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A systems information model for managing electrical, control, and instrumentation assets

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Abstract

Purpose – The purpose of this paper is to present a systems information model (SIM) that is akin to a building information model (BIM) and can be used by asset managers and staff to make more informed and quicker decisions about maintenance.

Design/methodology/approach – The problems associated with managing assets are examined alongside recent international efforts to standardize methods of data collection for meeting the objectives of owners. A case study in the domain of electrical, control and instrumentation (ECI) documentation is examined in detail, with particular reference to the amelioration of errors and omissions in "as built" drawings in order to provide the underlying foundation to support effective asset management (AM).

Findings – The findings show that object oriented data models such as SIM provide a robust structure for effective and efficient AM and associated leverage of benefits throughout the entire facility lifecycle of a project. In particular object oriented data enables appropriate and reliable information to be created as a project progresses through its lifecycle, at little cost to the creators.

Originality/value – The above special approach to enabling data collection at the point of creation is in alignment with recent Government initiatives such as Construction Operations Building Information Exchange, which are beginning to gather traction within the industry. While the potential benefits for AM of such systems are espoused throughout the industry, there are few successful examples in existence with measurable realization of benefits.

Keywords BIM, Systems management, Asset management, System design, Systems engineering, Utility life

Paper type Case study

Introduction

Asset management (AM) involves the balancing of costs, opportunities and risks against the desired performance of assets, to achieve an owner's objectives. It also enables asset owners to examine the need for and performance of their assets and their respective systems at varying levels. Having appropriate and reliable information about an asset (e.g. product data, warranties and preventative maintenance schedule) is pivotal for enabling AM to support decision making, planning and execution of activities and tasks of assets, particularly during operations and maintenance. A building information model (BIM) provides a structured framework for the assembly creation, and exchange of information about assets and therefore provides the underlying foundation to support effective AM. Yet within the resources and energy sectors "As Built" drawings needed for effective maintenance and operations of assets often contain errors and omissions, particularly electrical, control and instrumentation (ECI) documentation (Love *et al.*, 2013). If ECI systems are ineffectively and inefficiently designed and documented, then asset owners' plant, equipment and facilities will fail to operate, which can result in considerable economic loss as well as jeopardize safety.

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In order to address this ubiquitous problem, and improve collection of data during the design and construction of ECI systems a digital database of the systems information is presented and discussed in this paper. The systems information model (SIM) that is presented is akin to a BIM and can be used by asset managers and staff to make more informed and quicker decisions about maintenance.

Problems with managing assets

A considerable amount of documentation is needed for effective maintenance and operation of assets (Teicholz, 2013). Thus, it is imperative that information is collected, accessed and up-loaded efficiently. Yet, most existing facilities have this information stored in paper documents (e.g. rolls of drawings, folders of equipment information, file folders of maintenance record; Teicholz, 2013). The documentation is contractually requested by the owner and handed over after the building is already in use, often months later and placed in storage where is difficult to access. Figure 1 illustrates the storage of "As-Built" documentation. According to Gallaher *et al.* (2004) "an inordinate amount of time is spent locating and verifying facility and project information from previous activities. For example, "As-Built" drawings (from both construction and operations) are not routinely provided and the corresponding records of drawings are not updated. Similarly, information on facility condition, repair parts status, or a project's contract or financial situation is difficult to locate and maintain" (p. 121). Moreover, information is often contained on several documents (e.g. drawings, data

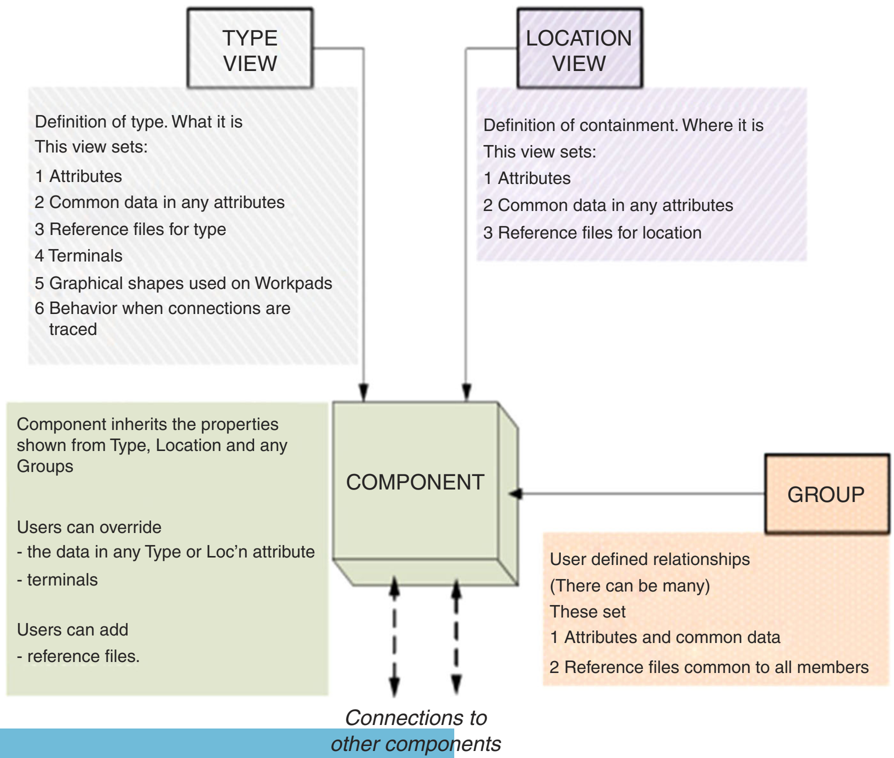

Figure 1.
Data model

sheets and test sheets), which can render the search for information during maintenance and operations an arduous task and adversely impact productivity.

Many asset owners have computer maintenance management systems (CMMS) and computer asset management systems (CAMS) in place, and thus the information contained within the test sheets, vendor information, maintenance (Mtce) data, etc., needs to be transferred into this system (Teicholz, 2013). This is typically undertaken manually, which is costly and time consuming. CMMS/CAMS are often not used until they contain all the necessary data and it has been checked for accuracy and completeness (Teicholz, 2013). The cost and time associated with entering, verifying and up-dating information in these systems can be phenomenal for owners and operators. For example, the study on the costs of inadequate interoperability from Gallaher *et al.* (2004) revealed that eighty percent of owners and operators interoperability costs are incurred during maintenance and operations. In addition, legacy data issues are often a problem as often information is stored in a variety of different media. Such information does not always reflect the true configurations of assets as "As-Builts" are often not maintained or were poorly communicated (Gallaher *et al.*, 2004).

SIM

To ensure that the appropriate information is available during operations and maintenance it needs to be entered as a project progresses through its life cycle. BIM can enable this to occur as it is essentially a process for managing the information produced during the lifecycle of an asset (NIBS, 2008). BIMs are typically created using an array of software applications, and subsequently integrated to form a single point of truth. Increasing emphasis has been placed on the development and integration of software packages for architectural, structural, heating ventilation and air conditioning and hydraulics. Such elements have scale, geometry and therefore can be visualized within the BIM. However, ECI systems have no scale or geometry and cannot be visualized in a three-dimensional (3D) view, though cable trays and components can be modeled. As a result, there is a reliance on the use of Computer Aided Design (CAD) to detail the connection and relationship between components. While BIM is beginning to be widely adopted by engineers within the construction industry, within the energy and resources sector CAD remains the primary tool to draft and design ECI systems (Zhou *et al.*, 2013).

Graphical and written representations developed by engineers are typically represented in two dimensions (2D) and constructed using CAD. When a change is required to a 2D drawing, the drawing and each corresponding view each have to be manually updated, thus a 1:*n* relationship exists (Figure 2). The modification of drawings can be a very time-

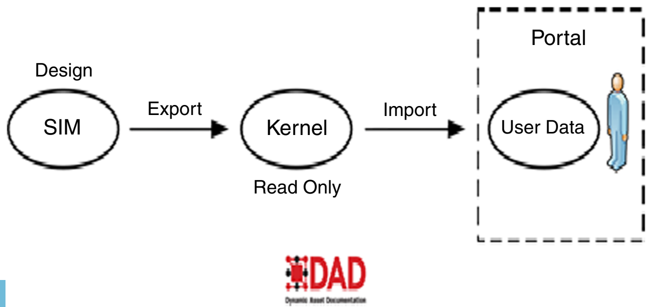

Figure 2.
SIM Portal

consuming and costly process. Furthermore, as drawings are invariably manually coordinated between views in 2D, there is a propensity for documentation errors to arise particularly in the design of complex ECI systems, which may comprise of thousands of drawings that are not to scale and have to be represented schematically. In this instance, information is often repeated on several drawings to connect each schematic. Consequently, the time to prepare the schematics can be a time consuming process, especially as the design gradually emerges and individual documents are completed. Inconsistencies can manifest between the documents, therefore requiring them to be re-edited and crosschecked before they can be issued for construction. In overcoming the inefficiencies associated with using CAD to design, engineer and document ECI systems, a novel SIM is propagated and presented in the next section of this paper.

SIM

SIM is a generic term used to describe the process of modeling complex systems using appropriate software. A SIM is a digital representation of the connected system, such as electrical control, or power and communication systems. When SIM is applied to design a connected system, all physical equipment 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. As a result, information redundancy contained within traditional CAD documents is eliminated. A SIM can be created using software such as Dynamic Asset Documentation (DAD) and applied throughout a project's entire lifecycle.

The practices associated with AM comprise of a set of data-intensive decision-making processes, which are undertaken throughout all stages of a project's life cycle. The development of an AM system commences by developing a database to store and manage asset data at the beginning of a project. Yet, current practice focusses on obtaining information at the end of a project, which is expensive and time-consuming to undertake. Within DAD, the approach is to enter data during design, construction and commissioning using the structure identified in Figure 1. 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. The model is similar in nature to the Construction Operations Building Information Exchange (COBie) standard, which requires that the data needed for the purposes of maintenance and operations is captured in a standard format, as it is created, during design, construction and commissioning of a project, so as to simplify the work necessary for project handover (East, 2007). COBie specifies the information needed to be passed from design and construction to operations and maintenance. As different parties in a project tend to use different kinds of software COBie provides a platform neutral standardized format for sharing data. COBie information can be exchanged in a several different formats, from a simple spreadsheet to the more complex sub-set of the Industry Foundation Class (IFC) file format.

As the COBie format gathers traction within industry, through initiatives such as the UK Government mandate (Great Britain. Cabinet Office, 2011), more and more BIM software vendors are providing mechanisms for exporting COBie formats through simple mechanisms such as "Save As …." The SIM presented in this paper specifically focusses on the ECI systems. It is an object oriented data model, with objects (or components) grouped into systems (see Figure 1), which lends itself well to facilitate simple export to COBie format either as a spreadsheet or as an IFC file.

Design and engineering

Engineering design and documentation can be undertaken simultaneously when using a SIM. The underlying characteristics of the role of a SIM in design are presented in the list below. Each piece of physical equipment to be constructed in the real world is modeled in the SIM as design progresses and is allocated with a unique tag name. Equipment is created with "Type" and "Location" attributes. The "Type" attribute is used to define equipment functionalities. The "Location" attribute is used to describe the physical position of equipment within a plant. With such a classification, engineers can browse the SIM model and locate the information they require. Cables and signal flows between equipment are modeled as "connectors." Shape, width and color can be chosen for each individual connector to cater for different scenarios. To facilitate the design, attributes, such as a device module, cable size and specifications, can be assigned to each individual object.

Key features of the design SIM:

(1) In design the users build a system information model (SIM). This creates a virtual system describing the desired system, a software prototype.

(2) Every component and connector is represented by a software object storing its information, connections and relationships within the SIM.

(3) Design simply specifies:

- what equipment is required;
- where it is to be installed; and
- how it is to be connected.

(4) Every object in the SIM has a full history tracking all user actions.

(5) As objects can be readily linked to visualization packages, equipment layout and cable routing can be designed more accurately.

(6) DAD enables a paperless design review and captures all review comments.

A complete history log is provided to monitor and record the activities that have been performed with the model. Any modification to a particular object, including the person who performed this activity, is automatically recorded in the system for future checking and verification. As a result, this function can be used to trace the revision history and assists engineers to compare previous and current design versions. When design is complete, a read only copy of the model is created, exported and made available as a "Kernel" to other project team members (Figure 2).

The users of the portals can access and import all or part of the design information within the Kernel depending on their respective authorization levels. Private user data can be added and managed via the portal such as editing attributes for the components or attaching additional documents to the model. To guarantee that all the parties involved in the project are working on an identical Kernel, users do not have the authorization to change the design during construction.

The Kernel containing the design can be issued to a number of parties for review (Figure 3). Parties having access to the design are able to review and provide comments. Thus, information delivery can be achieved digitally and instantly and no paper work is required. Feedback such as comments and approvals can be recorded in the SIM systematically which will be sent back to the design team. By adopting the DAD system as shown in Figure 4, information flows between the designers and reviewers can be entirely paperless resulting in more efficient workflows than traditional paper drawings based communication due (particularly due to the proclivity for increased cost if change orders are issued, as each drawing needs to be modified and re-issued (Figure 3).

The export of the SIM to the Portal replaces all the work associated with the issue and receipt of drawings and documents. All design information is made instantly available in a simple to use format. As a result, interfacing costs are eliminated. Portal users cannot edit the SIM as it is protected. Users can plan and record the tasks they perform on the real system by adding information to the SIM objects. There are a number of Portals with appropriate simple user interfaces for appropriate tasks such as construction, spatial and operation portals. As the design evolves there will invariably be requests for information (RFIs) from the Portal (reviewers) to the SIM (designers). If any error or omission has been identified within a SIM, users of the portals may raise RFIs to the design engineers

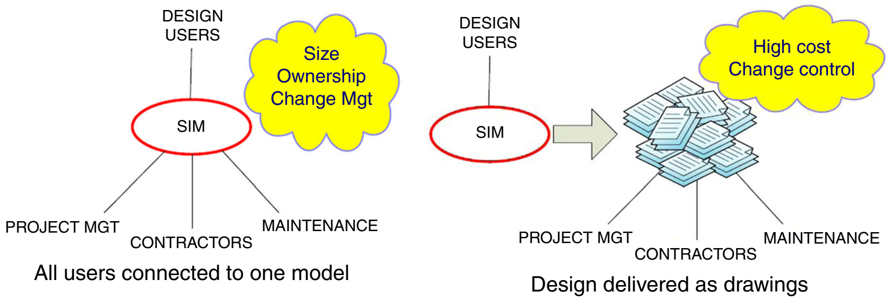

Figure 3. The issuing of design information

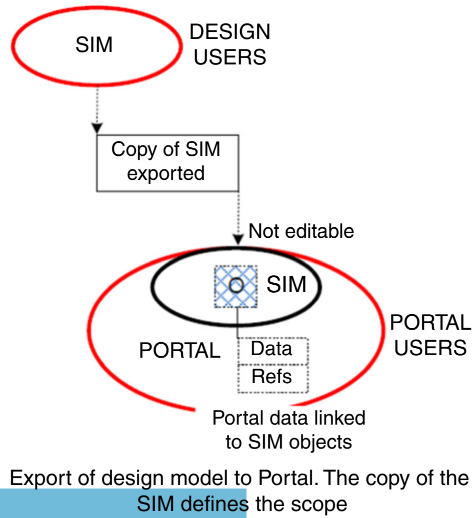

Figure 4. Exporting the design to the Portal

seeking solutions. Once the problem has been confirmed, the designers will revise the SIM and reissued it to all the users. On receipt of the new SIM, users could compare the current scope of work against the old one. If the user agrees the changes, he could replace the old SIM by the new one within the portal. All the private data saved can be retrieved and reused. The user may also reject the changes, as they would lead to contract disputes. Then, the user and the client would carry out negotiations until agreement can be achieved. If designers revise the SIM and wish to issue the new SIM to the Portal there is a strict protocol to be followed (Figure 5).

Construction

When the design is approved for construction, a SIM, a digital realization of the design, can be issued to different parties such as the procurement team and construction contractors. The key features of the SIM for construction can be found in list below. With the application of DAD, the design is encapsulated into a SIM. Due to the 1:1 mapping between SIM and its real world counterparts, information stored can be extracted more efficiently and as a result the time typically spent looking through masses of drawings is significantly reduced. Problems can be readily identified and revisions can be readily undertaken (Figure 6).

Key features of the construction portal:

(1) The Construction Portal is a DAD extension to plan and report work when systems are built.

(2) The Portal contains the SIM and all design data. This explicitly specifies:

- what equipment is required;
- where it is to be installed; and
- how it is to be connected.

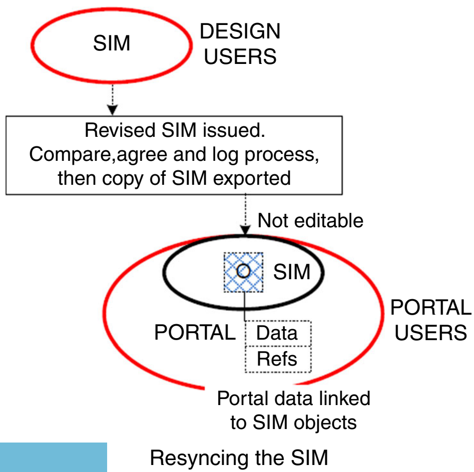

Figure 5.
Resynchronisation of the SIM

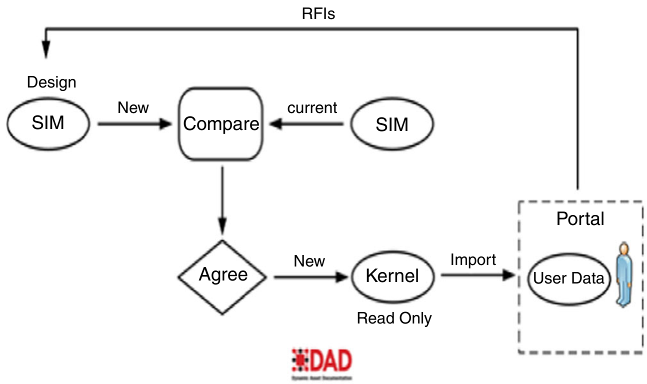

Figure 6.
Revision process

The work required to translate design data into construction management packages is eliminated with significant cost savings and integrity gain.

(3) The Portal allows users to:

- estimate and record costs;
- estimate and record times for each task;
- break up a task as necessary and package the work appropriately;
- to add reference files as supporting evidence;
- to log delays, rework and claims; and
- to manage cable drum use.

(4) The status and details for every component and connector can be found at any time.

(5) DAD transforms system construction into a simpler, more integrated realm.

A RFI folder can be created, should there be any errors or omissions identified within the design. The 1:1 mapping enables the problem to be readily located and confirmed in the SIM and as such alleviates the need for the site engineer to locate and compare the problem with reference drawings, as is the case in a CAD enabled environment. The site engineer can mark and describe the problem in the SIM, recorded by either a "pdf" file or a screenshot of the selected area. The object oriented nature of the data means that a "spreadsheet" can also be automatically generated containing all equipment information either in "Excel" or "pdf" file format. On receipt of the RFI, the design team can review the design and rectify the problem within the SIM immediately. A new kernel is then generated and exported to the users for further application as denoted in Figure 6. This process is more efficient than using the traditional CAD drawings, where errors and omissions must be manually updated in multiple locations when modification is required. The equipment that has been estimated, purchased, delivered, installed, terminated, tested and commissioned can be readily reviewed and, through the construction portal, project managers can monitor and control the progress of their project and examine actual cost and schedule against what has been planned.

AM

A SIM is specifically useful for asset managers as it enables information to be stored in a single digital model. In a CAD based environment paper drawings are typically handed over to the asset managers in the form of "As-Built," which reflect, in theory, the actual construction of every system, component and connection of EIC project. If an asset manager wants to maintain, repair or upgrade any portion of the plant, then the "As Built" drawings need to be used. However, recovering information contained on an array of drawings is a tedious task. Any error or omission contained within the drawings will potentially hinder the interpretation of the design. In some instances, the "As Built" drawings do not reflect the design that has been finally erected (Love *et al.*, 2013, 2014; Zhou *et al.*, 2013).

An operation portal is provided to cater for the needs of asset managers. The key features of the operations portal are presented in list below. Operations such as test, calibration, inspection, repair, minor change and isolation can be defined and scheduled. For instance, to maintain the safety control system of a Floating Production Storage Offloading vessel (FPSO) working at a healthy and reliable status, it has been scheduled that all the devices associated with the safety control system should be tested and calibrated regularly. If the required activity was not undertaken on time on any particular device, it will be highlighted to remind the operator before critical system failure could happen. It can be seen in Figure 7 that all the flame detectors have been scheduled to be tested once each year. A flame detector FD-511, which has not been tested according to the schedule, is automatically highlighted with a red spot shown in front of it. This enables the operators to identify those issues that need to be addressed so as to keep the system working in a healthy status. In addition, the operation portal can act as a training tool, which can be used regularly to assist operators to become familiar with the design.

Key features of the operations portal:

(1) The Operations Portal is a DAD extension to assist asset management of systems.

(2) The lifelike structures and behavior of objects in the SIM makes systems as simple as possible to understand.

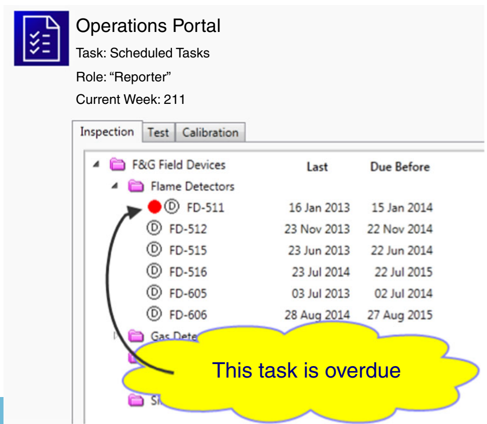

Figure 7.
Operations portal

(3) The Portal contains the SIM and all design data. This explicitly specifies:

- the equipment to be maintained;
- where it is located;
- how it is connected; and
- its technical references.

The work required to translate design data into maintenance management packages is eliminated with significant cost savings and integrity gain.

(4) The Portal allows users to:

- plan and record periodic tasks such as inspections and testing;
- record faults and repair work; and
- plan and record minor system changes/projects.

(5) The status and details for every component and connector can be found at any time.

(6) This improves asset management. It brings certainty about the current state of the system. The service history of all components is available. Compliance with statutory requirements can be readily assessed.

To expand the capability of DAD, interfaces between DAD and some other leading edge software packages have been developed. For example DAD can be applied in conjunction with Google Earth to identify underground equipment that is not visible on the surface. Coordinate information of equipment stored in the SIM is made accessible to Google Earth through the developed interface, so that the physical location of a device can be demonstrated dynamically on Google Maps. With such a technique, engineers are able to locate the devices very quickly and no drawings are required.

The 3D view in DAD can also be used to identify assets during the operation of a power plant through an interface which enables the communication between objects in the SIM and their counterparts in the 3D model. In such a way, operators can, not only access the operating information stored in DAD, but also virtually visualize the plant as the SIM and the 3D model are dynamically linked. Thus, if a problem has been detected during operation, the operator can access the design and operating information of the related devices and easily locate them within the plant allowing the engineers to analyze and resolve the problem efficiently.

Productivity and SIM

There has been very limited empirical research that has demonstrated that object-orientated models such as BIM and SIM can provide significant productivity improvements within the fields of engineering design and construction. This is an important issue that needs to be addressed to ensure that there is a shift away from manually based systems such as CAD, which hinders the need for improvements in productivity through a project's life cycle. In addressing this issue, Love *et al.* (2013) working closely with an instrumentation and electrical engineering company examined how SIM could be used to improve productivity and reduce the man-hours required to design. An examination of the "As-Built" documentation for ECI systems of Stacker Conveyor revealed that they contained 859 errors and omissions. The documentation had been prepared using CAD, and due to the 1:*n* relationship that exists there was naturally a proclivity for errors to be made. The documentation was reproduced using a SIM and it was revealed that a 94 percent reduction in man-hours and cost was achieved. In a similar study, Love *et al.* (2014) examined how a SIM could be used to reduce the impact of RFI's raised in projects. Retrospective analysis of "as-built" documentation that contained a significant number of errors indicated that the indirect cost of raising RFIs to the contractor was estimated to be 8.93 percent of contract value. Using a SIM it was demonstrated the reliability and transparency of information contained within the design can significantly improve and therefore result in a reduction in errors and omissions.

Conclusion

The difficulties in measuring benefits and costs are often the cause of uncertainty about the expected benefits, particularly in the case of innovation driven change through technologies such as BIM and SIM. This can in turn have a knock on effect on adoption rates. However, thinking of the data requirements to manage, maintain and operate an asset at the beginning of a project is pivotal for effective and efficient AM and associated leverage of benefits throughout the entire facility lifecycle. DAD, for example, which is based upon a SIM, enables a digital model that contains appropriate and reliable information to be created as a project progresses through its lifecycle, at little cost to the creators. This approach to enabling data collection at the point of creation is in alignment with recent Government initiatives such as COBie, which are beginning to gather traction within the industry.

While the potential benefits for AM of systems such as SIM are espoused throughout the industry, there are few successful examples in existence with measurable realization of benefits. For such systems to be adopted they need, at a minimum, to be able to interoperate with existing legacy systems, which further emphasizes the importance of interoperability with initiatives such as COBie. A SIM is considered to be a key an enabler for improving productivity, however, future emphasis needs to be placed on determining how processes can be re-designed within context of ECI systems, to facilitate performance improvement throughout an assets projects life-cycle. The changes that are enabled will not only improve productivity and performance but the integrity of asset over its life.

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Further reading

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