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Can the Application of the Visual Programme Tool Dynamo Assist in Streamlining Current COBie Requirements for Design Professionals

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Abstract - While in existence for over a decade, for many, Construction Operations Building information exchange (COBie) is still a misunderstood and miscommunicated topic. Despite the free distribution of supporting information, many errors remain in its practical application. This study explores strengthening COBie design practices, reducing computational expense by data automation and streamlining the workflow process without the need for designer's total immersion into COBie theory. Synergies between Autodesk Revit and Dynamo BIM were the chosen software utilised to achieve such a goal. A literature review is first employed to provide a current overview from academic and industry sources, with the principles of design science the chosen methodology in the development, implementation and evaluation of a solution orientated research strategy. Data was gathered via questionnaires from eight Mechanical, Electrical and Plumbing (MEP) engineering firms in Ireland who currently have a demand for COBie design deliverables. This paper reports a general lack of awareness for the open source COBie Testing software tool and a misconception as to exact COBie for Design deliverables. Results indicate considerable time saving across separate projects for six COBie parameters identified for streamlining due to inefficient workflows. Testing COBie data was fully verified in accordance with the international standard NBIMS v3 using the COBie Quality Control Reporter, making it compliant for Facilities Management software use.

Keywords–BIM, FM, Autodesk Revit, COBie, Dynamo, MEP

I. INTRODUCTION

The digital age is maturing at an exponential pace and with it, the need for businesses and organisations to increase their capacity for adopting automated data-driven decision making (Dearborn, 2015). With this, designers face challenges to evolve mirroring that of increasing software ability to produce such data. The rapid digitisation of building design and construction has undeniably impacted upon the later stages of building operations and maintenance, with the requirement for information to operate and maintain such assets even more imperative (Atkin & Brooks, 2009). Developed in 2007, the COBie exchange format sought to enhance the facility information handover of paper-based construction documents. COBie is a data exchange format for sharing details about the maintainable assets in a building and includes a list of components and the tasks needed to maintain them. The dataset can be viewed and edited using Microsoft Excel and has a series of hierarchal sheets that contain information about the facility, each floor in the facility, spaces within each floor, and in turn components in each space (Philip, 2017).

As this exchange format is becoming a more frequented project deliverable request globally, and more design practices are targeting BIM Level 2 in the UK and Ireland, understanding the practical application of COBie can be overwhelming. In addition, current best practice recommendations from leading design software indicate numerous manual and repetitious tasks for designers to achieve accurate COBie data. Such tasks create non-added value for the client including computational and time expense, increased risk of omissions and rework (human errors), less productivity and non-stimulating for the designer.

The need for this research results from uncertainty amongst BIM personnel relating to COBie and its deliverables. Many designers lack guidance on what specific maintainable assets within an asset information model are applicable for data extraction. Furthermore, the format of the data within each COBie parameter is inconsistent with any standard resulting in deliverable differences.

This research sets out to explore the concatenation of Autodesk Revit and Dynamo in streamlining COBie design workflows for MEP disciplines only, while verifying the spreadsheet data for compliance with the international standard NBIMS v3 utilizing the COBie Quality Control Checker. The purpose of the study is for the author to incorporate findings into daily design routines while such research may also interest clients, contractors, facility managers, BIM managers, and designers.

II. Literature review

a) Definition of BIM

Building Information Modelling (BIM) is a technology that allows relevant graphical and topical information related to the built environment to be stored in a relational database for access and management (Weygant, 2011). BIM's use goes beyond that of the planning and design phase of a project, extending throughout the building lifecycle, supporting processes that include cost management, construction management, project management and facility operation (Eastman, Teicholz, Sacks, & Liston, 2008). In recent decades the Architecture, Engineering, and Construction (AEC) industry, is increasingly gravitating towards full BIM adoption, enhanced by rapid development worldwide most notably in developing countries. Recognising its many advantages, including automated clash detection, sustainability analyses, quantity surveying, cost estimation, site logistics, enhanced 3D rendering and facilitation of team collaboration through a common model, large-scale projects have become widespread and international (Bryde, Broquetas, & Volm, 2013; Azhar, Khalfan, & Maqsood, 2015).

For BIM adoption in Ireland, the implications outlined in the Construction 2020 report suggest BIM is a powerful tool in driving efficiencies and increasing productivity in the construction industry while rapidly becoming a standard requirement internationally. Furthermore, and more recently the CIF Construction report 2027 (as cited in CITA:BIM Innovation Capability Programme, 2017) called for strong recommendations that industry organisations promote the use of BIM, so they can successfully compete in international markets. In late 2017 a government strategy to increase use of digital technology in key Public Work's Projects was launched, specifying that public bodies establish requirements for the use of BIM on design, construction and operations of public buildings and infrastructure on a phased basis over the next four years (Government of Ireland, 2017). Some global frontrunners include the Scandinavian countries whose BIM methods have been in existence for over a decade while the UK, Hong Kong, and South Korea governments have also been actively promoting BIM uptake in recent years. According to Azhar, Khalfan, & Maqsood, 2012, the overall goal of BIM is transferring the data into the Facilities Management (FM) operations.

b) The Impact of Inappropriate Facilities Management Practice

FM is a discipline that improves and supports the productivity of an organisation by delivering all needed appropriate services and infrastructures to achieve business objectives (RICS, 2010). At a corporate level, it contributes to the delivery of strategic and operational objectives. On a day-to-day level, effective FM provides a safe and efficient working environment, which is essential for the performance of any business – whatever its size and scope (BIFM, 2017). Inapt FM can impact the performance of an organisation because of equipment failure, the health of the organisation's staff, and the safety of building occupants. Conversely, a well-maintained facility can enhance an organisation's performance by contributing to the optimization of the working and business environment (Alsyouf, 2007; Atkin & Brooks, 2009; Roelofsen, 2002).

Traditionally, facility information is handed over from the contractor to the owner through paper-based construction documents, which include drawings, specifications, product data sheets, warranties, operation and maintenance manuals, and so on. These documents are collected from various vendors and organised by the contractors in a format to align with their needs (Goedert & Meadati, 2008). However, the efficient utilisation of facility information, its management, and its supporting technology in traditional FM practices have been somewhat problematic (Barrett & Baldry, 2003; Abel, Diez, & Lennerts, 2006; Dettwiler, Bainbridge, & Finch, 2009) and facility maintenance staff have experienced difficulties in preserving facilities when relying on paper-based document (Ani, Johar, Tawil, Razak, & Hamzah, 2015).

Including the geometric and non-geometric information of the building, there is a massive amount of information that should be handed over to the owner to operate the building upon a project's completion. Commonly, information handover processes to FM phase is done manually, the information is often incomplete and inaccurate (Lucas, Bulbul, & Thabet, 2013). Even when the documents are available digitally, lack of interoperability of software platforms reduces the usefulness of the information. Rework, and manual data entry are usually required to update FM systems, which leads to duplication of efforts and high chances of error (Ghosh, Chasey, & Mergenschroer, 2015). As a result, the industry is spending millions, and thousands of man-hours recreating such information and working with inefficient workflows (Keady, 2009).

c) BIM for FM

BIM can support and complement a wide range of information technologies used by facilities organisations by offering owners and operators a powerful means of retrieving information from a virtual model of a facility throughout the lifecycle phases (Teicholz, 2013). Organisations involved in FM have the opportunities to use BIM as a knowledge repository to document evolving facility information, support the decision made by the facility manager during the operational life of a facility (Takim, Harris, & Nawawi, 2013). This knowledge repository is a tangible asset that can increase the value of a property (D. Smith & Tardif, 2009). By using BIM models instead of paper blueprints, FM personnel can reconcile real components with corresponding 3D models and guide themselves through the system to promptly execute the plan of action (Golabchi & Akula, 2013). Furthermore, BIM models can bridge the information loss associated with handing a project from design team to construction team to building owner/operator by allowing each group to add to and reference information they acquire during their period of contribution to the BIM process (Lucas et al., 2013). In addition, as the facility data in BIM can be easily shared and reused by the project team (Sabol, 2008), it does not have to be re-entered into a downstream FM system. This reduces data entry cost and generates higher-quality data (Teicholz, 2013).

Despite its benefits and multiple efforts by the industry to leverage BIM in FM, owners resistance to change is a result of perceived differences in ideas, motives, plan or priorities that relate to five specific areas: the need for change, risk, goal and targets, leaders and treat of status (Takim et al., 2013 and Korpela, Miettinen, Salmikivi, & Ihalainen, 2015). One main challenge with BIM for FM implementation identified by Becerik-Gerber, Jazizadeh, Li, & Calis, 2011 is the fundamental difference in project-based business and lifecycle management. Most organisations that own or operate buildings in the long-term have a significant existing portfolio, and some existing software platform to manage the FM information. New buildings are usually a very small portion of the portfolio, and this situation raises several questions related to the adoption of BIM. Should the existing buildings be modelled for the new system, what is the required level of information, how much would the modelling process cost, what are the measurable benefits etc.

Another dominant barrier to BIM adoption is that facility managers are not being engaged in the early phases of a facility lifecycle. Hence, facility managers are not able to specify the required data and this results in a widespread use of a reactive approach (Williams, Shayeste, & Marjanovic-Halburd, 2014; and Teicholz, 2013). Studies show even if they were involved in the early stages of projects, they were not seen as valuable participants. Furthermore, owners and facility managers lack of BIM knowledge and the need for investment in infrastructure, training, and new software tools are seen as implementation barriers (BIM-Task-Group, 2015). The information needed by facility owners and operators is wide ranging from as-built drawings of the facility to serial numbers and installation dates of warrantied equipment (Autodesk, 2016).

Most projects deliver one of the three types of building information: “Banker-Box Compliant Building Information”, “Bookcase Compliant Building Information”, and most recently “Shoebox Compliant Building Information Models”. There are, of course, exceptions to these examples (East, O’Keeffe, Kenna, & Hooper, 2017). More recently, these paper submittals have been accompanied by CDs containing electronic versions of the same information. It may require thousands of hours to process and enter the data into systems used for facility management, operations, and maintenance.

In 2007, the US Army Corps of Engineers (USACE) developed the COBie exchange format as a pilot standard to remedy this situation for its own building projects. Since then, it has been expanded upon and used by many private and public organisations around the world and has been formally incorporated into many CAD and BIM standards (Autodesk, 2016). COBie is the UK Government’s chosen information exchange schema for federated building information management (BIM) (UK level 2), alongside BIM models and PDF documents, with the aim of integrating commercially valuable information with other parts of the employer’s business (BSI Standards Institution, 2014a).

d) Construction Operations Building Information exchange (COBie)

Developed as a testable, contractible alternative to document-based construction handover documents and specifically designed to include information supporting building maintenance, operation, and asset management of buildings, COBie was approved by the US-based National Institute of Building Sciences as part of its National Building Information Model Standard (NBIMS) in December 2011 (East, 2012). COBie’s intention is to simplify the work required and identifies the content of the information that must be captured and exchanged at each phase of the project while reducing waste associated with the traditional paper process (East, 2012 and Poirier, 2015).

Just as there are individual and regional differences in contract administration procedures, there are differences in how COBie is created and applied. COBie is a non-proprietary specification to allow its application to reflect and conform to regional and local procedures (East et al., 2017). In 2014 the UK government further developed its best practice recommendation documents for the implementation of COBie in pilot projects to support its BIM level two mandate on all public works by April 2016. Superseding COBie-UK-21012 which was previously developed from the original NBIMS standard in the US, BS 1192-4:2014 extends its definition for infrastructure and contains recommended attributes specific to new and existing infrastructure assets that apply to sewerage networks (BSI Standards Institution, 2014b).

For any standard to be effective, the user must be able to objectively test the deliverable (East et al., 2017). COBie software testing has evolved through several stages mirroring the increasing ability of software to produce COBie data. Given the need to evaluate large COBie files, the open source COBie Quality Control (QC) automated testing tool was developed to reduce the need for line by line evaluation of complex COBie data and assist designers and builders efficiently produce high quality COBie deliverables compliant with the NBIMS standard (East & Jackson, 2016). NBIMS v3, Chapter 4.2 Section 4.2.8.1.2 "Quality control test rule definition" (Page 221) defines only nine rules for every COBie file (NIBS, 2015). These nine rules, plus minimum checking for the type of data provided, apply everywhere a full COBie file is delivered regardless of the specifics of a given building. These rules "verify" that a COBie file meets the technical requirements of a NBIMS standard (NIBS, 2015; East & Bogen, 2016). Note that validation of such data is out of scope for this research. At the time of publishing, only two commercial software best practice published guides complete with testing files, and reports are available which comply with NBIMS (Prairie Sky Consulting, 2017). These include,

Delivering COBie using Autodesk Revit (2017)

This publication is the first comprehensive COBie "How-To Guide" using Autodesk Revit for designers with requirements for COBie deliverables in .xlsx format during design process.

Delivering COBie in Graphisoft ArchiCAD (2016)

This guide explains how to deliver quality COBie data during the design process and shows how to test that data for accuracy using ArchiCAD.

However, various other software solutions provide untested COBie applications, which have resulted in deliverable differences. This raises the question, which output is correct and how much time will be spent manually amending data leading to uncoordinated information (Oakley. P, 2017).

Despite the free distribution of COBie, volumes of supporting information, examples of design and construction COBie deliverables and free training videos many errors remain in its practical application, while detailed and systematic evaluations of COBie in specific FM use cases are still lacking and deserve noteworthy attention (East et al., 2017 & Patacas, Dawood, Vukovic, & Kassem, 2015). Many practitioners believe COBie provides universal coverage of all FM related parameters and fails to selectively filter what data is relevant to a building's bespoke O&M requirements (P. Smith, 2014). One year after the 2016 UK BIM level 2 mandate, the National Building Specification (NBS) National BIM report 2017 detailed the current situation in the UK, outlining numerous respondents raising the issue of additional time and resources required to compile COBie, making it unfeasible unless specifically requested & included in an agreed fee. 42% of those surveyed generated COBie output for projects they were involved with and 60% found COBie useful for delivering information about the management of the facility. When asked why there are not many more designers generating COBie the most common response by far was lack of client demand. Many clients do not know what a COBie output is and would not know what to do with it if they got it. (NBS, 2017).

"The intention was that information would be automated from the BIM by pressing the magical COBie button. The reality is completely the opposite with teams of people manually entering thousands of elements into a spreadsheet trying to work out if they have supplied "all the information" they are supposed to"(Oakley. P, 2017).

A more recent NBS BIM report in the UK (2018) notes that when producing drawings and models, Autodesk, with 66%, remains the most popular software vendor, followed by Graphisoft. When broken down further, Revit, with 44% usage, is the most popular package among respondents, followed by ArchiCAD. (NBS, 2018).

As a market leader, fully recognised by Dublin Institute of Technology, and a powerful parametric modelling and collaboration software the author has chosen Autodesk Revit as the preferred software of choice for the primary research. For this reason, the *Delivering COBie for Autodesk Revit* has been selected as the researcher's best practice published guide for investigating inefficient design practices. However, it must be noted there is limited literature and sources available on this guide, but it is the authors intention to identify over processed workflows and potentially streamlining this through the synergies of the visual programming platform Dynamo and Autodesk Revit. Dynamo is an application that can be downloaded as free software and run alone or as plugin to Revit. It is a growing visual programming tool globally that is accessible to both non-programmers and programmers alike.

e) Visual Programming – Dynamo/Dynamo Player

Dynamo was developed as an open source tool that creates numerous opportunities for designers to customise their workflow with a significantly reduced learning curve and design systematic relationships for manipulating model elements and parameters that would otherwise be impossible with conventional Revit tools (Miller, 2013; Pavlov, 2015; Rahmani Asl, Zarrinmehr, Bergin, & Yan, 2015). It aims to extend BIM with the data and logic environment of a conceptual graph method. The platform works on C## and Python programming language (Rahmani Asl et al., 2015) and primarily, accomplishes two tasks: it "creates its own geometry with parametric relationships" and it "reads and writes to and from external databases" (Sgambelluri, 2015). This transition into graphically driven parametric design introduces the possibility of bulk manipulation of components as well as quick modification of model entities allowing combatant users to increase both accuracy and workflow (Vogt, 2016).

Dynamo Player provides an effortless way to execute Dynamo scripts within Revit. This user-friendly interface displays a list of scripts in a specified directory, displays current status of each, and lets designers make project-specific adjustments without prior programming knowledge (Autodesk, 2018).

However, Dynamo is not immune to drawbacks. The hardware requirements can be substantial. Memory leaks have been observed, increasing with the time of use of the program and keeping RAM used until Revit is closed and reopened. Also, combining larger arrays of data into fewer, bigger arrays, causes the programme to use significantly more memory and processing time and at times crash during execution (Pavlov, 2015).

f) Linking COBie and Dynamo

All Revit elements have associated instance, type and COBie (once activated in a project setting) parameters. Dynamo allows for such parameters to "talk" to each other. Manipulation of this data in a powerful and easily accessible way, enables streamlining possibilities (Pavlov, 2015).

It is the authors intention to investigate linking COBie and Dynamo to streamline current best practice recommendation workflow eliminating deliverable differences and align with the NBIMS v3 COBie standard compliant for FM use. A limitation of the research is that not all visual programming tools were tested for automation.

III. Methodology

A literature review was adopted for the first objective designed to provide an overview of sources from academic papers, industry standards, guidelines and recent publications identifying current COBie practices. It focused on available literature included BIM, FM, BIM for FM, COBie, and Visual Programming. While other software is mentioned, the main focus is using Autodesk Revit as indicated in the last paragraph of Section (d).

The second objective was to investigate the concatenation between Revit and Dynamo, by developing and testing scripts for potentially streamlining COBie for Design best practice recommendations for MEP disciplines. This objective follows the principles of design science research (DSR) methodology steps one to three for Fig. 1. DSR originated in 1957 by R.Buckminster Fuller who defined it as a systematic form of designing. It involves the development and study of artifacts, which are human-made objects that aim to solve a generic problem experienced in practice (Johannesson & Perjons, 2014). The artifact in this paper corresponds to the developed dynamo scripts, which investigates automating COBie deliverables even further on current best recommendations. The DSR approach, described by (van Aken, 2005) outlines as a core mission "to develop knowledge that can be used by professionals in the field to design solutions to their field problems".

The third objective adopts steps four and five of the DSR process to critically examine the merits and limitations of the research and to verify the findings. The first part involves a qualitative approach of the data collected through two web-based questionnaires (Pre-& Post demonstration) during a workshop demonstration with leading independent industry practitioners. The second part involved a quantitative approach through the testing of the data between separate projects.

This paper uses the DSR framework of Johannesson and Perjons, which is based on the work of Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007. The framework described in Fig. 1 outlines five common phases; (a) diagnosing a problem; (b) proposing and (c) developing a solution; (d) implementing the solution & evaluating the process in action; and (e) specifying learning which all associate to the research in this paper.

The first phase of design science as outlined by Holmström, Ketokivi, & Hameri, 2009 is to address what is wrong, by *"diagnosing the primary research problem"*. The state of this primary research issue involved self-interpretation through reflection, that current COBie best practice recommendations require multiple, manual, and repetitional tasks, creating non-added value to the client.

Effects of this noted were:

- Computational and Time expense
- Increased risk of omissions/rework (human errors)
- Less productivity from designer
- Higher cost/less profitability for the company
- Repetitive and non-stimulating for designer

Voordijk, 2009; and Hevner et al., 2004 propose the second step is to develop the 'technological rule' (artifact) which will address the practical problem. Constructing a technological solution in design science demonstrates that the process can be automated and enables a change in current work practices (Hevner et al., 2004). For the solution to be relevant from an academic perspective the process to develop the artifact must be transparent. This requires an explanation of the developed process and the decisions that were made as the artifact evolved (Kehily & Underwood, 2015). A cyclical process of reflection and action is embedded in design science (van Aken, 2005; Voordijk, 2009; Hevner et al., 2004). This cyclical process is required where the artifact needs to be developed through what Azhar, Ahmad, & Sein, 2010 calls self-interpretation. This is a speculative process, proposing a solution that the researcher believes will work prior to any validation by the users (Johannesson & Perjons, 2012; Voordijk, 2009).

Thirdly, the artifact is designed and developed. All scripts are manufactured and tested rigorously to include repeatability across seperate projects.

Fourthly, the artifact is evaluated. Voordijk, 2009 states that methods used to carry out evaluation can be interviews, surveys, case studies and simulation (through empirical testing) with the intended users. Evaluation requires some way of determining how successful the proposed change is in its environment or simulated environment (Johannesson & Perjons, 2014; Hevner et al., 2004). (Voordijk, 2009) states that evaluation should start with the development of measurers and criteria which represent the goals of the process, the artifact's performance is subsequently evaluated against these criteria. In this paper evaluation is achieved by a workshop demonstration and multi-choice questionnaire from independent industry leaders. (Johannesson & Perjons, 2014) and (March & Smith, 1995) state that the research output in design science is not just the artifact, but also the affect the artifact has on the environment to which it has been introduced. This would instigate a process in BIM research that would entail evaluating a new BIM process or technology, but also its ability to affect change and improve practice in a work setting.

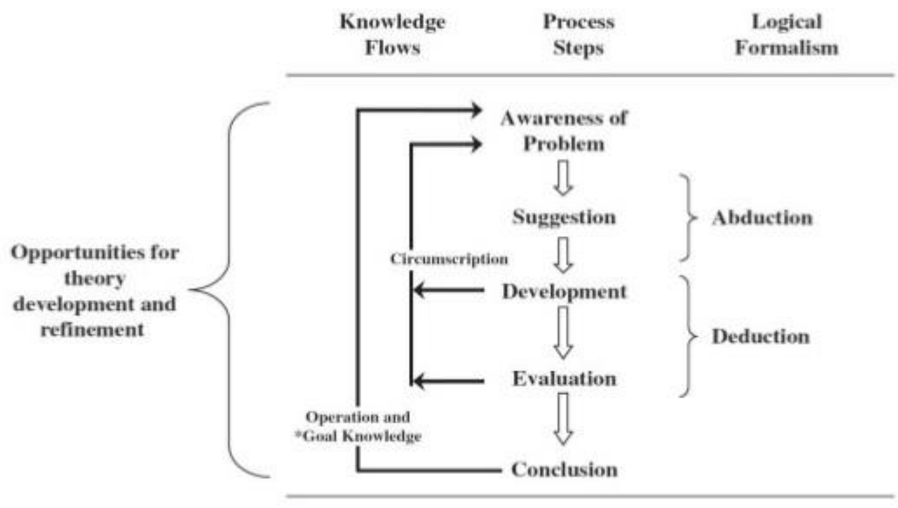


Fig. 1: Design Science Methodology

Fig. 2 is a brief workflow diagram for the benefit of the reader of the steps taken by the author.

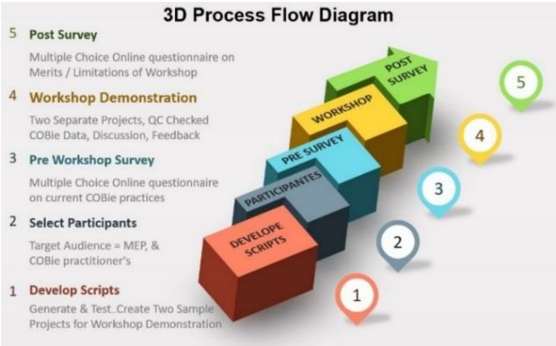


Fig. 2: Workflow Diagram

a) Ethics and Data Protection

Only summarised results are presented in this report, which ensures no individually identifiable information is distributed and enables for open and candid discussions. All participation was voluntary, and there were no incentives provided for completing the questionnaires and workshop. All participants were independent practitioners, and no information was collected from the authors' workplace. All participants signed a research study consent form that included the following,

- Their right to withdraw from the study at any point without explanation
- Information collected would be kept confidential and that the questionnaire was anonymous
- Agree for the interview to be audio-recorded
- Permission to withdraw data from the interview

IV. Primary Research - Testing

a) Development of Scripts

1. Acknowledgment

It is noted the author of this research is also a co-author of the published guide "Delivering COBie using Autodesk Revit." The authors' unique knowledge in current COBie best practice recommendations, formulas and specifications for each COBie parameter according to its standard, contributed as the primary reason for the research and development of the scripts. Considering this, the author wished to acknowledge that this paper could be seen as biased and non-critical by readers. However, it is authors intention to present information with informed assertions supported by credible evidence.

2. Setup

As COBie is a non-proprietary specification enabling its application to reflect and conform to regional and local procedures, uniclass classification was the system of testing preference. All assets used during testing comply with NBIMS v3 Page 219 & 220. COBie For Design is tested only, based on Mechanical, Electrical, and Plumbing (MEP) disciplines. All COBie spreadsheets files are fully verified via the COBie Quality Control Checker in accordance with NBIMS v3. Architectural discipline and validation of the information were not in scope for this research. The software used for testing included,

- Autodesk Revit 2018.1
- Dynamo 2.0.1.
- COBieQcReporter 1.1.
- COBie Extension for Revit 2018
- Classification Manager for Revit 2018

3. Identify Inefficiencies

COBie for Design consists of nine worksheets as illustrating in Fig. 3, totalling Fifty-two COBie parameters. The first objective was to scrutinise each COBie parameter within each worksheet and to ascertain how they are populated. Parameters that contain inefficiencies to include manual, repetitive, or copy and paste tasks were segregated for possible further streamlining. In total, six COBie parameters were identified, as highlighted in red boundary lines from Fig. 3,4,5 & 6.

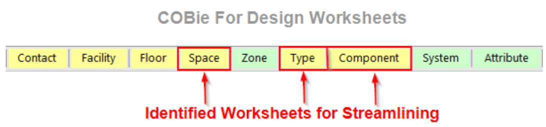


Fig. 3: COBie for Design Worksheets

COBie.Space

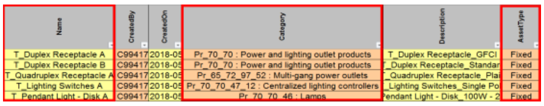
1. COBie.Space.Category

Name	CreatedBy	CreatedOn	Category	FloorName	Description
26	C99417	2018-05-	SL_90_10_51 : Lobbies	Level 1	WF
8	C99417	2018-05-	SL_25_10 : Educational spaces	Level 1	Leader
6	C99417	2018-05-	SL_25_10 : Educational spaces	Level 1	Leader
17	C99417	2018-05-	SL_35_80_89 : Toilets	Level 1	WC
14	C99417	2018-05-	SL_90_50 : Storage spaces	Level 1	Stock

Fig. 4: COBie.Space Worksheet

COBie.Type

2. COBie.Type.Name
3. COBie.Type.Category
4. COBie.Type.Assettype

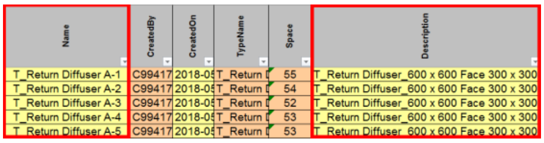


Name	CreatedBy	CreatedOn	Category	Description	AssetType
T_Duplex Receptacle A	C99417	2018-05	Pr_70_70 : Power and lighting outlet products	T_Duplex Receptacle_GFCI	Fixed
T_Duplex Receptacle B	C99417	2018-05	Pr_70_70 : Power and lighting outlet products	T_Duplex Receptacle_Standar	Fixed
T_Quadruplex Receptacle A	C99417	2018-05	Pr_65_72_97_52 : Multi-gang power outlets	T_Quadruplex Receptacle_Plai	Fixed
T_Lighting Switches A	C99417	2018-05	Pr_70_70_47_12 : Centralized lighting controllers	T_Lighting Switches_Single Po	Fixed
T_Pendant Light - Disk A	C99417	2018-05	Pr_70_70_46 : Lamps	Pendant Light - Disk_100W - 2	Fixed

Fig. 5: COBie.Type Worksheet

COBie.Component

5. COBie.Component.Name
6. COBie.Component.Description



Name	CreatedBy	CreatedOn	TypeName	Space	Description
T_Return Diffuser A-1	C99417	2018-05	T_Return D	55	T_Return Diffuser_600 x 600 Face 300 x 300
T_Return Diffuser A-2	C99417	2018-05	T_Return D	54	T_Return Diffuser_600 x 600 Face 300 x 300
T_Return Diffuser A-3	C99417	2018-05	T_Return D	52	T_Return Diffuser_600 x 600 Face 300 x 300
T_Return Diffuser A-4	C99417	2018-05	T_Return D	53	T_Return Diffuser_600 x 600 Face 300 x 300
T_Return Diffuser A-5	C99417	2018-05	T_Return D	53	T_Return Diffuser_600 x 600 Face 300 x 300

Fig. 6: COBie.Component Worksheet

4. Scripts and Testing

Once these parameters were segregated, rigorous development and testing of each script began.

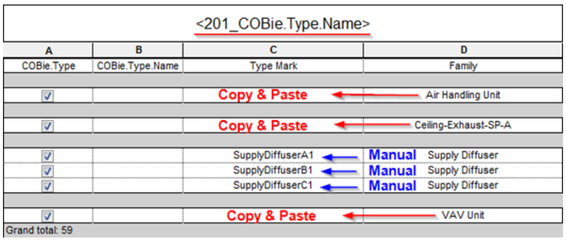
COBie.Space.Category

Common knowledge for Revit designers is architects use ‘Rooms’ from slab to ceiling, while engineers use ‘Spaces’ from slab to slab to provide useful volume properties. If a stand-alone COBie spreadsheet is required for an engineering discipline, the architectural ‘Room’ name, number and classification code must match that of the equivalent engineering ‘Space’ value. A bad practice example would be for the architect to classify a room as “SL_35_80_08 Bathroom” but for the engineer to classify the same as “SL_35_80_89 Toilet” resulting in duplication of the same room. Replicating the name and number is a simple automated exercise, however, replicating the classification is not so straightforward. Current best practices suggest this is made possible in two ways, (1) Copy and paste techniques using a Revit Schedule or (2) manually by the classification manager plugin. Depending on the number of rooms and spaces in a building this is time-consuming for the designer. The COBie.Space.Category script was developed to replicate the classification of the Room parameters assigned by the architect’s, to match that of the engineers’ Space parameters. These include:

SPACES		***ROOMS***
COBie.Space.Category	=	COBie.Space.Category
Class.Space.Number	=	Class.Space.Number
Class.Space.Description	=	Class.Space.Description

COBie.Type.Name

COBie.Type.Name according to current best practice recommendations should equal both the “Family” name and “Type Mark” value. If, however, we have multiple types of the same family then alphabetical values must be added e.g. Air Terminal A, Air Terminal B, etc. Again, this is done manually through copy and paste, sorting and filtering techniques in Revit schedules typical to Fig. 7.



<201_COBie.Type.Name>			
A	B	C	D
COBie.Type	COBie.Type.Name	Type Mark	Family
☑		Copy & Paste	Air Handling Unit
☑		Copy & Paste	Ceiling-Exhaust-SP-A
☑		SupplyDiffuserA1	Manual Supply Diffuser
☑		SupplyDiffuserB1	Manual Supply Diffuser
☑		SupplyDiffuserC1	Manual Supply Diffuser
☑		Copy & Paste	VAV Unit
Grand total: 59			

Fig. 7: Populating COBie.Type.Name

The COBie.Type.Name script partially shown in Fig. 8 was developed to automate this process and specifically add alphabetical letters to every family type applicable for data extraction within a project.

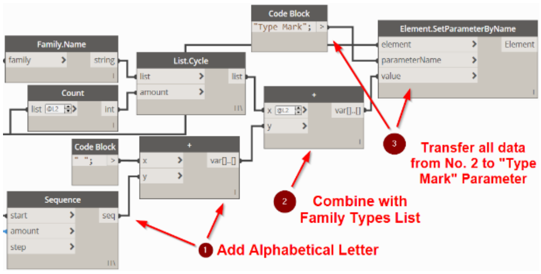


Fig. 8: COBie.Type.Name Script

COBie.Type.Category

COBie.Type.Category relates to the classification of the family type and is populated using the ‘Classification Manager for Revit’ plugin. Current best practice recommendations indicate assigning these values from project to project. Through research, it was identified that this type of parameter would have consistent values e.g. PR 70-60-04-02: Air Terminal, and testing encouraged this information to be stored within each family file once as per Fig. 10, and then subsequently exported from here project to project after that. This technique was discovered when the ‘Classification Manager for Revit’ dialogue box was also available within the “Edit Family” mode. This might require a substantial amount of time creating a new family directory specific to the classification (e.g. omniclass or uniclass) in the short term but estimated to have significant long-term time-saving benefits.

COBie.Type.Assettype

COBie.Type.Assettype according to NBIMS v3 4.2.3.2.2.58 (if not specified by contract) has default values of 'Fixed' or 'Movable'. Similar to COBie.Type.Category, current best practice recommendations indicate assigning these values from project to project. However, through research, it was identified that this type of parameter would also have consistent values for each family e.g. 'Fixed'. COBie.Type.Assettype was achieved by creating a shared parameter e.g. named 'Dynamo.Asset.Type', then mapping the information from that parameter to correspond with COBie.Type.Assetype via the dynamo script as per Fig. 9.

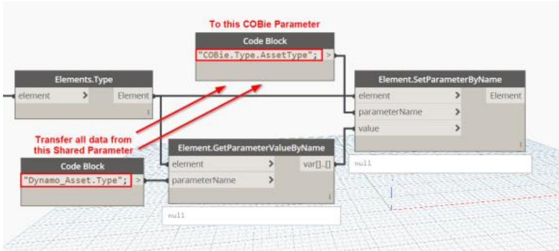


Fig. 9: Section of COBie.Type.Assettype Script

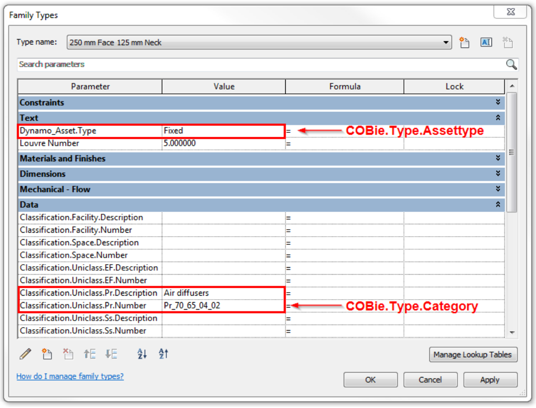


Fig. 10: Family Types Dialogue Box

COBie.Component.Name

For engineering disciplines, the instance parameter "Mark" must be manually typed by the designer to create a unique name for each component. Again, depending on the size of the project and the number of instances of a family, this technique is very time inefficient. For example, imagine having 500 sockets in a building and manually inputting one to five hundred. COBie.Component.Name script from Fig. 11 was created to automate Mark values as per each family type sequentially.

COBie.Component.Name = Type Mark + Mark

Supply Diffuser A50

COBie.Component.Description

For COBie.Component.Description, current best practices indicate a formulated solution as follows,

Component.Description = Type.Description

COBie.Type.Description parameter is populated automatically from the COBie extension for Revit plugin when first applying settings to a project. Current recommendations for this are to copy and paste all information in Revit Schedules. COBie.Component.Description script was developed to streamline this process similar to Fig. 9 and COBie.Type.Assettype.

Through research, two further scripts were required, developed and tested. These were COBie 'Tick-Box' parameters designed to tell Revit to export these elements to the COBie spreadsheet. Current best practices require advanced sorting and filtering techniques in Revit schedules. This technique can be cumbersome when dealing with a large project.

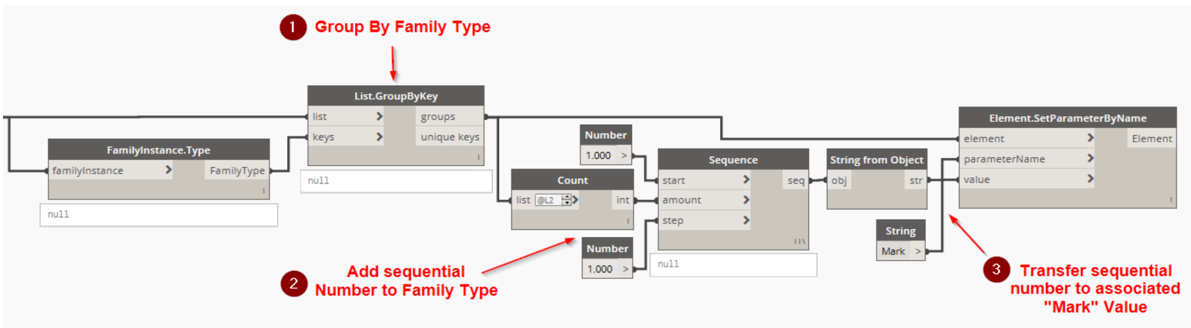


Figure 11: COBie.Component.Name Script

Fig. 12 is a script developed for exporting all spaces while Fig.13 shows the "Tick Box" in the Space properties box marked. COBie. Type and COBie.Component scripts are of a similar nature to Fig. 12 eliminating manual tasks from the designer.

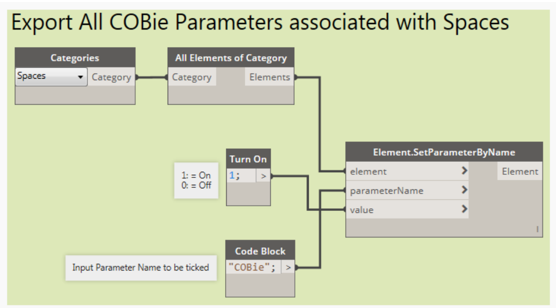


Fig. 12: Typical Script for Tick Box Exercise

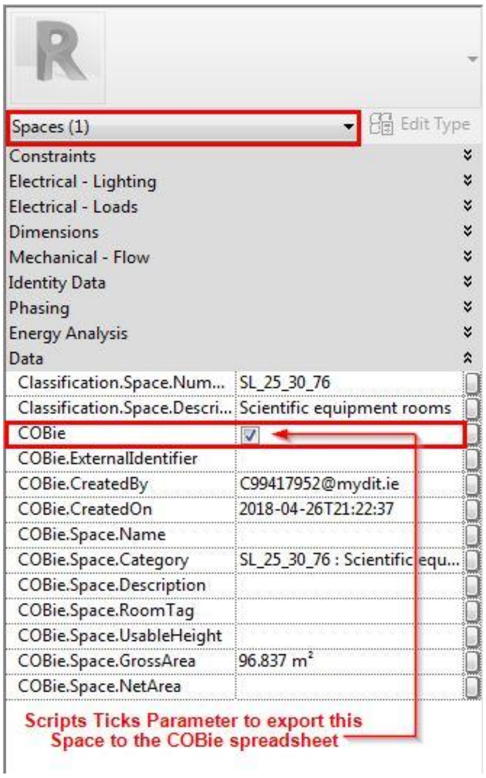


Fig. 13: Spaces Properties Box

5. Development of Scripts Conclusion

Eight dynamo scripts were developed in total. Each were named per associated COBie parameter, sequentially placed as per COBie worksheets (left to right, Fig. 3) and incorporated into Dynamo player as illustrated in Fig. 14.

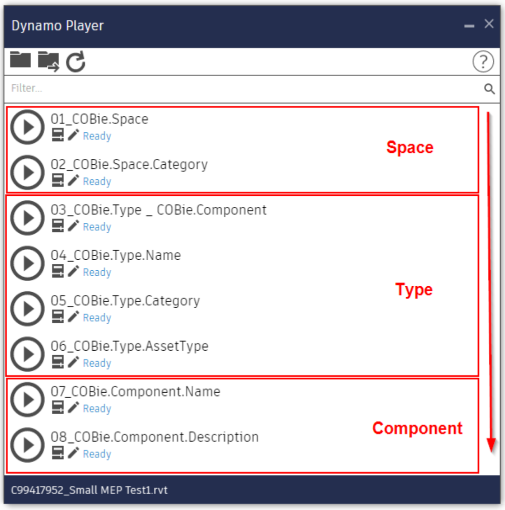


Fig. 14: Dynamo Player Testing Interface

Two of these scripts were termed "dependent scripts" e.g. they must be executed first before moving on to the associated script. These are,

- 01_COBie.Space
- 03_COBie.Type_COBie.Component.

6. Data Collection

Once all scripts were complete, a workshop demonstration was the selected technique for data collection. The justification for this includes the opportunity for group discussion between participants, the generation of possible new information from issues discussed and allowing for candid feedback by way of a follow-up questionnaire. Two testing files were developed for verification and repeatability purposes and used in demonstration workshops attended by independent industry practitioners.

7. Development of Testing Files

The first project was a Revit advanced sample project which included 1,287 elements divided into several Revit categories as shown in Fig. 15. The second project was a basic house which included only seven elements from two Revit categories (Air Terminals and Mechanical Equipment). Comparison tests were carried out and examined between current best practice recommendation and the findings using dynamo across both projects.

The large-scale project results with 1,287 elements pose for interesting readings. Current best practice recommendations undertaken by the author recorded a time of 1 hour 38 minutes to fully execute 8 scripts for six COBie parameters.

Air Terminals	=	307
Electrical Equipment	=	29
Electrical Fixtures	=	424
Lighting Devices	=	63
Lighting Fixtures	=	400
Mechanical Equipment	=	47
Plumbing Fixtures	=	11
Sprinklers	=	6

Family Type = 43
Individual Instances 1287

Fig. 15: Large Project Categories

In contrast, the execution of the researchers proposed streamlining techniques by the utilisation of dynamo scripts returned a total time of 4 minutes 36 seconds. This COBie data was also verified using the COBie quality control tool resulting in no errors. A full recording of this large test project can be found at the following link: https://youtu.be/XU1cmjI27OE

Similarly, a full recording of the small test project with verified data can be found at the following link: https://youtu.be/IBAinsnUvPM

A full breakdown comparison test for both projects can be seen in Fig. 16.

Fig. 16: Results Comparison Chart

b) Workshop Demonstration (Focus Group)

1. Targeted Audience & Format

The development of scripts related to MEP disciplines only and therefore justifies the target audience of independent MEP BIM practitioners based in Ireland, with a working knowledge of COBie, its current best practice recommendations, and the visual programming platform Dynamo. As this specific target group is limited, finding suitable candidates proved troublesome. Several participants were recruited through third parties or social media, while others through the author's' personal network. Workshops took place in May 2018 and lasted approximately two hours. In total, sixteen perspective participants were contacted at the outset. Thirteen participated, while nine of these fully completed the workshop with both questionnaires. Four failed to complete the online Survey B after the workshop. To avoid biases', no work colleagues of the author aided in any of the data collection or research. A summarized list of participants can be found below in Table 1.

2. Pre-Workshop Demonstration – Survey A Results

Survey A consisted of ten multiple choice questions via SurveyMonkey distributed by email before the workshop and averaged between two and eight minutes to complete. Its importance sought knowledge on current practices and difficulties COBie practitioners encounter, leading to further discussion of key factors during the workshop demonstration. These included,

- A general lack of knowledge as to what exact elements need to be exported to a COBie spreadsheet as per NBIMS v3. Participants were advised that P219 and P220 provided guidance on this subject.
- Many had no knowledge of the COBie Quality Control checking system or its "how to" published guide.
- There was a collective acceptance that COBie.Type and COBie.Component were the most troublesome worksheets to populate.
- An average of 36% was posted when asked: "What percentage of your COBie deliverables is manually populated by you or your designers?"
- 34% of participants were familiar with Dynamo & Dynamo Player.
- When asked how successful participants were exporting COBie Information from Autodesk Revit an average of 4.4 from 10 was posted

All responses to Survey A can be found at the following link. *Survey A - All Responses*

Table 1: List of Participants

Name	Year of Inception	Employees	Specialist	Participants
Company A	1912	5,001-10,000	Global Leader in Turnkey Engineering & Construction Services, Specialist Contracting, High Purity Process Installation / Equipment Hook-Up, and Engineering	BIM Coordinator
Company B	1999	51-200	Mechanical Installations, Heating & A/C, General Service & Maintenance, BMS, Electrical Services, Fire & Intruder Alarms, Automatic Doors, Security Gates	Contracts Manager
Company C	1952	201-500	Leading Irish general building contractor, building company delivering high quality, sustainable construction projects across a range of sectors including Commercial, Retail, Hotel, Leisure, Education, Industrial, Residential, Healthcare, Pharmaceutical and Municipal	BIM Coordinator
Company D	2009	11-50	BIM Consultancy, Architectural Drawings and Specifications, Building Information Modelling (BIM), BIM Implementation Support, BIM Training, BIM Libraries & Standard Details, BIM Production Outsourcing & Resources, and BIM Management	Managing Partner
Company E	1972	1001-5000	International provider of engineering solutions within construction industry. Mechanical Engineering, Electrical Engineering, Sprinkler Systems & Fire Protection, Data Technology Services, Life Sciences, Enterprise Data Centres, Hyperscale Data Centres, Building Services, and Healthcare	MEP BIM Manager
Company F	1998	51-200	Mechanical and Electrical Engineering Contractors provides a broad range of essential M&E services solutions for the commercial, pharmaceutical, industrial, residential, retail, health care, hotel and leisure industries sectors	BIM Coordinator
Company G	1992	501-1000	Leading International Mechanical & Electrical Services Installations provider	BIM Coordinator
Company H	1985	11-50	Engineering solutions contractor specialising in the commercial, industrial, medical & educational sectors, Facilities Management, Full Design & Build Packages, and Project Management	MEP Manager

c) *Workshop Demonstration (Active)*

1. Presentation

At the beginning of each workshop, there was a short PowerPoint Presentation which illustrated the six COBie parameters from the three COBie worksheets identified for streamlining as discussed in the primary research section, e.g. Fig. 3,4,5, & 6. This presentation also included current best practice techniques and images for the six parameters and the formula behind each. This proved immensely valuable in setting the tone for both parties and for a greater understanding. The repeatability across separate projects with verified data was fully acknowledged. In total, three workshops were recorded digitally, consent was received, and these were securely filed online. We note the number of participants invited was selected from a small pool of viable candidates. Consequently, any generalisation of the research findings is limited.

2. Step by Step Document

For the workshop to run fluently and to a timeframe, a researcher *Step by Step Document* for both projects was drafted. This was merely a reassurance guide during the workshop for the author.

3. Discussion

Most notably, questions and discussions revolved around the COBie Quality Control checker and potential time saving of the scripts. The clear majority did not know this checker existed and found it to be a valuable open source tool to use going forward. However, a further step by step demonstration would be required to teach this checking tool technique. Many acknowledged clear benefits to the scripts including its time saving, accuracy, repeatability, and accordance with the NBIMS standard. However, some noted that due to their current practices, which included populating COBie parameters as per contractor's advice, the benefits of the scripts to them currently might be limited until further industry wide understanding of COBie was achieved. Many agreed that these scripts would enhance standardised deliverables consistently and benefit designers COBie workflow substantially.

"…I think there is huge time saving in all of that, more than that even is the fact that you get it right…That's fantastic"

4. Post-Workshop Demonstration – Survey B Results

Survey B consisted of 10 multiple choice questions via SurveyMonkey distributed by email. This survey directly targeted the merits and limitations of the workshop demonstration according to the participants. Completion of the questionnaire took between 5 to 13 minutes and key findings included the following.

- Asked if this workflow would help designers produce better deliveries than currently being produced.

  Answer: 67% = Yes

  33% = Potentially

  0% = No

- Asked how much effort this workflow potentially could save.

  Answer: 59% = Yes (Average)

- Asked about the success of the repeatability across separate projects returned

  Answer: An average of 9 out of 10

"Scripts were very well written and performed consistently."

- Asked which script was the most powerful and most beneficial regarding time returned.

  Answer: COBie.Component.Name at 56%

- Asked how likely participants were to recommend these techniques to others creating COBie deliverables

  Answer: 87% = Yes (Average)

All responses to Survey B can be found at the following link. [Survey B - All Responses]

d) Reflection

An alarming consensus from practitioners, stated that industry currently does not adhere to any COBie standard and specifics vary from project to project and contractor to contractor. All scripts were designed to incorporate full compliance with NBIMS v3 upon execution, reduce the need for designer's complete emersion into COBie formula, while still yielding fully verified data results compatible for FM systems use. Participants requested that a quick project set up guide would be further beneficial and get models to the point where scripts can be executed, e.g. family naming, type naming, and not having to rename assets. Questioned if dynamo has the potential to streamline COBie design deliverables resulted in 78% replying 'Yes' and 22% replying 'Possibly'.

V. Conclusion

This paper presents an investigation into synergies between Revit, Dynamo, and Dynamo Player for streamlining COBie for Design deliverables for MEP disciplines. Current recommendations require designers having advanced Revit scheduling knowledge in conjunction with understanding each formula for populating COBie parameters. This research workflow aims to eliminate such requirements for designers, eradicating the possibility of human error and rework, while still being compliant with the international standard NBIMS v3. In the case of the large-scale project with 1,287 components, execution time was cut from 98 minutes 48 seconds to 4 minutes 36 seconds. This result approximately reduced the workflow by 95% on current best practice recommendations for these six COBie parameters. For the small-scale project with seven components, execution time was cut from 6 minutes 11 seconds to 2 minutes 13 seconds. This result approximately reduced the workflow by 64%. The lack of knowledge for the open source COBie QC testing tool and the disregard of adhering to a standard was alarming. To note this paper is for MEP disciplines only due to time restraints, but potential future works could include the development and testing of scripts for the Architectural discipline.

It is hoped the impact of this research with BIM for FM might contribute to enhanced standardised COBie deliverables, eradicating commonly incomplete, inaccurate, unverified information, and removing repetitive manual data entry to FM systems at handover. Considering that the FM phase lasts much longer than the design and construction phases, any process efficiency BIM can occasion will introduce higher cost savings (Akcamete, Akinci, & Garrett, 2010). Results of this research may interest clients, contractors, facility managers, BIM managers, designers or other individuals involved in design, construction and operations.

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