This process model implies that the proposed information architecture must support the life-cycle process, effectively capture knowledge, and act as an integrator of industry accepted decision-making tools. Finally, a knowledge-based approach to implementing the information architecture is proposed.

1 Introduction

Man has been constructing facilities for human habitation since the beginning of history. Early design and construction was founded on the principles of trial and error, which relies completely on experience to implement improved techniques. Facilities were essentially maintenance free and easy to operate. The logical culmination of this approach to construction was found in the "master builder." This master builder encompassed the complete range of knowledge to carry out each stage of a building project from concept to operation. With this single individual responsible for the project and making all of the decisions, communication and integration of knowledge and information was automatic. Changes in technology and specialization of services have gradually worked within the building industry to remove the master builder.

The present building process, with shorter construction periods than those enjoyed by the master builder, is driven by the collection and transfer of large quantities of information consisting of a variety of design documents (drawings, schedules, specifications, and calculations), verbal agreements, change orders, meeting notes, correspondence and contracts, government codes and regulations, inspection results, construction documents, and operating manuals between widely dispersed disciplines and individuals on a project. The data originators go through significant decision-making processes to translate their intent into these documents. At best, these documents represent the conclusion of such thought processes. They do not include much of the background reasoning that the data originators experienced. This results in suboptimal changes to these designs later in the facility's life.

Information is frequently transferred to the user in the format that is easiest for the originator. The existence of many types of software and various methods for data representation implies that data provided by one source will require some manipulation to the format understood by the end user. Even drawings with the same name, generated by similar organizations, contain different information. When different media are used, for example, knowledge bases, three-dimensional graphical data bases, drawings, and models, the confusion increases.

Another concern is that current media for communication of data, namely, drawings, specifications, and so on are produced, reproduced, distributed, received, and then reviewed. This process may take up to eight weeks on larger projects. Current methods do not facilitate rapid access across organizational boundaries due to different techniques for graphical representation of data.

Each user may require different information about the same component at different stages in the life of the project. Many of these users redevelop the data because it is inaccessible in the form they require it.

In summary, effective integration of the delivery process requires the development, assembly, coordination, and management of large volumes of very different types of data. Currently, this data is transmitted through media that:

1. Fail to communicate the intent or knowledge of the originator
2. Require manual translation to the following user's format, hence discouraging automation of the subsequent process
3. Limit real-time input and access to data, thus discouraging two-way communication or feedback to the previous process
4. Require regeneration of data

From these viewpoints it can be seen that there is a need for an integrated framework. Moreover, the industry lacks (1) a unified framework for representing the construction process and (2) a common open architecture and media for the representation, classification, capture, and real-time retrieval of data, information, and knowledge in their various forms. A system is needed that will allow multiple users to access interactively data stored in different forms in order to extract their own information requirements. In order to define the information architecture, we need a clear understanding of the essential functions required to provide a facility, including their definitions and interactions.

The preceding discussion shows that the construction process is highly knowledge-intensive. Many decisions are based on experience and human judgment. Artificial intelligence (AI) based strategies may be of considerable use in designing an efficient and integrated system. This paper focuses on the development of a process model, the characteristics of the information architecture, and the role of knowledge-based technology in its development.

2 The Process Model: Strategy and Methodology

Our approach to developing the process model was to define the essential functions to "provide a facility" to the end user. We did not model organizations, contracts, or job descriptions, but rather essential functions. These functions would ultimately be the same whether an individual was designing, building, and living in a house, or whether a team of many contractors was designing, building, and operating a manufacturing facility.

Parts of the U.S. manufacturing industry have gone through a successful, extensive implementation of computer tools to integrate the manufacturing process [1]. They have adopted standard modeling methodologies, such as IDEFo, and designed information architectures, which have led to increases in productivity. We thus included key researchers in this field in the team to provide cross-disciplinary fertilization of knowledge.

The project team assembled included expertise covering the life cycle of a facility, namely, architecture, engineering (mechanical, electrical, civil, structural, industrial, construction), and computing. An industry advisory board of five practitioners representing all phases of the life cycle of a project provided a formal "real-world" review mechanism for the project. An academic advisory board of five leading CIC researchers provides input to and reviews the model to ensure research integrity. Several other representatives of software companies, industry practitioners, and research organizations have reviewed and been involved in the effort.

The basic steps in the development of the process model follow.

2.1 Determination of the Current Building Life Cycle

The literature yielded several models of portions of the building life cycle [2–8]. These varied from narrow, rigid closed models to open models showing overviews of parts of the life cycle. Most models tied closely to job descriptions and were non-dynamic; they depicted a steady-state function. Discussions with the industry advisory board and leading researchers, and visits to local buildings in various stages of their life, showed that the proposed definition of the building life cycle as design, construction, and facilities management had to be expanded. Hence building activities with similar processes were regrouped into manage facility, plan facility, design facility, construct facility, and operate facility. These activities are discussed later.

2.2 Selection of the Modeling Methodology

The first activity here was to evaluate methodologies for process/information representation. Several modeling tools in use in the construction industry were reviewed for their modeling capability rather than content. Input-process-output models arranged in a hierarchy showed high potential, but the lack of a rigid method for decomposition to lower levels of detail presented a problem.

A set of criteria for the model was developed. These criteria were summarized into four categories, namely, technical merit (i.e., able to represent information and functions), ease of use, compatibility with the manufacturing and construction industry, and availability to the industry.

Ten manufacturing and industry modeling tools were analyzed. These included entity relationship models and process models. IDEFo [9] was selected