LEAN HANDOVER™: DELIVERING COBIE DURING CONSTRUCTION

E. William East[1*] and John Ford[2]
[1] Director, Prairie Sky Consulting, Illinois, USA
[2] Digital Information Manager, Galliford-Try, Matlock, Derbyshire, UK
* email: bill.east@prairieskyconsulting.com

Abstract

The replacement of traditional construction handover deliverables with Construction Operations Building information exchange (COBie) complaint deliverables has not been going according to plan. The original COBie 2007 specification demonstrated that existing construction administration activities could be harnessed to capture COBie data with little to no technology support. In its current form, the COBie Standard is an Industry Foundation Class (IFC) Model View Definition (MVD) that has been almost exclusively adopted by the Building Information Modeling (BIM) community. While the COBie MVD normalized the original process-based data structure, the meaning derived from the construction administration process has been lost. This paper re-introduces the original motivation behind the COBie standard and describes a small case study demonstrating that incremental changes to existing construction administration process may ultimately lead to a new way of working. The benefits to this new way of working are evaluated from the point of view of Lean Construction, hence the effort has been branded Lean Handover™.

Keywords: COBie, Lean, Construction, Handover, NBIMS-US, BIM

1. Introduction

During the development of National Building Information Modeling Standard - United States ® Version 3 (NBIMS-US), the Technical Committee developed a set of criteria to differentiate "standards in fact" from those which were simply "standards in name." The criteria used to evaluate NBIMS-US, V3 technical standards is show in Figure 1.

The first task in that process was to establish a clear business case. In fact, the question of the COBie business case arose well before COBie's inclusion in NBIMS-US (East 2007). This question was not unexpected since similar questions had been asked of the first author during the development and implementation of information technology systems and standards over the previous four decades. Several approaches to answer this question were attempted, but these proved incomplete (East 2004) (East 2008) or too difficult to explain to practitioners (East 2009). Following the initial development and publication of COBie (East 2007), another approach, "value-added analysis," was applied to construction administration with good result (East 2011). The essential insight of this new approach was to construct business process models at an "operational" level of detail to differentiate activities that added value versus those that did not. Seeing a way to tie-together the business process models required for the Information Delivery Manual directly to the potential benefits of process transformation, the 25 process models in the COBie standard were developed using the value-added approach (NIBS 2015). The power of the value-added approach to predict the potential effect of COBie-enabled business processes was demonstrated in the "COBie Calculator" (Fallon 2013). In addition to its use in the COBie standard, value-added analysis was also the basis for the Information Delivery Manuals for the Heating and Ventilating information exchange (HVACie), Water System information exchange (WSie), and the electrical system information exchange (Sparkie) standards published in the National BIM Standard - United States, Version 3® (NBIMS-US V3) (NIBS 2015) and the Building Automation Management information exchange (BAMie) specification.

The technical portion of each "information exchange" standard was used to "make standards" and included the Information Delivery Manual (Figure 1, Steps 1 and 2) and the Model View Definition (Step 3.a). To provide clearer picture for those who are unfamiliar with the STEP Physical File Format (SPFF), a spreadsheet mapping was also included in the COBie standard (Step 3.b). Unfortunately, many discussions about COBie do not pertain to COBie requirements (Steps 2.a thru 2c), but only to differences in mappings between the equivalent SPFF and spreadsheet format (Step 3.b).

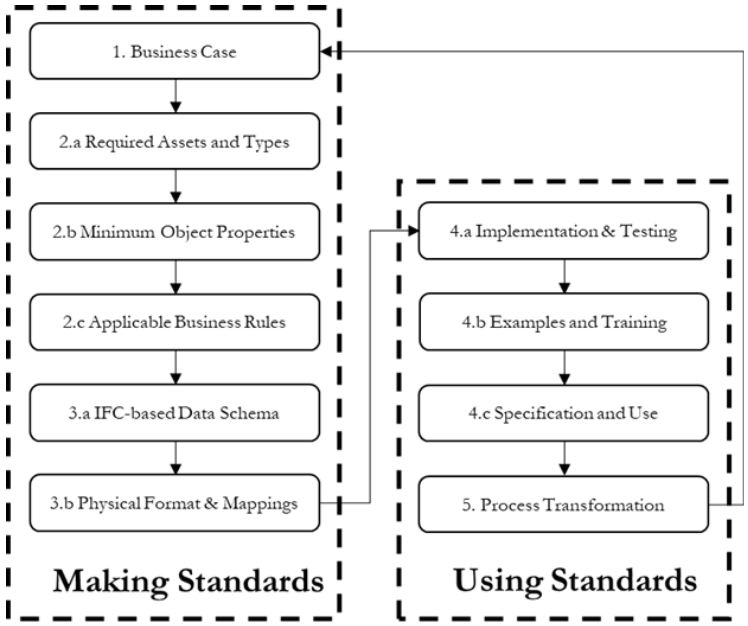

Figure 1. NBIMS-US V3 Information Exchange Standards

Beyond the technical aspects of the COBie standard, NBIMS-US V3 evidence of the use of the standards was also required. Documentation of commercial software implementation and testing (Step 4.a) against required business rules (Step 2.c) in any allowable format (Step 3a, 3b) was also required. Example files and training resources along with draft contract language supporting the "code," "commentary," and "specification" paradigm needed for physical construction deliverables were created (Step 4b and 4c). Through common understanding and implementation of the standard, process transformation (Step 5) was expected to validate the original COBie business case, allowing an ongoing process of innovation.

To date, the projects where the first author has directly engaged to help in capturing COBie data using the value-added approach described in the COBie business case (Figure 1, Step 1) have failed. In the view of the authors of this paper, the reason for that these failures is that those directly engaged with the production of COBie data are unaware of where, when, and who creates COBie data during the process of design and construction. As a result, the production of construction handover data (in COBie or any other format) remains unchanged from the traditional end-of-project data reproduction. The excuse for the ongoing use of traditional methods to create COBie data most often given to the authors of this paper is "we've just always done it that way." The authors of this paper are not alone, in COBie implementations encountered in the literature we can see that the expected construction industry innovations have not occurred. For many, the examples of COBie data (WBDG 2010)(PSC 2017) in spreadsheet format and the need to pull-apart overloaded IFC 2x3 Coordination MVD SPFF files are the stopping point when thinking about COBie. As the inventor of the COBie standard, I find it ironic that the COBie spreadsheet, the aspect of COBie identified as "the most important reason for COBie's success" by a representative of the largest US design software company, has also become a barrier to industry understanding and innovation.

2. Background

Prior to the formal publication of the COBie standard, Liu (2013) found that almost half of all Facility Management (FM) technicians had insufficient information to complete work orders. Even when FM staff participated earlier to include their requirements in the construction contract, the information provided was considered inadequate. A recent case study of the quality of construction handover data demonstrated that almost half of the handover information provided was incomplete or inaccurate and that collecting the information after construction was impossible due to physical obstruction or covering (Liu 2018). The most widely cited implementation of BIM (in the UK) attempted, as reported in Kelly (2013), to solve the construction handover problem by mandating that "BIM will provide a fully populated asset data set into CAFM Systems" with the aspiration that BIM use would increase accuracy and speed of information delivery and improve work order efficiency.

A question left unanswered in the UK mandate was noted in Volk (2014) to be the lack of objectively testable data quality standards. In 2015, however, the COBie standard proscribed a two-step COBie Quality Control (QC) process (NIBS 2015). The first step was to use pre-defined set of nine rules and "coverage" tables to verify that a data file conformed with COBie IDM's Exchange Requirement business rules. Free, open-source software automatically performs the verification testing (East 2016). The second COBie QC step was to validate that the information provided matched the information delivered on specific contract documents such as design schedules and construction submittals. Today, many continue to think that COBie deliverables must be customized for every project when, in fact, COBie data is objectively testable regardless of the specific project requirements.

Once owners began to include COBie data in contracts issues directly related to QC arose. The project identified in Pishada-Borzorgi (2018) encountered difficulties with the use and implementation of commercial software that claimed COBie compliance. Unfortunately, the conclusions drawn was not to properly QC deliverables using free software and enforce software's compliance with standard, but to hire "data wranglers" and incorporate proprietary software requirements. The authors of this paper, and many colleagues, have observed that COBie demonstrates our industry's willingness to pay double or triple the cost to partially fix something after the fact that could have been done once, correctly beforehand.

These difficulties are compound since the authors have first-hand experience, as do others (Kelly 2013), of the need to integrate construction handover data with multiple downstream information systems. One recent public owner organization encountered by the first author had different legacy maintenance, operations, asset management, and inventory control software in each of its three major facility portfolio divisions. The ability to achieve the UK proposed "BIMutopia" is further complicated by the reality imposed by the required life of building data when compared to that of the underlying contracts and technology (Miettinen 2014).

Of the case study papers reviewed, the one which reaches the heart of these problems used methodology derived from the field of sociology (Abdirad 2019). The primary conclusion reached in that paper was that contractors perceive COBie as a fixed deliverable requiring data management processes that conflict with the realities of a dynamic construction environment.

To address the complexity of construction handover, some authors have suggested adding new processes, software, and frameworks to capture COBie data (Florez 2018)(Matarneh 2018)(Alnagar 2019). Notably, Yalcinkaya (2019) suggests a visual interface to navigate COBie data that some readers will recognize as a "mind-map." As object-oriented data contains information in both relationships and objects, this abstract visualization is intuitively appealing. However, the root problem that COBie data is difficult to capture cannot be solved by layering on more software. We cannot continue to do "more of the same" and expect the outcome to be any different.

What is needed is an approach allowing project teams to capture COBie data as they work, creating, updating, and checking that data when it is captured and exchanged. In short a "Lean" approach. A comprehensive review of the application of BIM technologies to Lean Construction concludes that none of the Lean-BIM frameworks proposed in over 100 research publications can be practically implemented across the majority of construction companies (Tezel 2019).

3. Approach

To more clearly communicate how COBie implementation can lead to process transformation, the first author coined the term Lean Handover™. This objective of this phrase is to highlight the value-added benefits derived from an integrated COBie data collection method. This term also emphasizes that construction-phase COBie data is not created in BIM authoring software but in the construction administration processes documented in the original COBie report (East 2007) and listed below:

1. Identify submittal requirements
2. Define submittal schedule
3. Transmit submittal
4. Approve submittal
5. Install equipment
6. Commission equipment
7. Provide warranties
8. Provide spare parts sources
9. Transmit handover information

The book "Lean Handover™: COBie for Contractors" (East 2019) discusses the following topics: process-specific data mappings, procurement method variation, change processes, and delivery of real-time as-built project data. This book also describes the bench-testing of the approach by two Mechanical, Electrical, and Plumbing (MEP) subcontractors, one based in the US, the other in the UK. The project used for this testing was the "East Dormitory Project," a publicly available set of lifecycle building data (Prairie 2017) based on a small two-story building. The first story of this building contains dining, recreational, and meeting spaces. The second story of this building contains single *en suite* bedrooms. In this paper, we introduce one portion of the effort described in the book, the portion pertaining to the definition, preparation, and transmission of construction submittals.

4. Traditional Submittal Processes

The selection of products occurs (at least) three times during a project: bidding stage, submittal stage, and purchasing stage. Our case study considered the "submittal stage" process. The construction submittal process has two primary variants. Value-added process maps for the Design-Bid-Build variant were first published in (East 2011). The Design-Bid-Build submittal process often begins with the designer creating a master "submittal register" whose contents are delivered by subcontractors to the prime contractor and owner's representative for acknowledgement or approval. Subcontractors typically provide a single package of submittals for their entire set of specifications. Unless an extensive manual effort is undertaken, usually by the owner's representative, to match the designer's register with the contents of large subcontractor transmittal packages, most as-built submittal registers have little bearing with what was originally required by the designer. The matter is further complicated because the designer's list of individual documents may not be provided by the selected product manufactures.

Under a Design-Build procurement, each subcontractor maintains a running register of what has been submitted. There is no issue with a mismatch between what is submitted and what is required, because the list is only of what has been submitted. This does, however, beg the question as to the quality of what was submitted. As a starting point in this case study we obtained examples of real Design-Build submittal packages for Design-Build projects. A cursory review of these documents identified missing, inconsistent, and duplicative information. The review had to be accomplished manually as manufacturer data was only available as images with fixed page numbering.

As was demonstrated in the first value-added analysis of a construction administration process, significant time and cost savings can be achieved shared structured submittal data when compared to posting or emailing documents (East 2011). While there are software vendors providing services to support the distribution of submittal documents using internet-based services, the authors are aware of no systems that has addressed the collection of associated COBie-required data from within submittal documents.

5. Lean Handover™ Submittal Processes

The most critical COBie-required construction handover data, manufacturer and model number, is created during the construction submittal process. In a document-centric submittal process, this information is found in PDF documents identified with manually added boxes or arrows. The information itself is only found by manual human interpretation. In the Lean Handover™ process, we capture COBie.Type.Manufacturer and COBie.Type.ModelNumber as part of the submittal process itself by making a slight change to the contractor's transmittal form. A portion of the overall COBie-based transmittal form for our case-study project's specification section "22 00 00 - PLUMBING, GENERAL PURPOSE" is shown in Figure 2. In our case study, we generated the complete set of all required submittal forms directly from the published East Dormitory design COBie file.

In the first column of Figure 2, is the list of COBie.Type(s) identified against the specific specification section. In columns two through five, the submitter provides the manufacturer, manufacturer's model number, supplier, and product data file name. The manufacturer and supplier names link to a form back-page requiring the entry COBie-compliant company information. In column five, the file name of the original manufacturer's product data sheet is provided. This file name can be copied and pasted to minimize data transcription errors. The product data file will also have boxes, arrows, and/or text comments to identify the selected model number. By copying and pasting the product model number directly from the PDF file, the COBie-based submittal form again minimizes transcription errors.

Name & Description	Manufacturer	Model Number	Supplier	Product Data
Bath Tub (Bath Tub_1675 mmx915 mm - Private)	Kohler	K-715	Champaign Lowe's	bath tub_K-715_spec.pdf
Lavatory - Vanity 1200 750m (Lavatory - Vanity 1200 750m_760 mmx455 mm - Private)	Corian - DuPont Corp	810	Champaign Lowe's	lavatory vanity_810.pdf
Lavatory-Vanity (Lavatory - Vanity_760 mmx455 mm - Private)	Elkay	EFU131610TC	Amazon	sink efu131610tc_spec.pdf
Lavatory-Wall Mounted (Lavatory - Wall Mounted_510 mmx455 mm - Public)	PickCompany	n/a	PickCompany	n/a
PLU-BallValveA (PLU-BallValve_15mm)	Milwaukee Valve	UPBA-475B 1/4"	Champaign Lowe's	valves UPBA475B.PDF

Figure 2 COBie-based Submittal Form (Part 1)

In addition to collecting manufacturer and model number when the product is first submitted, the fourth row of data in Figure 2 also highlights a quality control benefits of identifying product data before the product is installed. In the fourth row, the wall mounted lavatory product data file was not provided. Because the list of all COBie.Type(s) for each specification section is provided on the form, this omission is obvious to anyone visually scanning this information. The omission can be fixed, and the form resubmitted, rather than leaving the problem to a post-project data wrangler.

Of course, submittals for most products are not limited to product data files. Either by requirement or convention, files containing information related to testing reports, warranties, installation instructions, and operations and maintenance manuals may also be available and/or required to be provided. These files may be identified in that same COBie-based submittal form in Figure 1 with additional columns to the right of those pictured. In Figure 2, four additional documents type columns are shown. For our case we provided a fixed set of possible documents that may be provided, or not, depending on information available from the manufacturer. In the bathtub example, two separate files are provided. In the case of the vanity, submittal data of three different types is available in the same file.

Name & Description	Mfg Test	Mfg Warranty	Instructions	O&M
Bath Tub (Bath Tub_1675 mmx915 mm - Private)	n/a	Kohler_warranty.pdf	bath tub_K-715_install.pdf	n/a
Lavatory - Vanity 1200 750m (Lavatory - Vanity 1200 750m_760 mmx455 mm - Private)	n/a	n/a	n/a	n/a
Lavatory-Vanity (Lavatory - Vanity_760 mmx455 mm - Private)	n/a	sink efu131610tc_warranty.pdf	sink efu131610tc_install.pdf	sink efu131610tc_manual.pdf
Lavatory-Wall Mounted (Lavatory - Wall Mounted_510 mmx455 mm - Public)	n/a	n/a	n/a	n/a
PLU-BallValveA (PLU-BallValve_15mm)	n/a	n/a	n/a	n/a

Figure 3 COBie-based Submittal Form (Part 2)

While fixtures and other simple products can capture COBie-based submittals in a single row for each COBie.Type, some products are more complex. Such products will also have "accessory" products. It is not possible to specify these accessory products *a priori* since the details of each assembly are manufacturer dependent. As a result, a "pivot table" version of the COBie-based submittal form is also required, Figure 4.

The same basic information found in Figures 2 is also found at the top of Figure 4. However, the pivot submittal form lists additional documents (shown horizontally in Figure 3) vertically down the form. In the case the example Air Handling Unit, the manufacturer identifies twelve additional accessory products whose information (in this case) is provided in the product's data booklet (Figure 4).

Action:	Product Type:	Manufacturer	Model Number	Supplier
Initial	Air Handling Unit (Air Handling Unit_63300000 J)	VES Andover Ltd	MAX37/A/SW/S	VES Andover Ltd
Attached Data Files				
Product Data:	Air Handling Unit.pdf			
Mfg Test Report:	n/a			
Mfg Warranty:	Air Handling Unit Warranty.pdf			
Instructions:	Air Handling Unit Operation.pdf			
Maintenance Manual:	Air Handling Unit O&M.pdf			
Replacement Parts:	Air Handling Unit Warranty.pdf			
Field Test Reports:	n/a			
Accessory Products	**Accessory Name**	**Attached Data file**		
Product Data:	Fitted & Pre-Wired Isolator To Suit 1	Air Handling Unit.pdf		
Product Data:	24V Open Close Damper Motor	Air Handling Unit.pdf		
Product Data:	Filter Pressure Switch - Fitted	Air Handling Unit.pdf		
Product Data:	Magnehelic Gauge To Suit 0-250 Pa	Air Handling Unit.pdf		
Product Data:	Airflow Pressure Switch - Fitted	Air Handling Unit.pdf		
Product Data:	ELGN1050 Motor Isolator Supplied Fi	Air Handling Unit.pdf		
Product Data:	Filter Pressure Switch - Fitted	Air Handling Unit.pdf		
Product Data:	Magnehelic Gauge To Suit 0-250 Pa	Air Handling Unit.pdf		
Product Data:	Airflow Pressure Switch - Fitted	Air Handling Unit.pdf		
Product Data:	ELGN1050 Motor Isolator Supplied Fi	Air Handling Unit.pdf		
Product Data:	Fitted & Pre-Wired Isolator To Suit 1	Air Handling Unit.pdf		
Product Data:	24V Open Close Damper Motor	Air Handling Unit.pdf		

Figure 4 COBie-based Pivot Submittal Form

6. Observations

In this case study, two subcontractors were asked to download a set of simulated construction drawings. The scope of each subcontract was decided upon. Based on that scope the appropriate set of COBie-based submittal forms were provided to each subcontractor. Following a 15-minute introduction to these forms, the subcontractors completed the assigned forms. Observations made from written communications between the authors and case-study participants are described in the paragraphs below.

Initial discussion about the differences between US and UK construction were determined not to be differences in English-language dialects at all, but differences in assumptions related to Design-Bid-Build or Design-Build procurements. While the process of product selection in Design-Bid-Build projects is prescribed by tradition and contract requirements, the variety of "flavors" of Design-Build procurement methods, means that the creation of a set of submittal forms prior to construction may not be as helpful. Regardless of the specifics of the procurement, the responsibly to produce COBie-based submittal forms should fall to the design consultant (or subcontractor's designer) who develops the construction documents (or shop-drawings). If needed, production of COBie-based submittal forms may be accomplished by the overall BIM Coordinator when each subcontract is signed.

Subcontractors in the US and UK found the COBie-based Submittal Forms were easy to understand and use because the forms were like those encountered on all other projects. This was a critical finding since the foundation of the Lean Handover™ approach is based upon the idea that small changes to existing methods may have profound effects. Subcontractors reported that they completed all forms in the same time required to prepare traditional submittals. The ultimate result of this observation is that providing COBie-based submittal forms, instead of pondering the apparent complexity of COBie spreadsheets, eliminates the need for project teams to hire COBie-specific resources or conduct post-construction surveys to recollect approved submittal information.

While the general use of COBie-based forms was understood, case study participants were less clear about the use of the forms in several important ways. First, the specific example forms provided did not support or enforce a complete set of COBie-compliant company contact data. As a result, full company details required by COBie did not always match the information provided by the subcontractors. Next, while the organization of products by specification section is consistent with traditional practice, there were situations where this was not completely satisfactory. For example, some specification sections included the delivery of general products that would have been purchased by multiple subcontractors. In some cases, the subcontractors suggested that product listings by product category might be relevant.

A third aspect of the COBie-based forms noted by the subcontractors was the need to reference the list of individual components when selecting products. While initially created COBie-based submittal forms included a linkage to show the individual COBie.Component(s) and spatial containment, these more detailed forms were not provided to the case-study participants specifically to determine if such information was required. Our study identified that such information may be helpful but would not be applicable to all types of products.

Our subcontractors recognized the internal value to capture equipment manufacturer and model number before building the project. Given subcontractor's familiarity in working with PDF submittal documents, they were able to copy and paste file name and model numbers into the COBie-based Submittal forms for most products. We did not access the accuracy of manual data entry when only locked product data files were available.

The assumption that specification sections could be used as the basis for the pre-production of all COBie submittal forms from COBie.Type data was found most applicable to Design-Bid-Build projects. Depending on the "flavor" of Design-Build procurement, either a contractor-hired design team or a subcontractor-hired design team will be responsible for COBie.Type definition. As a result, the Lean Handover™ process must flexibly adapt to project-specific requirements

Although participating subcontractors have extensive experience using BIM software for construction coordination, they had not previously considered nor were concerned about the coordination of BIM and COBie data. This observation clearly speaks to the understanding, by subcontractors, that COBie data is not directly linked to current BIM processes in the construction trailer. It was also understood that unless the construction back-office data were captured in a way that allowed COBie data to be linked to BIM, that some owners might require them to manually re-type some of the COBie data within those BIM platforms.

7. Discussion

The transformation of small, corner groceries to the interconnected just-in-time business networks of Tesco and Walmart were not caused by client-facing technological innovation. The innovation we see today on a myriad of phone-apps are the affects, not the causes, of information technology innovation. Innovation in back-office processes led to the consolidation of retail and industrial sectors happened long before you could buy groceries on your phone. Today, the construction industry is awash in technology chasing users. It is awash in affects without causes. Demonstrations of user-facing technology shown to be wildly successful, are only so if the project has overheads to manually process and enter information across multiple systems. Such innovations cannot become mainstream. Each example use of the new technology requires another pilot project team to (ironically) prepare its own unique “Standard Operating Procedure.”

The only way to allow our industry to grow without mandating a “data wrangling” tax on every project is to fundamentally transform the systems that create back-office information. This paper demonstrated one of the most fundamental of these processes, is that of construction submittals. Rather than introduce new user-facing processes, terminology, and technology, the Lean Handover™ approach leverages existing processes, terminology, and technology. The small process changes made that seem second-nature to subcontractors after a 15-minute presentation will have a more profound and enabling effect upon innovation than our collective BIM aspirations. To prove that this claim is true we make the following predictions that can be validated by capturing information that can be directly coded as “type of work” on employee timecards.

Today, contractors, subcontractors, and facility operators must search for information by returning to the shop, gang box, or jobsite trailer. It was reported from a leading US university facility manager that a detailed audit indicated their operators had a “time on tools” value of 20%. Mechanics we know would rather work their trade than drive around looking for information or finding the necessary tool or part for six (6) hours a day. Unnecessary trips to the shop, gang box, or project trailer can be eliminated through the Lean Handover™ process.

Facility managers we have interviewed recognize that their parts inventory system is broken. This can be seen by multiple half-used boxes of the same type of part from different suppliers. With COBie data delivery of spare parts can be managed the same way as just in time delivery of parts for manufacturing lines. There is no need for each crew to have its own set of specialized tools, if the use of those tools can be tracked and shared. The wasted cost and accounting for parts and tools inventories can be eliminated through the Lean Handover™ process.

Today, there is no way to determine if construction administration or handover information is correct. This means that people, correctly, provide incomplete and incorrect handover data. Without a common way to assess what is required, it is not possible to understand when a job is completed. The wasted effort spent going back to complete partially finished handover data can be eliminated through the Lean Handover™ process.

Today, even when we attempt to use electronic file cabinets, the lack of underlying organization and version control for those documents means that multiple copies of virtually every document are kept by all parties with the resulting confusion. Knowing exactly what was approved, installed, and tested is only possible through a shared understanding of a common workflow. The wasted effort finding and moving duplicate versions of product data can be eliminated through the Lean Handover™ process.

Today, project teams wait until the fiscal completion of a building before preparing facility management data. Often this is months or years after the building has been occupied. In addition to having to recollect information that already exists, this delay typically means that product manufacturer warranties are voided since recommended maintenance activities were not completed by the contractor following prior to occupancy, or by the owner after occupancy. The wasted effort spent chasing and as-built and maintenance information can be eliminated through the Lean Handover™ process.

8. Conclusions

Owners know that traditional construction handover information is unusable. As a result, many large portfolio owners conduct post-occupancy surveys at a cost of millions of dollars per year. Owners are starting to demand a higher-quality construction handover product, but many are unclear exactly how to proceed. This case study demonstrates the most important of information - product manufacturer and model number - can be captured during the project eliminating cost of the post-construction job survey.

Today, contractors wait until the end of the project to send experienced staff or bespoke subcontractors to re-collect information known to subcontracting staff who selected and installed those products. There is international agreement that the tens or hundreds of thousands of dollars spent by contractors to produce document-based handover deliverables is wasted effort. The question for contractors and subcontractors is how to deliver faster, cheaper, and at higher quality products their competitors. This case study has demonstrated that the most important handover information can be captured regardless of the final output format required by the owner, COBie or not. While the full presentation of the Lean Handover™ approach is published in book form, the purpose of this paper was to identify issues where contractors and subcontractors expressed difficulty in adopting a single, generic approach to capturing part of the COBie data set in real-time. Those difficulties are to be expected given the fervor of those promoting BIMutopian visions when compared to the dynamic, yet enduring, need to capture construction information.

This case study, and work cited in this paper, should give pause to anyone who thinks that the development of a new process or software will be enough change the construction industry. This includes funding organizations, such as the Pankow Foundation, who considered development of steel and concrete MVD's to be the end-goal of their "standards" project. Despite the pedagogical interest in standards development, creating a standard is, in fact, the "easy" part of promoting industry change. It is one thing to create a data schema and even to mandate the delivery of standard data in contracts, but as the case of one of the most widely known MVD's, COBie, demonstrates, wishing does not make it so. If you build it, "they will not come." Changing our industry requires orders of magnitude more effort at a much different level of detail. An effort that requires testing and enforcement. An effort that demands working directly with those who create, use, and change project data.

The authors of this paper have been engaged in the application of computers in the construction office since they first arrived in the 1980's. In our view as much time has been spent by users of each round of "more efficient" technology arguing about outputs on paper or screens than has been spent talking about the subject project. This is the case because users with different backgrounds and experience have different expectations of what is to be accomplished. Without a common understanding of the system in which work is to take place, no effective agreement about the use of technology is possible. Rather than wait "five years" for the next round of emerging technology to be proposed as the next magic solution, we predict that construction information integration can only occur through the evolution of small changes to existing practice. The approach presented here is but a first step.

Acknowledgements

The authors wish to acknowledge the contribution of the following individuals and companies in the application of Lean Handover™ principles on the example East Dormitory project: Galliford Try, UK;

Gavin Dunstan, SES (Engineering Services), UK; and Alan DeLuce, Commercial Service of Bloomington, IN, USA. Lean Handover™ is a trademark of Prairie Sky Consulting®.

References

Abdirad, Hamid, Dossick, Carrie S. (2019) "Normative and descriptive models for COBie implementation: discrepancies and limitations", Engineering, Construction and Architectural Management, 26(6).

Alnaggar, Ahmed, Pitt, Michael (2019) "Towards a conceptual framework to manage BIM/COBie asset data using a standard project management methodology," Journal of Facilities Management, 17(2), pp.175-187.

East, E. William, Kirby, Jeffry G., Perez, Gonzalo (2004) "Improved Design Review through Web Collaboration," Journal of Management in Engineering, American Society of Civil Engineers, 20(2), 51–55.

East, E. William, Kirby, Jeffry G., Liu, Liang Y. (2008) "Verification and Validation of a Project Collaboration Tool," Automation in Construction, 17.2 (2008), 201-214.

East, E. William (2007) "Construction Operations Building Information Exchange (COBIE) Requirements Definition and Pilot Implementation Standard," U.S. Army, Corps of Engineers, Engineer Research and Development Center, TR 07/30.

East, E. William, Martinez, Julio C., Kirby, Jeffrey G. (2009) "Discrete-Event Simulation-Based Performance Quantification of Web-Based and Traditional Bidder Inquiry Processes," Automation in Construction, 18(2), 109-117.

East, E. William, Love, Danielle (2011) "Value-added Analysis of the Construction Submittal Process," Automation in Construction, 20(2011), pp. 1070–1078.

East, E. William, Smith, Dana "Deke" Kennish (2016) "The United States National Building Information Modeling Standard: The First Decade," Proceedings of the 2016 CIB W078 Conference, Brisbane, Australia, October 2016.

East, E. William, Bogen, Chris (2017) "Construction-Operations Building information exchange (COBie) Quality Control," Prairie Sky Consulting, 2016, ISBN: 978-1-365-41018-5.

East, E. William, Ford, John (2019) "Lean Handover™: COBie for Contractors," Prairie Sky Consulting, ISBN 978-0-359-61006-8.

Fallon, Kristine, Fadojutimi, Omobolawa, Williams, Gregory, Craford, Naila, Gran, Danielle, East, E. William (2013) "Assessment of Life Cycle Information Exchanges (LCie): Understanding the Value-Added Benefit of a COBie Process," Engineer Research and Development Center, Contractor Report, ERDC/CERL CR-13-6.

Florez, Laura, Afsari, Kereshmeh (2018) "Integrated Facility Management Information into Building Information Modeling using COBie: Current Status and Future Directions," Proceedings. of 35th International Symposium on Automation and Robotics in Construction

Hosseini, M. Reza, et.al (2018) "Integrating BIM into Facility Management: Typology Matrix of Information Handover Requirements," International. Journal of Building Pathology and Adaptation, 36(1), pp. 2-14.

Kelly, Graham, et.al (2013) "BIM For Facility Management: A Review and Case Study Investigating the Value and Challenges," Proceedings 13th International Conference. on Construction Applications of Virtual Reality.

Liu, Rui, Issa, Raja. (2013) "Issues in BIM for Facility Management from Industry Practitioners' Perspectives," Proc. ASCE International Conference on Computing in Civil Engineering, pp. 411-418.

Lin, Yu-Cheng (2018) "Developing Final As-Built BIM Model Management System for Owners

During Project Closeout: A Case Study," Advanced Engineering Informatics, 26(2018), pp. 178-193.

Matarneh, Sandra, et.al. (2018) "Developing an Interoperability Framework for Building Information Models and Facility Management Systems," Proceedings of the Creative Construction Conference.

Miettinen, Reijo, Paavola, Sami (2014) "Beyond the BIM Utopia: Approaches to the Development and Implementation of Building Information Modeling," Automation in Construction, 43(2014), pp. 84-91.

NIBS (2015) "The National Building Information Model Standard - United States," buildingSMART alliance, National Institute of Building Sciences. COBie - Chapter 4.2 and Annexes.

Pishdad-Bozorgi, Pardis, et. al. (2018) "Planning and Developing Facility Management Enabled Building Information Model," Automation in Construction, 87, pp.22-38.

PSC (2017) "East Dormitory Test Files," Software Testing, Prairie Sky Consulting (https://www.prairieskyconsulting.com/testing.htm (cited 16-Nov-2018).

Tezel, Algan, et. al. (2019) "Lean Construction and BIM in Small and Medium-Sized Enterprises (SMEs) in Construction: A Systematic Literature Review," Canadian Journal of Civil Engineering, Vol 2019.

Volk, Rebekka, et.al (2014) "Building Information Modeling (BIM) for Existing Buildings - Literature Review and Future Needs," Automation in Construction, 38(2014), pp. 109-127.

WBDG (2010) "Common Building Information Model Files and Tools," Whole Building Design Guide, National Institute of Building Sciences (https://www.nibs.org/page/bsa_cobiemm (cited 28-Apr-2019).

Yalcinkaya, Mehmet, Singh, Vishal (2016) "Evaluating the Usability Aspects of COBie Standard," Proceedings of the CIB World Building Congress.

Yalcinkaya, Mehmet, Singh, Vishal (2019) "VisualCOBie for Facilities Management: A BIM Integrated, Visual Search and Information Management Platform for COBie Extension," Facilities, 37(7), pp.502-524.