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Systems information modeling: From file exchanges to model sharing for electrical instrumentation and control systems

Peter E.D. Love [a,*], Jingyang Zhou [a], Jane Matthews [b]

[a] Department of Civil Engineering, Curtin University, GPO Box U1987, Perth, WA 6845, Australia
[b] Department of Construction Management, Curtin University, GPO Box U1987, Perth, WA 6845, Australia

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ABSTRACT

The mining industry in Australia is in a period of intense introspection as it seeks to improve its productivity and competitiveness in global markets. With mining projects experiencing increasing overruns on capital expenditure, there is a need to re-examine existing business practices to address the prevailing productivity crisis that the industry is experiencing. In addressing this issue, within the context of electrical instrumentation and control systems (EICS), a case study that examines the development of a systems information model (SIM) to improve productivity during the engineering, construction, maintenance, and operations processes of a magnetite iron ore processing plant is presented and discussed. By transforming the established document oriented information exchanges that are typically used in EICS projects to a more collaborative data-sharing environment, processes were streamlined and errors, as a result of duplication and inconsistency, were significantly prevented from occurring. While still working within the restriction of discipline-specific models, the creation of a SIM is the first step towards an integrated and interoperable data without a reliance on drawings.

1. Introduction

> “The mining industry is decades behind other parts of the economy on productivity, and the industry, not government, must raise its game. In the mining industry, we're some 20 to 30 years behind other more progressive sectors in terms of productivity and business practices.” Mark Cutifani, CEO, Anglo American (Ernst & Young, 2013–2014:p.20)

The demand for minerals such as bauxite, coal, iron ore, and nickel from emerging economies has resulted in an unprecedented number of mega-projects being constructed in Western Australia (WA). Such projects, however, have been typically subjected to cost and schedule overruns with poor levels of productivity being experienced. Several factors have contributed to the mining sector's inability to estimate and deliver new projects within their capital expenditure (CAPEX) budgets (e.g., skills shortage, a lack of standardized design and construction processes, and an overemphasis being placed on the early production of the resource). A lack of focus on CAPEX predictability and assurance reviews, for example, contributed to Barrick Gold's Pascua–Lama Gold project's cost estimate increasing from US$0.5 billion in less than 5 months to US$8.5 billion during 2012. Yet, as a consequence of increasing CAPEX overruns, the volatility of currency fluctuations, limited access to infrastructure, and increasingly restricted access to capital, have resulted in executives demanding increasing emphasis being placed on understanding the benefits and risks of the capital execution processes before a project is approved. While there is an increased focus on judicious project selection and planning being undertaken by asset owners, technological innovations such as Building Information Modeling (BIM) can also play a pivotal role in mitigating risks associated with capital execution and operations and maintenance [13,14]. The mining sector has been typically utilizing aspects associated with BIM during the Front End Engineering Design (FEED) process such as three-dimensional (3D) visualization, which is often linked with a schedule to provide a four-dimensional (4D) environment for the purposes of optimizing construction, operations, and maintenance sequences.

Definitions of BIM are abounding in the normative literature with the most comprehensive and meaningful being propagated by the US National Building Information Model Standard Project Committee who defines it as “a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition” [12]. An inherent feature of BIM is collaboration between project participants and the sharing of information throughout an asset's life cycle. As a result, BIM is often used in combination with relational-based project delivery strategies such as Integrated Project Delivery (IPD). Within the mining sector, however, there has been a proclivity for Engineering Procurement and Construction (EPC) and Engineering Procurement

* Corresponding author.
E-mail addresses: p.love@curtin.edu.au, plove@iinet.net.au (P.E.D. Love), j.zhou@curtin.edu.au (J. Zhou), jane.matthews@curtin.edu.au (J. Matthews).

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Construction and Management (EPCM) contracts to be used by resource-based companies to deliver their projects. Such arrangements are not relationship-based, and as a result, they have contributed to hindering the sector's ability to develop cost-effective engineering solutions that could potentially improve the performance and productivity in an asset's life cycle [13]. Furthermore, they are short-term and tend to focus on the tactical management of contractors rather than establishing long-term strategic relationships where the owner and contractors mutually learn and share knowledge in order to acquire improved efficiencies.

An underlying issue impacting the productivity and performance of mining projects are errors and information redundancy contained within contract documentation, particularly that of electrical instrumentation and control systems (EICS). Traditionally, computer-aided design (CAD) has been used to detail the connections and relationships between ECIS components. However, ECIS have no scale and geometry and therefore are unable to be visualized in a three-dimensional (3D) view, though cable trays and components can be modeled. Recognizing the inherent problem with using CAD to design and document EICS, this paper presents a case study of an iron ore mine owner working collaboratively with the engineering consultants and contractors who implemented a systems information model (SIM) rather than exchanging drawings between each other during the design process; the parties shared digital models; the research presented describes how this process was achieved. Noteworthy, a SIM forms the basis for software that can be integrated to form a single point of truth (SPOT) within a BIM environment. As there has been limited research that has examined the nature of BIM for EICS particularly within the mining sector, a case study approach was undertaken (e.g., [8,9,13]).

2. Research approach

A case study is an empirical inquiry that investigates a phenomenon within its real-life context [4,6,18]. A case study can be either exploratory or explanatory [22]. An exploratory case study investigates distinct phenomena characterized by a lack of detailed research [15]. Contrastingly, an explanatory approach not only explores and describes phenomena but can also be used to explain causal relationships and to develop theory using both qualitative and quantitative research methods. For the purposes of this research, an exploratory approach is adopted to obtain an understanding about how EICS are BIM enabled using a SIM.

Active engagement with industry professionals was required to acquire information about how EICS were designed, engineered, documented, and managed using a SIM. Therefore, a participatory action research (PAR) approach was adopted under the auspices of the exploratory case study [1,10,17,20]. According to Susman and Evered [21]) PAR is

- participatory;
- cooperative, engaging organizational members, and researchers in a joint venture in which both equally contribute; and
- a way to balance research and action.

In this context, the research aimed to understand both the practical concerns of the organizations, and the research goals (i.e. investigating how a SIM can improve productivity and reduce costs), by working collaboratively for a selected case study project. As practitioner involvement was required, they were treated as both subjects and co-researchers. As documentary sources such as drawings, cable schedules, requests for information (RFI) were not issued and used in a paper-based format; the researchers were given access to the SIM and digital models. For the purposes of confidentiality, the names of the companies involved with the research presented in this paper are suppressed.

2.1. Case study background

The case study investigated is a AUD$380 million magnetite iron ore processing plant, which is located in the Pilbara region of WA and covers an area of approximately 5141 ha. The project comprises two main facilities:

1. An iron ore mine area: approximately 1230 km north–north-east of Perth and 110 km south–south-east of Port Hedland.
2. Iron ore processing plant.

The new open-pit mine is approximately 4.5 km in length and 1 km wide. The mine comprises a waste rock dump, tailings storage facility, low-grade ore stockpile, process rejects waste landform, crushing and screening hub, magnetic separation processing plant, power station, roads, and other associated mine infrastructure. The project aimed to process up to 30 million tons of magnetite ore per year by extracting up to 107 Mtpa of ore and waste rock over a mine life of 45 years. The ore undergoes crushing, screening, and magnetic separation. Up to 15 Mtpa of product will be sent to Port Hedland for export as magnetite concentrate. The ore mining methodology employed for the project involved conventional drill and blast, followed by hydraulic excavation and haulage to processing facilities and stockpiles by off-road haul trucks. The iron ore processing procedure consists of the following elements, which are identified in Fig. 1:

1. run of mine (ROM) pad;
2. primary crushing and secondary crushing;
3. stockpile and reclaim;
4. high-pressure grinding;
5. air classification;
6. dry magnetic separation;
7. wet magnetic separation;
8. concentrate thickening and tailing thickening; and
9. concentrate dewatering.

The processing procedure commences from the primary crushing plant, which is located at the top right corner of Fig. 1. The ROM ore is taken from the ROM stockpile via haul truck and fed into a primary gyratory crusher. Then, the crushed ore will be fed into a secondary circuit of three cone crushers to further reduce the size of ore. This ore is then transferred to the primary stockpile.

Ore is then recovered from the primary stockpile via an apron feeder and delivered via conveyors to a High Pressure Grinding Roll (HPGR) to further reduce the size of ore to a diameter of less than 150 μm. The obtained ore particles are sent to the Air Classification (AC) building such that they can be separated: (1) particles greater than 3 mm will be returned to the HPGR feed bin; (2) particles with diameter between 3 mm to 150 μm will be delivered to Dry Magnetic Separation (DMS) building; (3) particles less than 150 μm are further split into oversize (150 μm to 50 μm) and undersize (less than 50 μm). Oversize particles will report to coarse Wet Magnetic Separation (WMS) circuit and undersize particles will be sent to fine WMS. The DMS building services is an iron ore separator, which separates the ore particles into magnetic and non-magnetic fractions. The magnetic fraction is transported to the HPGR feed bin for further size reduction. The non-magnetic fraction will report to the tailing stockpile via tailing conveyors.

Particles with less than 150 μm diameter discharged from the AC building are sent to the WMS facility to be slurried by water. The iron ore slurry will be put through a series of drums and mills by which it is separated into concentrate and tailing and delivered to Concentrate Thickener (CT) and Tailing Thickener (TT), respectively. The discharge from the CT is pumped at a nominal wet solid content of 62% to a Concentrate Dewatering (CD) plant and filtered to produce a final product concentrate cake at 8% weight to water residual moisture. The discharge from the TT is transported and disposed to the tailing storage facility.