
# Lifecycle Exchange for Asset Data (LEAD): A Proposed process model for managing asset data flow between building stakeholders using BIM open standards


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| Journal: | *Journal of Facilities Management* |
| Manuscript ID | JFM-06-2019-0030 |
| Manuscript Type: | Research Paper |
| Keywords: | Lifecycle Data Exchange, Building Information Modelling (BIM), Facility Management, Asset Data Management, Digital Engineering, COBie Process |
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# Lifecycle Exchange for Asset Data (LEAD): A Proposed process model for managing asset data flow between building stakeholders using BIM open standards.

**Purpose:**
The purpose of this research is to outline the problems associated with asset information management using the Construction Operation Building Information Exchange (COBie) standard and analyse the causes of industry failure to successfully adopt the standard so far. Based on this analysis, the paper will propose a process model namely LEAD (Lifecycle Exchange of Asset Data) to manage asset data flow between all building stakeholders from design to construction and ultimately to the facility management team. This model aims to help the construction supply chain to produce complete and high-quality asset data that supports the operation phase of the built environment.

**Design/methodology/approach (limit 100 words)**
A review of relevant studies provided a theoretical background for this study. The authors then collected and analysed COBie data from five live BIM projects from different design and construction companies. The process model is based on an industry placement within Bouygues UK construction company, which is a tier 1 building contractor in London in the period from December 2016 to December 2018. The researcher used an inductive approach observing current practises in two construction projects to produce "LEAD" model. Then a focus group was conducted with industry experts to discuss and refine the process model.

**Findings (limit 100 words)**
Analysis of literature and data collected in the course of this study revealed that although COBie is a BIM level 2 standard in the UK, there is currently a low success rate in producing complete and accurate COBie data in the UK construction industry. This low rate is due to COBie's rigid data syntax/structure, complexity, and ambiguity of its data exchange process, which suggests that COBie maybe not be the future of the industry. Based on these findings, the study proposed a process model, namely "LEAD" to improve COBie output and also can be used with project-specific information requirements.

**Practical implications**
This paper is one of the first research papers that focuses solely on asset data exchange process using COBie standard and highlights the problems the industry faces in this remit. The study is based on industry placement for two years, so the analysis is based on actual and current industry problems. Current industry practices also informed the "LEAD" model, and the model provides a step by step guidance in producing and exchanging BIM asset data in all stages of the building lifecycle.

**Originality/value (limit 100 words)**
This paper provides a detailed analysis of the most common problems associated with COBie as an asset data exchange standard. Understanding these problems is of high value for industry practitioners to avoid them in projects. The paper also proposed a novel process model that can be used either to improve COBie quality or can be used with any project-specific data requirements.

**Keywords:** Lifecycle Data Exchange, Asset Data Management, Asset Information Requirements (AIR), COBie Process, BIM, Facility Management, Digital Engineering.

## 1.0 Introduction:

Facility and asset management (FM/AM) industry is one of the largest contributing industries to the Gross Domestic Product (GDP) in the UK directly through income generated by FM/AM companies and indirectly by supporting strategic AM for other organisations. A research report by the British Institute of Facilities Management (BIFM) estimated that FM/AM industry directly contributed £121.8 billion to the UK economy in 2016 (BIFM, 2017). While the global built asset performance index estimated that “built asset returns” contributed 26.3 % of the UK’s GDP in 2016 (Arcadis, 2016). These figures show that the optimisation of built asset performance and cost is critical to achieving sustainable growth for the UK economy. Asset management is defined as “a strategic and integrated set of processes that are used to gain maximum lifetime value and return from physical assets through achieving the desired balance of cost, risk and asset performance” (Shuman & Brent, 2005) (ISO 55000, 2014). That is why effective asset management should cover all stages of the asset lifecycle, including design, procurement, installation and operation and maintenance.

Asset management is an information-intensive industry; it requires facility managers to collect, analyse, store, exchange and manage an enormous amount of data about the built assets throughout the building lifecycle. Building Information Modelling (BIM) with its open standards has the potential to allow the exchange and re-use of asset data created from the design and construction phases of building lifecycle to the operation phase (Kare, 2015). BIM research and industry practices so far are focusing on design and construction. While, limited work done in extending BIM capabilities as an information-rich platform for the asset operation phase (Pärn et al., 2017); (Zadeh et al., 2017); (Hu et al., 2018); (Pishdad-Bozorgi et al., 2018) although it is widely recognised in the industry that this phase accounts for 75 to 80% of the lifecycle costs of buildings.

The first aspect of extending BIM capabilities to operation and asset management phase of building lifecycle is interoperability (Farghaly et al., 2018). In BIM context, interoperability is ensuring that the data created by BIM authoring software, and Common Data Environment (CDE) can be exchanged successfully and reused by the Computer Aided Facility Management (CAFM) systems in the operation phase. The Industry foundation classes (IFC) and the Construction Operations Building Information Exchange (COBie) are the currently agreed BIM data exchange standards between Architecture, Construction and Engineering (AEC) and facility management teams. Although COBie exists in the industry for more than a decade, and despite it being one of the BIM level 2 standards in the UK, the successful adoption of COBie in the industry is very limited (Love et al., 2014). Furthermore, the quality of COBie output in the vast majority of construction projects is not enough for the data to be used effectively in the operation phase.

Research shows that one of the main problems of the low quality of COBie deliverable is the lack of clarity of the process of asset data exchange for this standard (Eadie et al., 2013). This process ambiguity causes the BIM data delivered to FM to be incomplete, inaccurate and of low quality and in many cases requires the facility manager to use traditional ways of recreating asset data lists for use in the operation phase. These problems have many negative implications in the asset management industry, including loss of cost, wasted time, low productivity, less efficiency and decreased lifetime cost of assets (Guillen et al., 2016). Despite the broad consensus of this process problem, there is limited research done in developing a clear, simple and standardised process to manage BIM asset dataflow between all stakeholders involved in the building (Pishdad-Bozorgi et al., 2018).

This study responds to this problem by proposing a process model for asset data creation, flow and management throughout the building lifecycle. The process model is called “Lifecycle Exchange of Asset Data (LEAD)”. This process model is created through the observation and analysis of current practices in two major construction projects throughout two years (December 2016 to December 2018) within an industry partner’s premises. It is also based on the analysis of COBie data of five construction projects from other design and construction companies. The process will guide the optimum mechanisms and workflows of asset data exchange between Architecture, Engineering, and Construction (AEC) teams and Facility Management (FM) team throughout the building lifecycle.

**2.0 Current COBie Practices:**

The National BIM survey of the National Building Specification (NBS) of UK estimates that not more than 25% of construction projects in the UK produce COBie data (Thenbs.com, 2016). While this percentage has increased to reach 41% according to the latest UK national BIM survey in 2019 (Thenbs, 2019) the adoption rate for the COBie standard is still not adequate especially when we consider that the standard was published in 2006, i.e. 13 years ago at the time of this study. Even for the companies that use COBie, (Parn & Edwards, 2017) estimated that 70% of construction projects fail to comply with COBie requirements and provide a complete COBie data to client which means that the majority of asset management companies don't get to use the standard as far. Arguably, one of the main reasons for this industry failure of adopting COBie thus far is the lack of clarity of the process of producing COBie data (Cavka et al., 2017). The COBie data exchange standard (NBIMS-US V. 3.0) provided a set of detailed business processes in the context of lifecycle data exchange for buildings. However, this set of processes offer guidance related to "what" aspects of data exchange will be eliminated or automated as a result of using COBie, but it doesn't provide answers to "how" COBie data itself will be created and exchanged throughout the lifecycle (Masania et al., 2015). Furthermore, none of these processes provided a clear and easy to use data flow process between building stakeholders in the preparation and exchange of COBie (Kelly et al., 2013).

There are many ways to produce COBie data; this includes manual entry of data which is not practical but still being followed by sub-contractors in small scale buildings when the number of assets is not significant (East, 2007). The second way is by extracting COBie data from the BIM authoring software directly. The problem with this method is that the main contractors end up with many COBie files coming from different subcontractors, and these subcontractors do not necessarily follow the same naming convention, so when the main contractors try to federate the files, many problems of asset naming and asset repetition occur. The third and most favourable method is to unify all the IFC models from all subcontractors in one file, then exclude the COBie Model View Definition (MVD) from the federated IFC file.

There are a lot of problems in COBie management that are related to process identified as follows:

- Lack of precise COBie requirements in the Employee Information Requirements (EIR). This is caused by inadequate knowledge in the facilities management industry about the BIM process and COBie structure (Azhar, 2011).
- Improper definition of the required assets and attributes in the Asset Information requirements creates confusion in the architecture and contractor side about what asset information to extract into COBie, and what not to include (East, 2007). This causes improper costing and scheduling for this critical data task, and it becomes a contractual problem when the client eventually requests the data in a later stage of the project.
- Lack of clarity about COBie related roles and responsibilities between client/FM, architect, main construction contractor, subcontractors of different disciplines (Edirisinghe et al., 2017) like MEP, Architecture, landscape...etc., makes it challenging to identify who provides what and when concerning COBie throughout the project lifecycle.
- The use of different BIM authoring software packages within various subcontractors (Grilo & Jardim-Goncalves, 2010) and lack of structured process to creating and consolidating COBie output from these different software packages (Love et al., 2013).
- Poor quality control; and management of COBie along the required four COBie drops results in the sub-contractors to leave the preparation of COBie to the latest stage of the project (Kang & Choi, 2015), then it becomes very difficult to collect all the required asset data in a limited time.
- Lack of knowledge of the mapping process between COBie and CAFM systems (Kassem et al., 2015).

To date, there is no standardised way or process to guide construction supply chain on which way to follow. In the UK, the British Standard BS 1192-4:2014 "Collaborative production of information Part 4: Fulfilling employer's information exchange requirements using COBie – Code of practice" included information about the COBie structure, and the data that needs to be included in COBie spreadsheet. However, it also didn't include a clear process for COBie creation and management. Fig 1 shows a screenshot of COBie governance from the British standard BS1192-4, which provides a very general illustration about the process of asset data exchange using COBie standard.

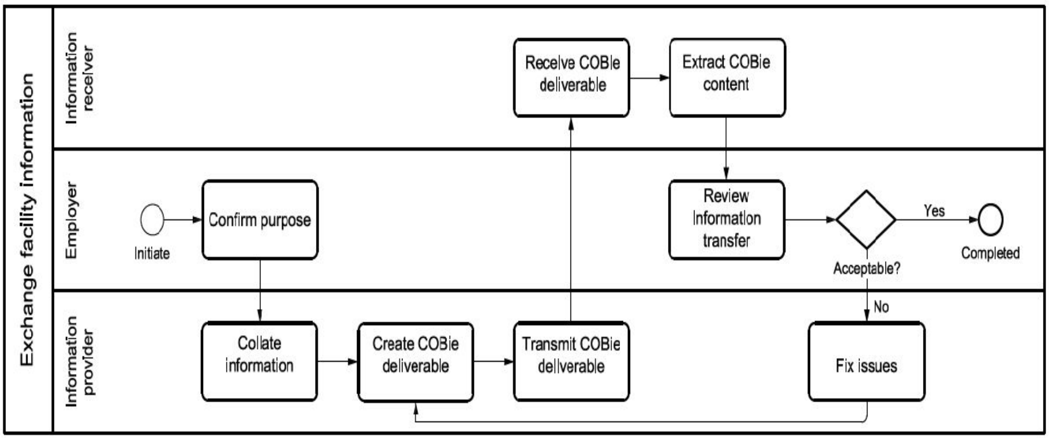


*Figure 1: COBie governance according to BS1192-4*

This graph only shows how the information is provided and quality checked by the client. However, it doesn't offer any specific guidance on the party from the supply chain who is responsible for providing this information (Architect, main contractor, subcontractors), when it is provided, and at what stage of the building lifecycle. This brief review of relevant research leads to the main research question which is: What is the optimal process for the creation and exchange of asset data that should be followed by BIM supply chain to guarantee completeness and quality of asset data in the operation phase?

**Methodology:**

The data collection in this study is based on a mixed research methodology. First, an inductive method is used in which the researcher collects data about certain phenomena and use this data to create a theory or a theoretical framework about the phenomena (Gioia et al., 2013) (Sang et al., 2017). The inductive methodology is often used when there is the limited theoretical base to explain the area of research (Ketokivi & Mantere, 2010) which applies in the case of COBie data process flow because there are limited research studies done in this area. The researcher participated as an active observer of the process within the industry partner's headquarter for about two years. The process started by a review of literature, industry reports and project related documents, then the researcher collected data from real-life project meetings, formal and informal discussions and project documentation to create the model.

The second research methodology used is a deductive methodology which is the opposite of inductive method in the sense that it follows a top-down approach in data collection, so it uses a well-recognised theory about a particular phenomenon, then collects data about this phenomenon to either confirm or refute the theory in the investigated context. The deductive method is the most widely used research methodology because it follows the rigorous structure of research however it doesn't contribute significantly to the discovery of new knowledge compared to inductive methodology (Jebb et al., 2016) because the data collected is used in the sole purpose of testing an already existing theory. Using the deductive method, data is collected via a focus group with asset management industry experts from the "Constructing Excellence – Asset Management theme group" who discussed, analysed and provided feedback about the model. The feedback from the focus group was recorded, transcribed, coded, analysed and used to refine the process model. Rigorous research must have a balance between the two research methodologies (Hanson, 1985) (Vickers, 2014), an inductive method to explore new theory based on the data collected, and a deductive approach to validate the theory and its applicability.

**4.0 Analysis of project data to inform LEAD model:**
The process of creating COBie process model had the following stages:

**4.1: Review of literature and industry standards and publications.**

- A review of relevant literature in order to capture the state of play and research gaps in the area of BIM implementation for facility and asset management.
- A thorough review of the BIM and COBie industry standards and documents such as:
    - Relevant British and international standards:
        - PAS 1192 suite
        - BS 1192-1:2007
        - BS 8536 parts (1,2)
        - ISO 19650
    - The Construction Industry Council (CIC) BIM protocol
    - The Royal Institute of British Architects (RIBA) Plan of Work (PoW) 2013.
    - BIM Forum 2015 LOD Specification
    - COBie standard (National BIM standard US – NBIMS_US V. 3.0)
    - Industry reports and case studies in the area of BIM for FM

**4.2: Review of live project documentation from the industry partner's ongoing projects.**
Review of live project documentation from the industry partner's ongoing projects.
Based on the literature and industry standards and documentation review, the researcher started to review BIM implementation plans and documentation in different projects undertaken by the industry partners. Based on the different stages of BIM implementations in each project, various project BIM documentation was reviewed, for example:

- BIM strategy documents
- Employer's information requirements (EIR)
- Asset Information requirements (AIR)
- BIM Execution Plans (BEP)
- Master Information Delivery Plans (MIDP)
- Live COBie drops from different projects

The documentation mentioned above was reviewed for five BIM projects from various design and construction companies.

The review of the above project documentation revealed many problems. For example, in two projects, there was no "Asset Information requirements (AIR)" document provided by the client to guide the process of asset data exchange using COBie. This means that the client either doesn't have enough expertise in managing BIM or the client has decided that BIM asset data will not be used in the operation phase. Both scenarios will create many problems in the operation phase (Cavka et al., 2017). Because without an AIR, the asset data generated in BIM will not be of any use in the Operation phase (East, 2016).

Additionally, in the third project, an (AIR) document was prepared and provided to the main contractor; however, this was done in stage 5 of the project, i.e. Construction phase. This means that at this stage, COBie drop 3 is due, and all the work is done in asset naming, zoning of space needs to be re-done to comply with the new AIR. Another problem is that for several projects, the Exchange information requirements (EIR) did not put in a change management mechanism to recognise the time and cost associated with such changes in data management. On the contrary, the EIR stated the following:

> *"The Employer intends to develop this document and others that form the Employer's Information Requirements with the involvement of the Supplier, the Employer's internal stakeholders and the Employer's specialist advisers. The Supplier shall therefore make an allowance for this planned development."*

Arguably, this phrase is misleading and too general and may result in many confusions for the supply chain. It also does not give precise answers to many vital questions that are supposed to guide the asset data exchange process (Becerik-Gerber et al., 2012). For example:

- Who will develop the EIR, and when?
- Who will discuss/agree on the changes from the contractor side
- What parts of the EIR can be improved/updated during the project, and what parts cannot?

Contractually, the phrase at its current form means that the employer can -at any time- issue an updated EIR with updated data requirements regardless of cost and schedule implications. This is creating misunderstanding between the client and the main contractor about the time and cost needed to rectify the data to comply with any changes done in the EIR (Aziz et al., 2016).

**4.3: Preforming quality control check of the COBie drops for the 5 projects:**

The tool used for COBie quality check in this study is the COBie QC reporter tool. It is a free tool that is based on a Java environment and can be used in "Microsoft Windows" and "Mac" operating systems. The tool provides a cell by cell check of the COBie file against the rules identified in the NBIMS V.3 COBie standard. Its Microsoft Windows interface is based on Command Prompt (cmd) where the user specifies the input COBie file name in Excel spreadsheet format and the output file name in HTML format. Figure 2 is a screenshot of the use of the tool for project 1 of this study.

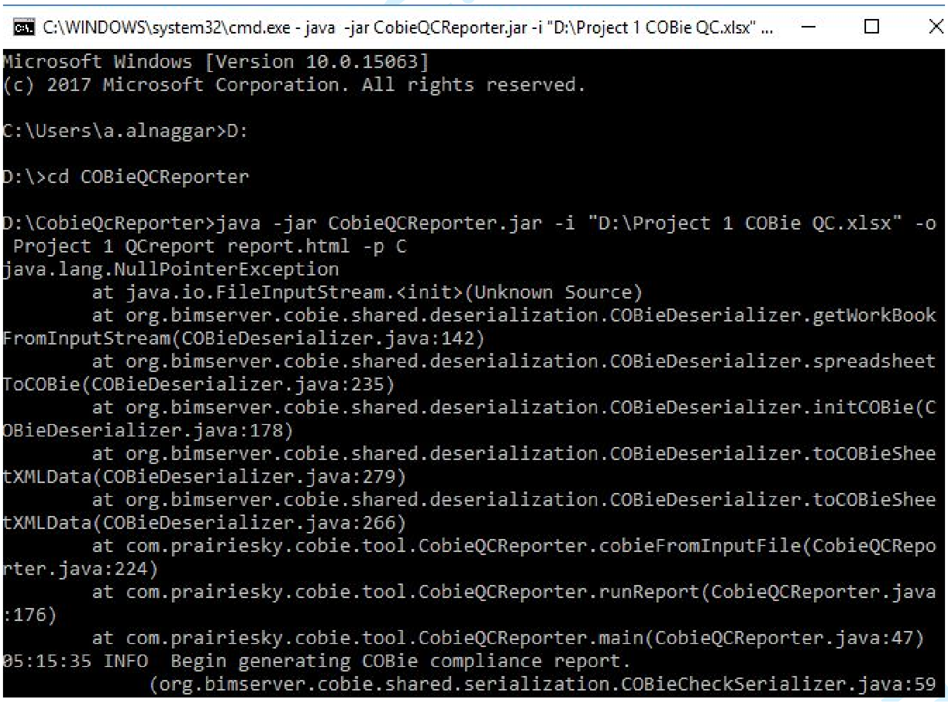


*Figure 2: Screenshot of the use of COBie QC reporter tool*

The tool only enables verification of the quality of COBie file content, i.e. it checks that the syntax of COBie output of the project adheres to the data structure and format stipulated in the COBie standard. However, the tool can't perform any validation of the semantics or the content of the COBie file and its adherence to the project or client specifications (Zadeh et al., 2017). For example, if the floor height of any level of the building is incorrect, the tool will not report an error if the format of the data for this floor in the COBie file is correct. The following table provides the results of automated COBie quality check for 5 construction projects in the UK using COBie QC reporter

**Project 1**

| Worksheet | Has Rows? | Row Count | Row Warning Count | Row Error Count |
|---|---|---|---|---|
| Contact | FALSE | 0 | n/a | n/a |
| Facility | TRUE | 1 | 0 | 1 |
| Floor | TRUE | 9 | 0 | 9 |
| Space | TRUE | 853 | 0 | 853 |
| Zone | FALSE | 0 | n/a | n/a |
| Type | TRUE | 633 | 0 | 633 |
| Component | TRUE | 16492 | 0 | 16492 |
| System | FALSE | 0 | n/a | n/a |
| Assembly | FALSE | 0 | n/a | n/a |
| Connection | FALSE | 0 | n/a | n/a |
| Spare | FALSE | 0 | n/a | n/a |
| Resource | FALSE | 0 | n/a | n/a |
| Job | FALSE | 0 | n/a | n/a |
| Document | FALSE | 0 | n/a | n/a |
| Attribute | TRUE | 290637 | 0 | 290637 |

**Project 2**

| Worksheet | Has Rows? | Row Count | Row Warning Count | Row Error Count |
|---|---|---|---|---|
| Contact | TRUE | 3 | 0 | 0 |
| Facility | TRUE | 3 | 0 | 2 |
| Floor | TRUE | 2 | 0 | 0 |
| Space | TRUE | 31 | 0 | 0 |
| Zone | FALSE | 0 | n/a | n/a |
| Type | TRUE | 60 | 0 | 60 |
| Component | TRUE | 156 | 0 | 72 |
| System | FALSE | 0 | n/a | n/a |
| Assembly | FALSE | 0 | n/a | n/a |
| Connection | FALSE | 0 | n/a | n/a |
| Spare | FALSE | 0 | n/a | n/a |
| Resource | FALSE | 0 | n/a | n/a |
| Job | FALSE | 0 | n/a | n/a |
| Document | FALSE | 0 | n/a | n/a |
| Attribute | FALSE | 0 | n/a | n/a |

**Project 3**

| Worksheet | Has Rows? | Row Count | Row Warning Count | Row Error Count |
|---|---|---|---|---|
| Contact | TRUE | 2 | 0 | 1 |
| Facility | TRUE | 1 | 0 | 1 |
| Floor | TRUE | 11 | 0 | 11 |
| Space | TRUE | 969 | 0 | 34 |
| Zone | FALSE | 0 | n/a | n/a |
| Type | TRUE | 2069 | 0 | 2069 |
| Component | TRUE | 25665 | 0 | 25665 |
| System | TRUE | 17807 | 0 | 17807 |
| Assembly | FALSE | 0 | n/a | n/a |
| Connection | FALSE | 0 | n/a | n/a |
| Spare | FALSE | 0 | n/a | n/a |
| Resource | FALSE | 0 | n/a | n/a |
| Job | FALSE | 0 | n/a | n/a |
| Document | TRUE | 1674 | 0 | 1674 |
| Attribute | TRUE | 9121 | 0 | 1030 |

**Project 4**

| Worksheet | Has Rows? | Row Count | Row Warning Count | Row Error Count |
|---|---|---|---|---|
| Contact | TRUE | 1 | 0 | 0 |
| Facility | TRUE | 1 | 0 | 0 |
| Floor | TRUE | 25 | 0 | 0 |
| Space | TRUE | 574 | 0 | 10 |
| Zone | TRUE | 574 | 0 | 0 |
| Type | FALSE | 0 | n/a | n/a |
| Component | FALSE | 0 | n/a | n/a |
| System | FALSE | 0 | n/a | n/a |
| Assembly | FALSE | 0 | n/a | n/a |
| Connection | FALSE | 0 | n/a | n/a |
| Spare | FALSE | 0 | n/a | n/a |
| Resource | FALSE | 0 | n/a | n/a |
| Job | FALSE | 0 | n/a | n/a |
| Document | FALSE | 0 | n/a | n/a |
| Attribute | FALSE | 0 | n/a | n/a |

**Project 5**

| Worksheet | Has Rows? | Row Count | Row Warning Count | Row Error Count |
|---|---|---|---|---|
| Contact | TRUE | 1 | 0 | 1 |
| Facility | TRUE | 1 | 0 | 1 |
| Floor | TRUE | 5 | 0 | 5 |
| Space | TRUE | 219 | 0 | 219 |
| Zone | FALSE | 0 | n/a | n/a |
| Type | TRUE | 75 | 0 | 75 |
| Component | TRUE | 2541 | 0 | 2541 |
| System | FALSE | 0 | n/a | n/a |
| Assembly | FALSE | 0 | n/a | n/a |
| Connection | FALSE | 0 | n/a | n/a |
| Spare | FALSE | 0 | n/a | n/a |
| Resource | FALSE | 0 | n/a | n/a |
| Job | FALSE | 0 | n/a | n/a |
| Document | TRUE | 75 | 0 | 75 |

*Table 1: Results of COBie Quality check for five different Projects*

The data for the five projects shows that there is a severe problem with the overall quality of the COBie data produced. Although the data came from different projects and different design and construction companies, the quality of the COBie output for all projects was unusable for the operation phase. For example, none of the five projects has produced any data for COBie tabs assembly, connection, spare, resource and job. Since all the five projects' BIM models were built using Autodesk Revit and Autodesk Navisworks, Investigating this problem revealed that there is no possibility to exchange these five COBie tabs using Revit or Navisworks. The following screenshot shows the COBie extension of Revit which doesn't have a mean to export any of these five tabs from the BIM model.

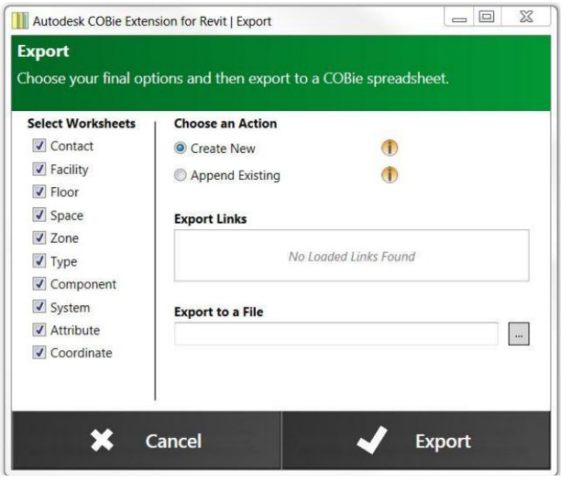


*Figure 3: COBie extension for Revit*

Although these five tabs are optional as per the COBie standard, there is no practical reason for them to exist in the COBie standard if the technology available in the market cannot support them.
The following table 2 shows a summary of the errors percentage for the five projects. The summary indicates that even for the COBie tabs that are supported by BIM authoring software, the error rate in the data was very high.

*Table 2: Summary of COBie QC check for the 5 projects checked*

| Project | Number of Cobie records | Number of errors | Percentage of error |
|---|---|---|---|
| **Project 1** | 308625 | 308625 | 100 % |
| **Project 2** | 255 | 134 | 53% |
| **Project 3** | 57319 | 48292 | 84% |
| **Project 4** | 1175 | 10 | 1% |
| **Project 5** | 25941 | 25941 | 100 % |

Table 2 also shows a significantly low quality of the COBie data output for all the projects with projects one and five scored 100% errors, and project three scored 84% errors. Even for project two that scored 53% errors, the number of overall components in the project was just 156 only which suggests that significant data is missing for the assets and also there was no information in the COBie "systems" tab. Finally, project 4 scored only 1% error, but again this is because there was no data in the type, component, or system tab which also suggests that the COBie data for this project is also not complete and not usable for the CAFM system.

**4.4: Identifying the problems with COBie data in the reviewed projects:**
From the review of the live project data of COBie drops, it is evident that the COBie asset data produced for all the projects were incomplete and of low quality. This suggests that this COBie data cannot practically support the operations for the assets for these projects, and it will create many

problems if uploaded to any CAFM system assuming that an upload process will be successful. For example, the following screenshot shows the actual output of the HTML file of COBie QC reporter tool for project 3, and it indicates that 100% of the records in the COBie file have data errors.

| Worksheet | Has Rows? | Row Count | Row Warning Count | Row Error Count |
|---|---|---|---|---|
| Contact | true | 2 | 0 | 1 |
| Facility | true | 1 | 0 | 1 |
| Floor | true | 11 | 0 | 11 |
| Space | true | 969 | 0 | 34 |
| Zone | false | 0 | n/a | n/a |
| Type | true | 2069 | 0 | 2069 |
| Component | true | 25665 | 0 | 25665 |
| System | true | 17807 | 0 | 17807 |
| Assembly | false | 0 | n/a | n/a |
| Connection | false | 0 | n/a | n/a |

*Figure 4: A screenshot from the html file output of COBie QC tool report*

A thorough review and analysis of the data in the COBie files from the five projects could identify the following causes of errors in the final COBie output:

1. The data of the COBie drops came into many files; this suggests that there was no coordination among the supply chain in producing the COBie data (Lavy and Jawadekar, 2015). This means that every subcontractor in the supply chain provided own COBie file with no central point of data check, data federation or quality control.
2. The asset naming convention between the several COBie drops of the same project was inconsistent. This suggests that either the information requirement documents from the client did not dictate a uniform asset naming convention to be followed by the supply chain, or an asset-naming convention was there, but it was not followed or enforced by the information manager in the design or construction team.
3. The asset names within the same COBie drop is not unique and not consistent. If this data is uploaded to the CAFM system, every duplication will be handled as a separate entity be it space or an asset which makes asset maintenance using this data almost impossible

| Name | CreatedBy | CreatedOn | Category |
|---|---|---|---|
| COLD ROOMR_0.8.7 | | 2016-05-1 | SL_20 |
| CONCIERGER_0.50.2 | | 2016-05-1 | SL_20_15_71 |
| CONCIERGER_0.50.3 | | 2016-05-1 | SL_20_15_71 |
| CORRIDOR0.22.8 | | 2016-05-1 | SL_32_80_89 |
| CORRIDORC_0.5.2 | | 2016-05-1 | SL_32_80_89 |
| CORRIDORC_0.5.2 | | 2016-05-1 | SL_32_80_89 |
| CORRIDORC_0.5.2 | | 2016-05-1 | SL_32_80_89 |
| CORRIDORR_0.1.13 | | 2016-05-1 | SL_32_80_89 |
| CORRIDORR_0.2.14 | | 2016-05-1 | SL_32_80_89 |
| CORRIDORR_0.20.13 | | 2016-05-1 | SL_32_80_89 |
| CORRIDORR_0.24.5 | | 2016-05-1 | SL_32_80_89 |
| CORRIDORR_0.25.16 | | 2016-05-1 | SL_32_80_89 |
| CORRIDORR_0.25.17 | | 2016-05-1 | SL_32_80_89 |
| CORRIDORR_0.26.1 | | 2016-05-1 | SL_32_80_89 |
| CORRIDORR_0.26.1 | | 2016-05-1 | SL_32_80_89 |
| CORRIDORR_0.26.1 | | 2016-05-1 | SL_32_80_89 |

*Figure 5: Duplication in asset naming in the COBie file*

4. Many cells of the asset data have no value. This missing information is an indication of lack of quality assurance (Nical and Wodyński, 2016) even at the minimum level between BIM managers in the main contractor and information managers in design teams and sub-contractors.

**4.5: Analysing the causes of the low quality and responding to it in the COBie process model:**

Analysing the problems found in these projects from the COBie data based on the researcher's prior experience and through continuous discussions with project teams, the reasons that caused these problems could be identified as follows:

1- Lack of knowledge from client facility management teams about the asset requirements that need to be included in the "Asset information requirement (AIR) document. This causes severe delays to provide information requirements to the design and construction teams and causes a lot of confusions and misunderstandings about what data is required. In many cases, the information received from the client is not complete enough to start a proper review process for the asset data requirement. This information is considered as the scope of data requirement that guides the COBie management process throughout all pre-operation phases of the building lifecycle. The proposed COBie process model responded to this problem by mandating the client to provide an adequate AIR document either by using local expertise or by hiring a digital engineering consultant (DEC) with BIM/COBie experience. Having client facility management engagement in as early as stage 0 of the project lifecycle will solve the problem of unavailing expectations about asset data requirements and will help in managing the expectation of the supply chain about what data is required for operation phase and why it is required.

2- Lack of coordination for the supply chain in all pre-operation phases of the building lifecycle. This is caused by the absence of a clear COBie management plan that specifies the roles and responsibilities of each stakeholder, what data is required, and in which stage it is required. COBie as a deliverable has always been seen as a side requirement from design and construction teams which makes it often disregarded until construction phase, and by this phase of the building lifecycle, a lot of errors accumulate from the architect and design consultants. Furthermore, some data gets missing because the party who was supposed to provide it early in the project is not existing in the project anymore. For example, an MEP consultant could do some design work in RIBA stage 3 "developed design" and RIBA stage 4 "technical design" phases of the building lifecycle, and then they leave the project in construction phase because their scope of work is finalised which is only design. In this case, any asset specification data that this design consultant has not included will not be in the model or the COBie file. LEAD model responded to this problem by providing clear guidance for all stakeholders about their role in providing data in each stage of the building lifecycle.

3- Lack of quality control for the data produced by different stakeholders. This causes a lot of data errors and duplications. These issues accumulate in various stages of the building lifecycle, causing the overall data in the COBie file to have an unmanageable number of errors in the construction and handover phase. COBie process model responded to this problem by integrating a quality control check in each stage of the building lifecycle. This ensures that before the COBie asset data is handed over between stakeholders, it is checked, and errors are corrected on time to prevent the accumulation of errors.

4- From several formal and informal discussions with projects' teams, different stakeholders from the supply chain used different methodologies to create COBie files. Some created it manually, some exported COBie from IFC file format, and some used the COBie extension in their BIM authoring software to extract COBie. All these methods are valid; however, there should be a process to coordinate how this data will be federated and coordinated between teams. Such a process was not in place for all the projects examined in this study.

### 5.0 Lifecycle Exchange for asset Data (LEAD) Process Model

LEAD process model is an extension of a study that proposed the use of a project management methodology of four phases to manage COBie asset data flow throughout building lifecycle (Alnaggar and Pitt, 2018). This study proposed the mapping between these four phases and the Royal Institute of British Architects (RIBA) plan of work stages. The phases set out in this study were: Initiation (RIBA stage 0,1), Planning (RIBA stage 2,3,4), Execution (RIBA stage 5) and Closeout (RIBA stage 6,7) as shown in Fig. 6. LEAD model will build on this mapping by developing asset data exchange processes for each of the four phases. These processes can be used to deliver asset data for the operation phase using COBie standard or any other project specific information schema required by the client.

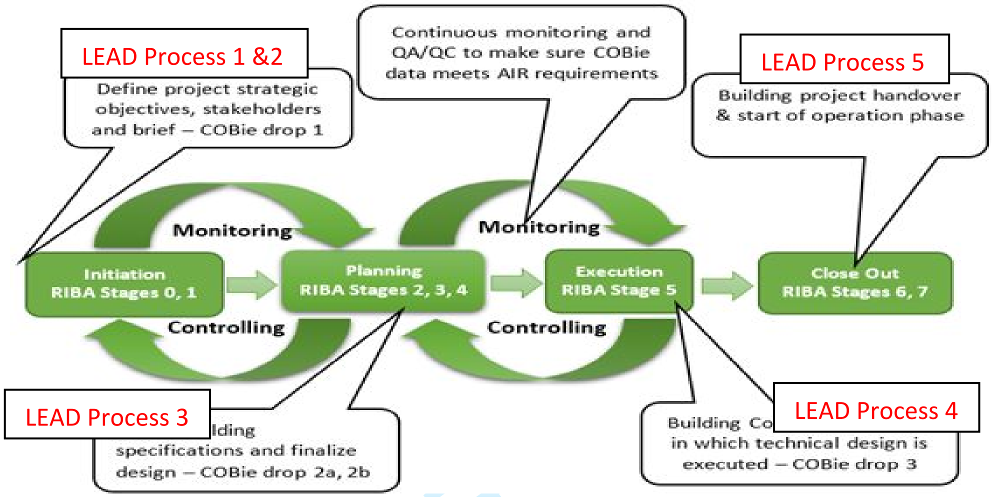


*Figure 6: Mapping PMI project management methodology with RIBA PoW (Alnaggar & Pitt, 2019) Updated with LEAD model processes*

The LEAD model will focus on the “Develop own operate” contractual scenario (PAS 1192-3, 2013). In which, a building owner/client retains control of assets throughout the building lifecycle. First the asset is designed in liaison with an architect then constructed in coordination between the owner, the architect (lead designer) and a construction supply chain including the main contractor, then after the handover, the building and assets are operated and maintained by the owner’s facility management team or by a facility management supply chain. However, the proposed process in this research is focused on the asset management lifecycle, so most of the processes in LEAD can be amended and used in other types of construction and ownership scenarios. These scenarios include “develop own let” or “develop own sell” because the asset lifecycle is the same, but the difference lies in the party who manages the data in later phases.

The model assumes that the client does not have in-house BIM expertise. This assumption is aligned with the current state of the asset management industry. That is why the model suggests hiring a digital engineering consultant (DEC) or BIM consultant to support the client/owner asset management team in preparing their information requirements such as Organisation Information Requirements (OIR), Exchange Information Requirements (EIR) and Asset Information Requirements (AIR) documents. DEC will also perform quality management of the COBie deliverables in different stages of building lifecycle and will sign off BIM deliverables received from supply chain to the client (Nisbet, 2008). The model assumes that the project’s stakeholders are the Client/FM team, the Digital Engineering Consultant (DEC), the Lead designer/Architect, design consultants, the main contractor, and construction sub-contractors. The following section will present the four phases of the LEAD model that are aligned with the Project Management Institute project phases (PMI) with analysis of the processes of each phase mapped with RIBA stages. It will also provide a coordination mechanism for the “COBie drops” management from the concept design phase until the handover phase of the building lifecycle.

**5.1 LEAD Process 1 – PMI Initiation Phase**

The initiation phase of the LEAD model will have two processes. Fig 7 shows the first process that will ideally take place at RIBA stages 0 (strategic Definition). The purpose of this process is to make sure that the scope of the COBie information delivery project is set properly, and includes all information that needs to be delivered (Boyes et al., 2017) This process will be initiated by setting up the consultation agreement between the client/owner and their asset management team and the Digital Engineering consultant (DEC). This step is assuming that the client asset management team does not have enough BIM skills to manage the COBie workflow in-house which is the current reality in most of the facility and asset management companies (Faltejsek and Chudikova, 2019). However, if the client has their own BIM specialist that can manage the COBie workflow, then this specialist will act as the DEC in this process model.

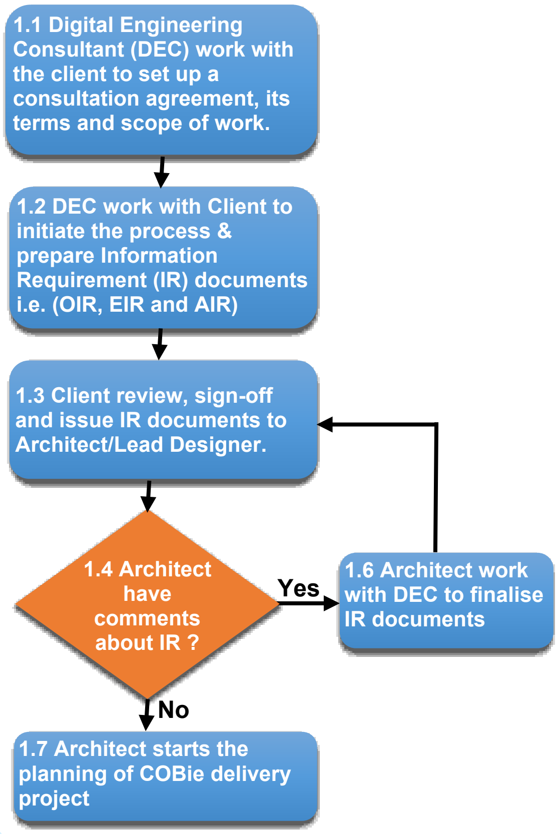

*Figure 7: LEAD process 1 - RIBA stage 0*

The primary function for the DEC at this stage is to work with the client FM team to prepare the Information requirements documents (IR) this includes the Organization Information Requirements (OIR), the Asset Information Requirements (AIR), and the Exchange Information Requirements (EIR). The role of the DEC in this process is to translate the strategic objectives of the asset management team of the client into asset-related requirements from the BIM project implementation and prepare the requirements that will guide the BIM implementation throughout the lifecycle (Patacas et al., 2015). DEC will present the COBie management plan template (Alnaggar and Pitt, 2019) for the client and architect/lead designer's team to establish clear expectations about the COBie information delivery in the project. This will ensure the agreement of the COBie project scope boundaries in this early stage. It will also set a common ground of the COBie data deliverables between client FM and architect and will make it easier for the construction supply chain that will join the team later in the construction phase to deliver complete and high-quality COBie data.

Another advantage of preparing the information requirements documents at this early stage of the project is that it gives the client asset management team a chance to connect between the BIM objective and the strategic objectives of the organisation (Brunet et al., 2019). This vital connection will provide great value in the operation phase because the required information in the BIM model will be based on the real business value that the organisation aims to achieve from the assets. It is also crucial that the architect/lead designer review the information requirement documents, and provide feedback or ask for clarification about the COBie scope. This removes all ambiguities later on from the process and proactively solve potential problems like unclear naming conventions, classification standards or lack of zoning strategy. Having the architect review gives a chance to agree on all information requirements of the COBie scope up front. Once the scope of the COBie data is agreed and finalised, the architect team then starts the planning phase of the COBie management process.

### 5.2 LEAD Process 2 - PMI Initiation Phase

The second process of initiation phase fig. 8 takes place in the RIBA stage 1 (Preparation and Brief) After the COBie scope is agreed with the client, the architect prepares the COBie management plan document which includes all the information required by the construction supply chain to deliver the information requirements in the COBie scope.

This approach of treating information management in BIM as "a project" is critical because the rigorous methodology associated with project management will improve the information governance of BIM throughout the lifecycle (Alnaggar and Pitt, 2019). Similar to any project management plan, the COBie plan should include roles and responsibilities between all stakeholders and COBie schedule that illustrates the COBie drops and when it is due to deliver each drop. It should also include the communication plan between project stakeholders with the planned schedule for meetings, and final COBie drops exchange, the quality plan that explains clearly who will perform quality control in each stage and how quality control will be undertaken.

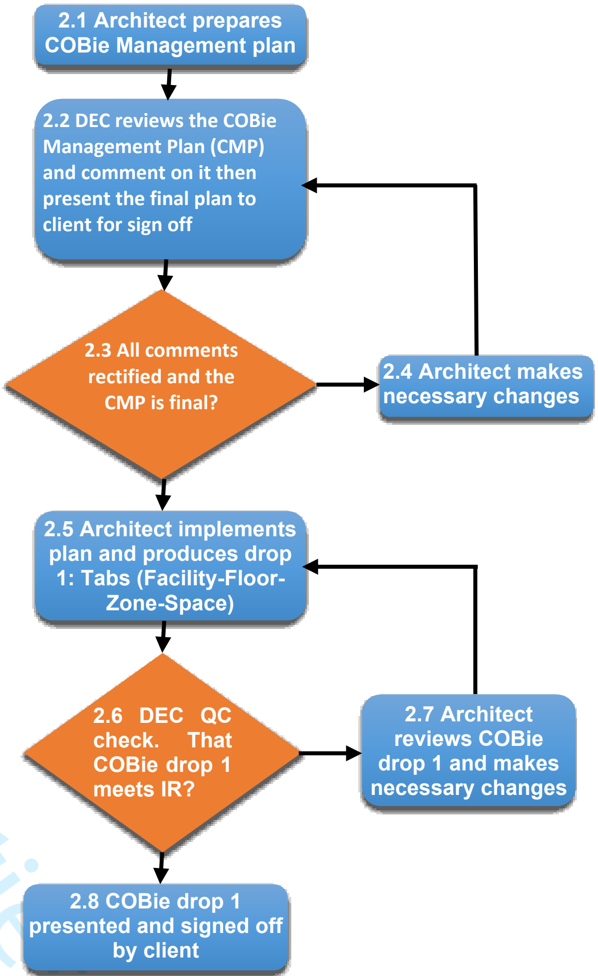

*Figure 8: LEAD process 2 - RIBA stage 1*

This plan takes place in the RIBA stage 1 of the building lifecycle. By finishing the plan in that early stage, it becomes clear to all parties as who will manage the COBie deliverables, who will deliver COBie data, when it is delivered, and the quality criteria of checking COBie data throughout the project until it is handed over for operations phase. Once the plan is reviewed and signed off by the client, the architect starts populating the COBie sheet with information about facility, floor, zones and spaces as agreed in the (AIR) document. This information should be available in stage 1 in the building design programme.

Getting the client team or their digital consultant involved at this early stage is also aligned with the Government Soft Landings (GSL), and it helps the supply chain have the right expectations about the data delivered to operation team, and ensures the data is suitable to support asset management (Faltejsek and Chudikova 2019). The DES then (On behalf of the client) performs the first quality check for the COBie drop 1 to make sure the naming convention for floors is consistent because this will allow the supply chain to use consistent naming of the levels and avoid duplicate naming. In many construction projects, the architect, for example, use different naming for the floor than the mechanical, electrical and plumbing (MEP) consultant. For instance, the ground floor is named as G01 and MEP would name it as floor 00, and this will create problems later when the different BIM models are federated in a coordinated model. The zoning strategy should also be checked for consistency, and the agreed classification should be precise for the architect in this early stage. This early quality check is not only crucial for asset management, but it also helps with the BIM implementation in the project because it will stress on the coordination between the architect, the main contractor and subcontractors (Martin, 2011). Rectifying these problems in stage 1 is more manageable, less costly, and requires much less effort, and time for the project BIM team.

### 5.3 LEAD Process 3 – PMI Planning Phase

This process takes place during the design stages of the RIBA Plan of Work (PoW), namely concept design, design development and technical design fig. 9. Since every project has its circumstances, and different base of development (Hautala et al., 2017), the team must be flexible in implementing this process. For example, in some projects, the main contractor will be on board during the technical design phase, in this case, the COBie management plan should be shared and introduced to the main contractor, and in turn, the main contractor will share the plan with the construction supply chain. However, for all design work undertaken before the main contractor is appointed, it is the responsibility of the architect (lead designer) to implement the process and get its deliverables signed off by DEC on behalf of the client FM team which is aligned with the government soft-landing policy (in case of UK projects).

The process starts by an update to the "COBie drop 1" with information from the model as it becomes available from the design development phase, this information is often related to building systems in COBie tabs (Systems, Components and types). By the end of the design development phase, the COBie drop 2a should be complete, quality checked and submitted for DEC to perform a client quality check. Once COBie drop 2a is approved, the model will be gradually updated until COBie drop 2b is issued by the end of the technical design phase.

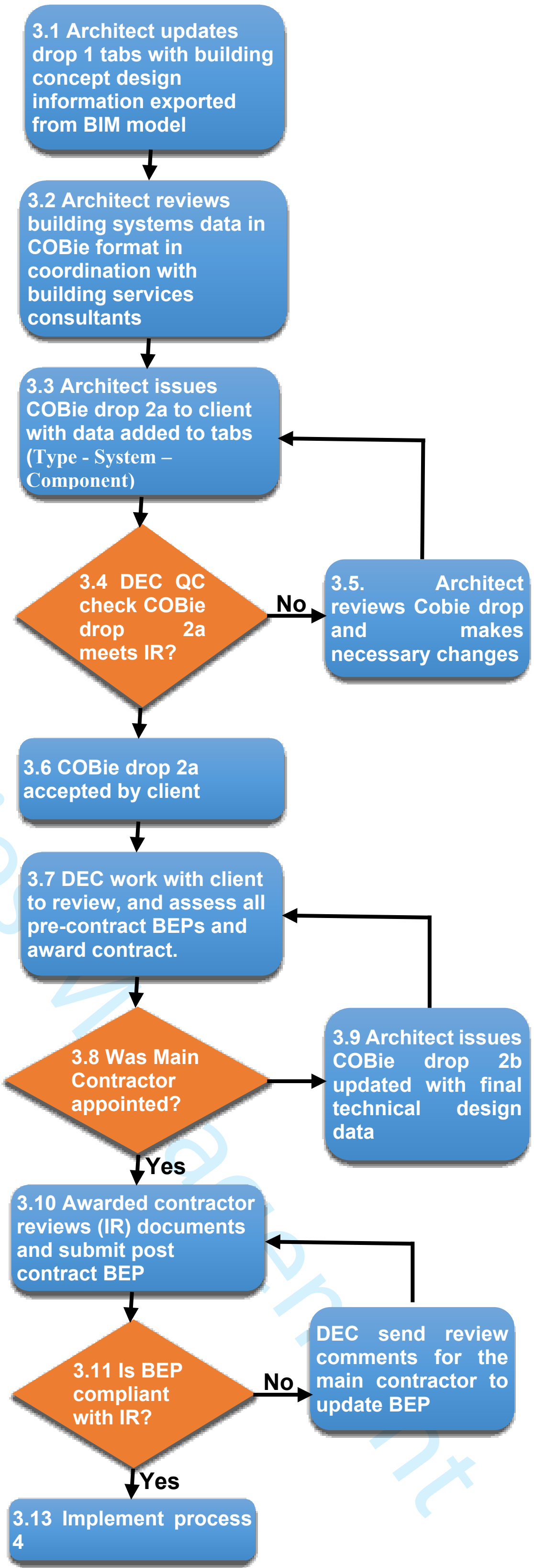

*Figure 9: LEAD process 3 - RIBA stage 2,3,4*

Until the end of the technical design phase, the architect should act as the curator of the BIM model and the COBie data. Once the main construction contractor is appointed, the architect should have a BIM coordination meeting to present the information requirements documents and the COBie management plan to the main contractor. From this point on in the project, the main contractor will take the lead in the BIM model and the COBie management implementation. Once the main contractor submits the post-contract BIM Execution Plan (BEP), DEC will undertake a comprehensive review of this document to ensure that all required components of COBie are in place. These components include, for example, the naming convention of assets (Hitchcock et al., 2017), the classification standard that will be followed, and the list of assets that will be included and so on. If DEC finds any missing piece of data, then an iterative process of review and proposal of missing data takes place until the BEP is complete to a satisfactory standard in compliance with ISO19650, PAS 1192-3, BS1192-4 and NBIMS V3.0. This will make sure that the scope of COBie data is clear and will eliminate any future confusion about the data delivery throughout the project (Hoeber and Daan, 2016).

**5.4 LEAD Process 4 - PMI Execution Phase:**

This process takes place during the construction phase, i.e. RIBA stage 5 (fig. 10). The process commences by a review of three components: the AIR, the COBie Management Plan, and "COBie drop 2b. This review must be done in collaboration between the DEC on behalf of the client FM team, the COBie lead from the architect side and the information manager of the main contractor. The contractor's Information Manager (IM) then appoints a COBie lead from each building subcontractor, and all the previous deliverables of COBie will be presented to all subcontractors gradually when appointed.

The main Contractor's IM then classifies the required COBie data in chunks and gives each subcontractor a list of COBie requirements that are related to their work. For example, an MEP subcontractor takes the MEP requirements of COBie, including all the attributes, systems and components that will be updated in COBie drop 2b and included in COBie drop three during the construction phase.  A series of meetings take place then throughout the construction phase between the architect, the main contractor's COBie lead and the subcontractors' COBie leads to update the COBie management plan, and review the COBie output from each subcontractor.

Once the plan is finalised, The COBie Lead from subcontractors will be responsible for providing COBie data. If a specific subcontractor is working with the BIM model such as an MEP subcontractor, the COBie lead from the subcontractor will feed the data in the BIM model. However, some sub-contractors will not work with BIM such as a floor finish subcontractor. In this case, the subcontractor's COBie lead will provide the required data to the main contractor's information manager to be included in the model or directly in the COBie file.  At this stage, it is the responsibility of the main contractor's Information manager to decide on how COBie file will be federated with information from subcontractors, and what technology will be used for that as per their finalised BIM Execution Plan. The output of this process is a partially complete COBie drop three which will be concluded by the end of the process.

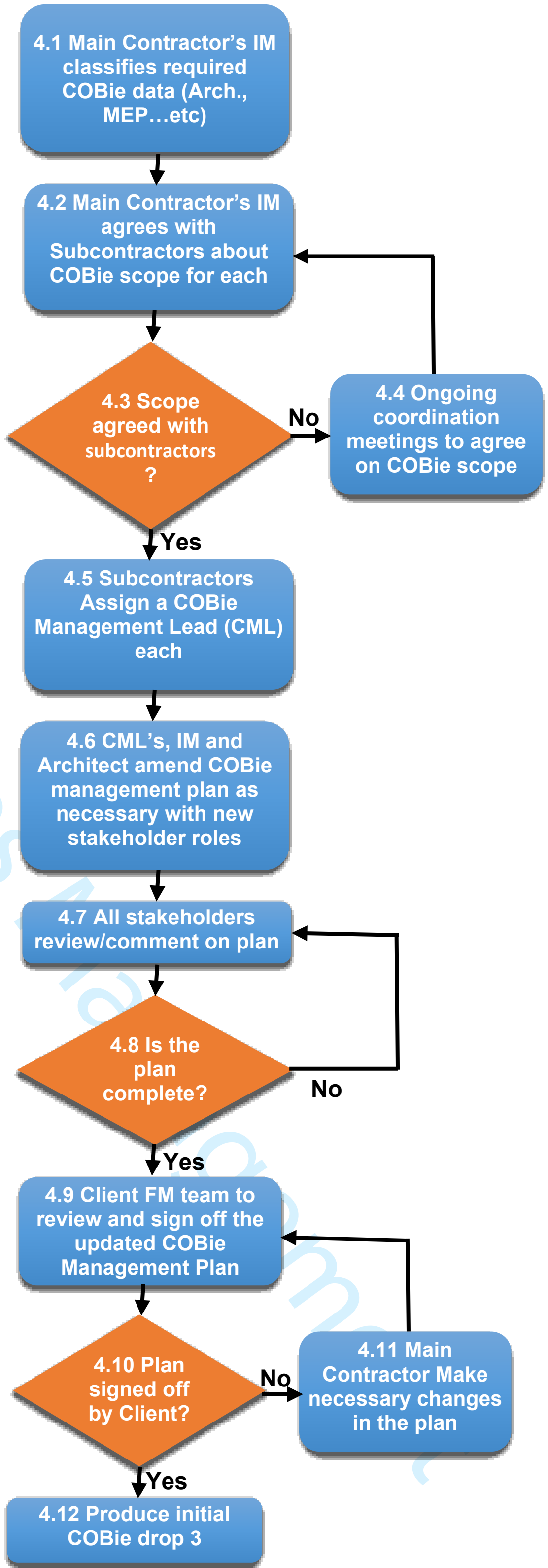

*Figure 10: LEAD process 4 - RIBA stage 5*

### 5.5 LEAD Process 5 – PMI Closeout Phase

This process takes place throughout RIBA stage 5 and 6, namely the construction and handover/close-out phases of building lifecycle (fig. 11). During this stage, the main construction contractor takes the lead in delivering the final COBie drop 3 in collaboration with the construction supply chain. The process starts by gathering all the BIM models from sub-contractors in the IFC format (Vanlande et al., 2008). The main contractor then federates the IFC models creating a fully coordinated model of the building; then a final quality check process takes place by the main contractor and the COBie Management Lead CML from the architect side to make sure all the components of the last COBie drop meets the requirements stipulated in the AIR document.

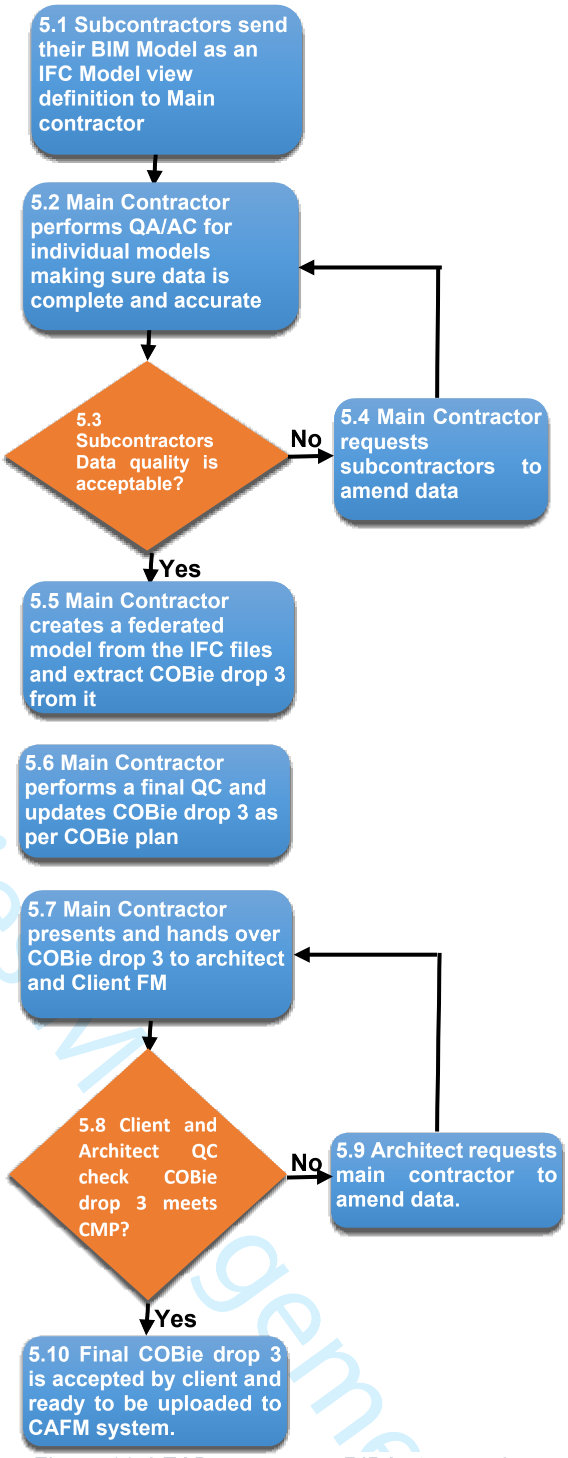

*Figure 11: LEAD process 5 - RIBA stage 5, 6*

For subcontractors who will be performing minor work and will not be using BIM model, they will provide their requested asset data for the main contractor's information manager who will be responsible of including this data in the BIM model, or entering it in the COBie file manually as illustrated earlier in process 4.

After the quality check by the main contractor, the final COBie drop will be submitted for approval by the client (Love et al., 2015). The DEC on behalf of the client, in turn, performs all acceptance and quality checks for the COBie drop and sends their feedback to the main contractor in case any final amendments are needed. Once the client accepts COBie drop three, the COBie drop three will then be uploaded to the CAFM system for the start of the operation phase of the building lifecycle.

In some CAFM systems, a mapping process is required between COBie parameters and its associated fields in the CAFM system database. If this is the case, the DEC will perform this mapping process then upload the COBie data in the CAFM system. By the end of RIBA stage 6, which is the closeout phase, all the BIM data using COBie standard should be successfully uploaded and ready for the operation phase of the building lifecycle.

### 6.0 Conclusion and future work.

Building Information Modelling (BIM) has outstanding potential in the facility and asset management industry. However, the focus of BIM implementation in research and industry is mainly focused on design and construction. Several reasons are contributing to the lack of BIM adoption as a standardised way of asset data exchange between design and construction phases and operation phase of the building lifecycle. These reasons include Lack of the skillset in the asset management industry to provide adequate information requirements to support operations and the ambiguity of the process of asset data exchange for the design and construction supply chain. Furthermore, the slow base of technology development in BIM authoring software, and also in Computer-Aided Facility Management (CAFM) systems that are required to achieve simple and smooth asset data flow throughout the building lifecycle.

The Lifecycle Asset Data Exchange model (LEAD) proposed in this study provided a clear process for asset data exchange for all building stakeholders. The model guides the asset data exchange process in each stage of the building lifecycle, making it clear for the supply chain: Who will manage asset data? When? And to what quality standard? LEAD model is based on COBie standard because it is the only asset data exchange standard currently used in the industry. However, COBie as a standard has many problems including its rigid and complex structure, the lack of practical value of some of its elements/tabs, and absence of technology support for some of its contents. More work needs to be done in updating COBie standard from policy makers, industry bodies, and BIM technology developers to make it more accessible and easier to use for the industry. Otherwise, the standard in its ci=current structure will not be the future of the asset data exchange in the Architecture, Engineering and Construction and Operations (AECO) industry. LEAD model is a step in the direction of updating COBie standard and clarifying its processes. However further research should be done to develop standardised asset lists that can be used as a base of information requirements to support asset management and make it easier for facility and asset managers to identify and manage information requirements throughout the building lifecycle. Another area of future research could be in investigating other ways of exporting BIM asset data from BIM authoring software to make it easier, faster and less costly for the supply chain to re-use this asset data in the operation phase.

**Acknowledgments:**
The authors would like to thank Bouygues UK and Bouygues Energies and Services (BYES) for providing the funding, and enabling access to the BIM documentation that formed the core for this research. Also thanks to the several industry partners who provided the data for the projects that were analysed as a part of this study. Finally, special thanks to the Constructing Excellence Asset Management Theme Group for collaborating and providing invaluable feedback about the developed model.

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## Appendix 1: Glossary of Terms

**AIR:** Asset Information requirements

**BEP:** BIM execution Plan

**CAFM:** Computer Aided Facility Management

**COBie:** Construction Operation Building Information Exchange

**CML:** COBie Management Lead

**CMP:** COBie Management Plan

**DEC:** Digital Engineering Consultant

**EIR:** Exchange Information Requirements

**GDP:** Gross Domestic Product

**IFC:** Industry Foundation Classes

**IM:** Information Manager

**OIR:** Organisation Information Requirements

**RIBA:** Royal Institute of British Architects

## Appendix 2: Focus Group - Information sheet

In collaboration with Bouygues UK, and Bouygues Energy and Services as industry partners, a process was developed that governs data flow between all building stakeholders i.e. (Client/FM team, Architect, Design Consultants, Main Contractor, and Sub Contractors). The process is called Lifecycle exchange Asset data (LEAD). It is based on COBie standard but it can be used with any project-specific information requirements schema. The process model includes sub-processes of data management for each of the RIBA stages. This process is developed as part of the PhD research project titled: *"A sociotechnical analysis of BIM as an enabler of digital transformation in facility management organisations: Towards an automated lifecycle asset management based on the Internet of Things (IoT)"*. The main aim of this research is to investigate asset lifecycle data management using BIM for all pre-operation phases in building lifecycle and enhance this data with real-time indicators about asset performance in the operation phase using the Internet of Things (IoT). A first workshop was held which was internal to Bouygues UK to discuss and validate the process, in which we had useful discussion and feedback. This focus group with the CE Asset Management Theme Group aims to initiate a wider discussion with industry about the proposed process framework.

During the workshop, the researcher will present the conceptual framework of the proposed process which is already a published research paper at the "Journal of Facility Management", and then present the actual technical process that outlines data-flow in alignment with RIBA stages clarifying the role of each stakeholder; what data to be provided, when and to what quality standards.

After the presentation, we will open a discussion about the process, and collect feedback that will be used to refine the process, and will be included in the second technical research paper, with acknowledgment to the CE asset management group members.

**Appendix 3: Focus Group - Consent Form**

**Research project title:** *"A sociotechnical analysis of BIM as an enabler of digital transformation in facility management organisations: Towards an automated lifecycle asset management based on the Internet of Things (IoT)"*

**Researcher name:**

**Supervisors:**

**Declaration:**

I agree to participate in the (LEAD Process Model Review focus group) to aid with the PhD research titled: (Building Information Modelling (BIM) adoption in facility management organisations: Towards a connected asset lifecycle data management based on the Internet of Things (IoT).

This is to confirm that:

- I have read the information sheet related to this focus group and understand the aims of the project.
- I am aware of the topics to be discussed in the focus group.
- I am fully aware that I will remain anonymous throughout data reported and that I have the right to leave the focus group at any point.
- I am fully aware that data collected will be stored securely, safely and in accordance with Data Collection Act (1998).
- I am fully aware that I am not obliged to answer any question, but that I do so at my own free will.
- I agree to have the focus group recorded, so it can be transcribed after the focus group is held.
- I understand that the information I have submitted will be published. Confidentiality and anonymity will be maintained and it will not be possible to identify me from any publications.
- I am aware that I can make any reasonable changes to this consent form.

**Printed Name:**

**Participants Signature:** **Date:**

**Researcher's Signature:** **Date:**

**Appendix 4: Focus Group - Facilitator Questions**

- Drawing upon your own knowledge and expertise, is there any area in the process model that might be non-compliant with a current known BIM standard or a process?
    - Please explain why non-compliance might be an issue?
    - Is there an example that comes to mind that might demonstrate such non-compliance?
- Are there any aspects that are missing, which you would consider a vital addition to the model that we ought to focus on exploring?
    - We're open to your thoughts in terms of people, process and/or technology.
- In terms of stakeholders participating in COBie management and their roles, do you think the process has captured the stakeholder's roles accurately? Or would you suggest any changes?
- In terms of data requirements, and technology considerations, how can this process be improved? (Software, data standards used, …) (Technical aspect)
- In terms of timing of COBie deliverables. If any, what amendments are required to improve the process? Would you recommend any fundamental changes that would improve the process, coordination between stakeholders, timing of data delivery schedule, etc.? (Process aspect)
- What kind of potential for impact do you think this process might deliver in practice?
- Any further thoughts on how to improve the model?