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Object oriented modeling: Retrospective systems information model for constructability assessment

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ABSTRACT

Object oriented modeling (OOM) has become an integral part of the design process in construction due to advances in computer software. Despite these advances there remains a tendency for Computer-Aided-Design (CAD) to be used as the medium to assist in the creation, modification, analysis and optimization of Electrical and Instrumentation (E&I) systems within heavy industrial engineering projects. In this paper, a retrospective OOM (i.e., Systems Information Model (SIM)), for the E&I systems of a utility facility, which was constructed for an Engineering Procurement and Construction (EPC) contractor for the purpose of undertaking a constructability assessment prior to the commencement of construction is presented and discussed. The CAD drawings and cable schedule produced by the EPC were provided to an E&I organization to undertake a constructability assessment; errors, omissions and information redundancy were identified and quantified. The SIM model was then used to examine a tender proposal from a construction subcontractor (CS) of the EPC; discrepancies were identified and it is suggested that differences arose due to the prevailing errors and omissions. The potential use of a SIM during construction as a quality assurance/control (QA/QC) is then examined, as it is suggested that it can be used to ensure the development of an 'As-built' model and provide a realistic representation of the constructed asset, which safeguards its integrity for operations and maintenance.

Introduction

"We cannot solve our problems with the same thinking we used when we created them"

(Albert Einstein)

Object oriented modeling (OOM) has become an integral part of the design and engineering process in construction due to advances in computer science which have resulted in an array of software tools and platforms being developed specifically for the construction industry (e.g., [1,4,5,10,19,23,26]). In the context of construction, OOM is the digital representation of an asset as a collection of objects that contain a hierarchy of stored values for variables. This hierarchical structure means that information about each type of object needs to only be defined and stored once, as this information is 'inherited' by all the individual instances of this type. As a project progresses from design through to implementation the data attached to each object evolves to become more detailed, and the central focus shifts toward understanding how the system will be constructed and function.

Despite the advances enabled by OOM such as Building Information Modeling (BIM), within the field of electrical engineering there remains a tendency for Computer-Aided-Design (CAD) to be used as the preferred medium for design and documentation [8,9,17,18]. When CAD is used in this way there is a high risk of errors, omissions, and redundant information occurring, particularly when producing 'As-built' drawings [16].

In acknowledgment of the problems that may materialize by producing 'As-built' electrical and instrumentation (E&I) drawings using CAD, an EPC contractor approached an electrical organization to undertake a retrospective constructability assessment (i.e. to identify and eliminate errors and omissions from the design before the project commences construction). The EPC contractor was aware of the potential of errors and omissions to have materialized in the E&I drawings developed in CAD thus developed a retrospective System Information Model, which is based on OOM, to identify obstacles before their project was actually built to reduce or prevent errors, delays, and cost overruns that could potentially materialize [11]. According to Gambatese et al. [7] constructability is in part a reflection of the quality of the design documents that have been produced; if documentation is difficult to

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understand and interpret, a project will be difficult to construct. Another aim of this process was to examine how the developed SIM could be used during construction as a tool for quality assurance and control (QA/QC) to ensure that it can provide a realistic representation of the constructed asset and safeguards is integrity for operations and maintenance. It is outside the scope of this paper to provide a detailed review of the constructability literature, however, this subject has been examined extensively by O'Connor and Tucker [21], O'Connor et al. [22] Uhlik and Lores [28], Jergeas and Put [12] and Lancine et al. [3].

Systems Information Modeling

A SIM is a generic term used to describe the process of modeling complex systems using object-oriented software [30]. A SIM is a digital representation of a connected system, such as electrical control, power and communication systems. When a SIM is applied to design a connected system, all physical equipment (or objects) and the associated connections to be constructed can be modeled in a database. Each object is only modeled once. Thus, a 1:1 relationship is achieved between the SIM and the real world (Fig. 1). This is in stark contrast to traditional CAD approach to producing electrical instrumentation and control systems (EICS) documentation identified in Fig. 1, which focuses on the production of drawings where an object can be represented on many drawings (m:n).

Within the extant literature, there has been a paucity of research that has been able to empirically quantify the benefits of adopting an OOM approach, with those that do exist focusing on the benefits relating to the management of geometry. For example, it has been found that the adoption of OOM in the structural engineering design and detailing of reinforced concrete building structure can provide a productivity improvement of 15% to 41% [25]. As a result of this research, Sacks and Barak [25] suggested that such improvements may result in a decline in the role of drafting staff. However, structural elements are represented as geometric objects, which in an OOM approach will have embedded parametric relationships [27]. However, EICS do not possess geometric components, with the exception of cable trays, cabinets and the like, and thus the benefits of an OOM approach in this domain remain untested. As an illustration, the creation of three-dimensional (3D) model of cabling as noted in Figure 2, for example, would be an impossible undertaking.

To demonstrate the efficiency and effectiveness of using a SIM, Love *et al.* [16] examined the 'As-built' documentation that had been produced for EICS for a Stacker Conveyor system. Analysis of 106 'As-built'electrical drawings and a cable schedule revealed a variety of documentation errors manifested themselves as labeling mistakes, inconsistent labeling, drawing omissions, missing labels, wrong design and incorrect connections. Omissions from drawings and the cable schedule accounted for 93% of all errors identified. It was revealed that a total of 803 extra man-hours would have been needed to address the omissions. In the case of all documentation errors at a total of 859 extra man-hours would be required. Love *et al.* [16] observed that there was considerable information redundancy contained within the 107 electrical documents. For example, 357 items appeared twice on documents with as many as 42 items appearing five times. The creation of the information redundancy contained within the 107 documents equated to an additional 598 man-hours. The Stacker Conveyor's 'As-built'cable schedule was used to create a SIM to examine how it would eliminate documentation errors and information redundancy. The average time to produce a single drawing out of SIM was two hours compared to the estimated 39 h using CAD. By using a SIM Love *et al.* [16] revealed that a 94% cost saving and improvement in productivity could have been attained.

A SIM can be created using software such as Dynamic Asset Documentation (DAD) and applied throughout a project's lifecycle [30]. The practices associated with asset management, for example, comprise of a set of data-intensive decision-making processes, which are undertaken throughout all stages of a project's lifecycle. The development of an asset management system commences by developing a database to store and manage asset data at the beginning of a project. Yet, current practice focuses on obtaining information at the end of a project, which is expensive and time-consuming to undertake. With a SIM, data can be entered during design, construction and commissioning using the structure identified in Figure 3.

Entering data into the SIM throughout each stage of development within a project enables asset owners to leverage the benefits associated with productivity and data integrity (Fig. 4).

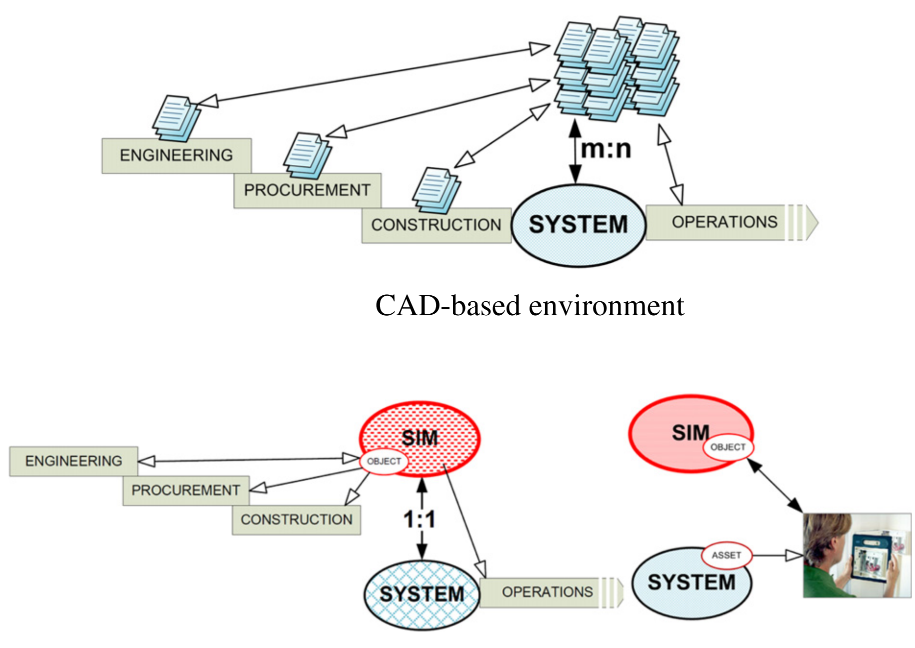

Fig. 1. The shift from CAD to a SIM-based environment.