Facility Management Handover - Equipment Maintenance MVD:
Lessons Learned and Requirements

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Executive Summary

This report documents lessons learned from the use of national adaptations of the 2009 buildingSMART international (bSI) Basic Facility Management (FM) Handover Model View Definition (MVD). From these lessons learned, the direction and scope of a new bSI project FM - Handover - Equipment Maintenance MVD has initially been established. Following a full review of these requirements by our international team of sponsoring owners, designers, contractors, and facility managers, this report may be updated.

Included in this document are lessons learned gained from the application of national implementations of the original 2009 MVD. These lessons learned are based upon experience from use on real world projects which has helped identify changes needed to effectively deliver building equipment maintenance data from designers, contractors, contractors, and suppliers, on every building project regardless of the size or available technology.

The intended audience for this document includes: (1) potential software implementors of the future FM Handover - Equipment Maintenance MVD, and (2) those who may have produced, evaluated, or consumed deliverables based on national or local implementations of the bSI Basic FM Handover MVD.

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Version Control

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3.0	05-Mar-2021	Incorporated comments from bSI Business Office

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1.   INTRODUCTION

In 2007, a process-based specification identified the sources of information needed to support the operations, maintenance, and asset management of a building project (East 2007). Figure 1 illustrates the process for a traditional design-bid-build contract identifying the party who creates the required data and who should be responsible to capture and deliver that information.
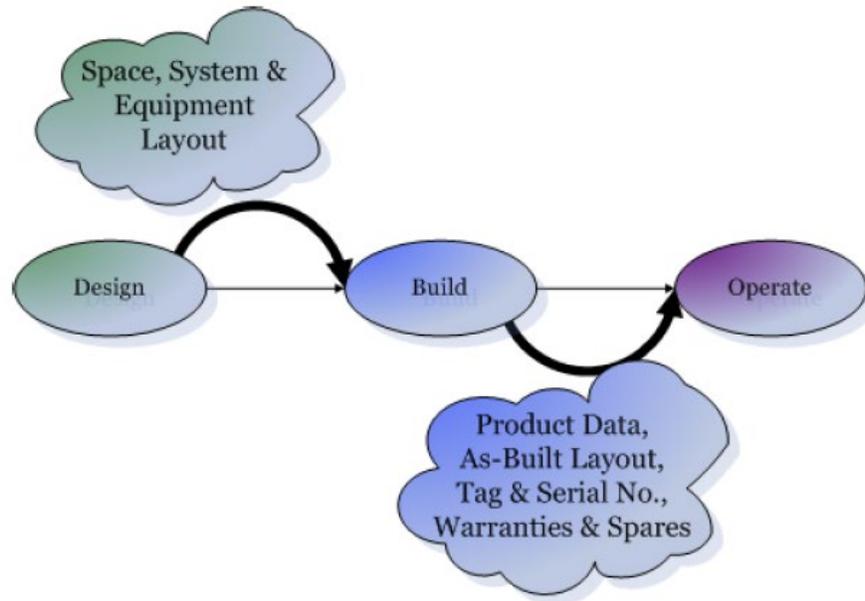

Figure 1 Basic Construction Handover Schematic Diagram (East 2007)

To ensure compatibility with the relevant International Standard (ISO 16739), a formal Industry Foundation Class (IFC) 2x3, Model View Definition (MVD) was produced. This schema and the resulting updates to the spreadsheet presentation of this schema was adopted as an official IFC MVD called the "Basic FM (Facility Management) Handover MVD" (bSI 2009). With the advent of IFC 4.1, an additional update to the MVD was completed for the Construction Engineering Research Laboratory by the chair of the bSI Model Support Group who documented his work in the bSI mvdXML format in 2013. That updated MVD, listed as COBie 2.4 in the bSI Model View Definition database (bSI 2020), was published under copyright in the National BIM Standard - United States, Version 3.0 with attribution to buildingSMART International.

From 2008-2014, over 30 vendors implemented the FM Handover MVD in their software products. The largest single group of software directly supported facility management or facility asset management. Many software systems supporting the aggregation of equipment maintenance data during construction also participated. Of the 30 products, four were design authoring tools.

These implementations were required to satisfy pre-defined tests, referred to as "Challenges" not "certifications," consisted of live public demonstration of what was required to be working commercial software. Initial events were conducted allowing software providers to use data of their own choosing. The next set of events required software providers to demonstrate the delivery of data on one small building (the "Duplex Apartment"). The last of these events required vendors to demonstrate how information in design authoring tools could be used to create drawings and information deliverables from the same underlying model. These tests used a much larger model

(the "Medical/Dental Clinic") that was a publicly released redacted set of medical/dental clinic project drawings and operations and maintenance manuals. A report identifying these three sets of models was also published by the Construction Engineering Research Laboratory (Johnson 2011).

Several lessons were learned from these implementations. For example, the inclusion of spatial "blocking and stacking" models was to demonstrate an architectural programming workflow (East 2008). An extensive set of product type property sets were included to support the "Specifiers Properties information exchange" project (East 2011a). From the UK, government-mandated information related to health and safety impacts, and environmental compliance issues were added to the scope of the MVD without identifying the sources and uses of that information.

To emphasize the lack of agreement regarding these four undocumented extensions, not one of the 30 software vendors were tested for their ability to produce or consume specific product properties. A recent survey of bSI construction handover certified professionals has indicated that they are not aware of a one project in which these four extensions were delivered.

In addition to the four undocumented extensions, the requirements for three other areas were insufficiently defined. Instead of providing requirements that could be easily interpreted, the specification relied on users to understand meaning and application of IFC object models related to systems, assemblies, and connections. As a result, only a general organization of systems, connections, and assemblies was provided. While some owners forced the manual creation of system data, information about connections and assemblies are rarely used, and inconsistently used on real projects.

What can be learned from these efforts is that the core of equipment and maintenance data defined in the original Basic FM Handover MVD (bSI 2009), have proven to be useful in practice and the requirement for designers and builders to deliver equipment maintenance data has been included in contracts for procuring projects throughout the world.

This world-wide interest in the Basic FM Handover MVD (bSI 2009) and the need to internationally resolve issues described later in this report, have led the bSI to undertake international leadership to develop an international standard for delivering facility maintenance handover data. The topic in this report is, of course, only one of several types of construction data needed by facility managers. A recent bSI Strategy Presentation, documented bSI's international leadership role in addressing non-geometric delivery of many types of FM and FM Handover data sets (Ouellette 2020).

2.   INFORMATION DELIVERY MANUAL

While some readers may be familiar with the original justification of the Basic FM Handover MVD, originally published by the Construction Engineering Research Laboratory on the IAI International Users Group Information Delivery Manual (IDM) repository. An updated IDM was designed to support business process simulation by explicitly defining value-added and non-value-added activities (Fallon 2013). While discussion of the 2013 IDM documentation is outside the scope of this report, a general discussion is provided below.

2.1. FACILITY MANAGER'S BUSINESS CASE

The now famous picture of the facility manager inspecting such documents was published as part of that pilot test (Figure 2). It is noteworthy that the pictured facility manager identified several types of problems he encountered when trying to use the information. First, the needed information was difficult to find. For example, two days were required to find information needed to order a replacement for a large piece of industrial equipment. Second, is that in many cases the needed information may not have been delivered at all. The facility manager cited a common situation where buildings would have to be taken out of service for several days to replace a large piece of heating or cooling equipment. Had correct equipment information been provided, the building outage could have been limited to the replacement of a part over the course of a few hours. Finally, additional costs are added since replacement equipment is typically over specified since information about the original design and construction selection criteria was not available.

Figure 2 Traditional Handover Documents (East 2008b)

Facility owners attempted to improve information delivery by specifying the format of information to be delivered. The resulting handover document sets were created by scanning traditional construction handover documents. Of course, a technological approach did little to solve the problem of late and inaccurate information. All the electronic handover files reviewed by the lead author of this report were found to contain images, not searchable text. Some of the files provided had errors indicating that those producing the deliverable had never attempted to open their own

files. The implication also meant the contents of these 5,000 page image files were never tested to determine if the pictures provided accurately represented the recently completed project.

A final concern for the delivery of electronic documents was identified when visiting the facility management office of another large US government organization. In that case, the set of discs for all their facilities was kept in a box on the desk of someone who had retired from the organization. The implication here was that a single disc with electronic versions of documents is less available than the boxes shown in Figure 2.

Beyond the case studies and site visits conducted by the author of this report, other researchers have benchmarked the impact of poor-quality maintenance information. The first of these studies documents the daily activities of maintenance technicians (Lee 2009). By shadowing maintenance technicians throughout their workday, to identify the root-causes of facility management inefficiencies (Figure 3). Based on the real-world data collected, the author calculated that 20% of the time taken by maintenance staff can be directly traced to lack of information. Providing accurate and timely as-built/as-operated building data can therefore be the equivalent of getting one new productive day of work per week from each maintenance crew.

In 2013, it was discovered that half of maintenance technicians studied had insufficient information to complete their work (Liu 2013). Even when FM staff participated in the formulation of construction contract requirements to specify needed deliverables, the following basic information was regularly unavailable to tradespeople:

- Equipment Manufacturers and Model Numbers
- Equipment Operations and Maintenance Manuals
- Spare Part Information
- Accurate As-Built Plans
- HVAC, Plumbing, Electrical, and Security system information
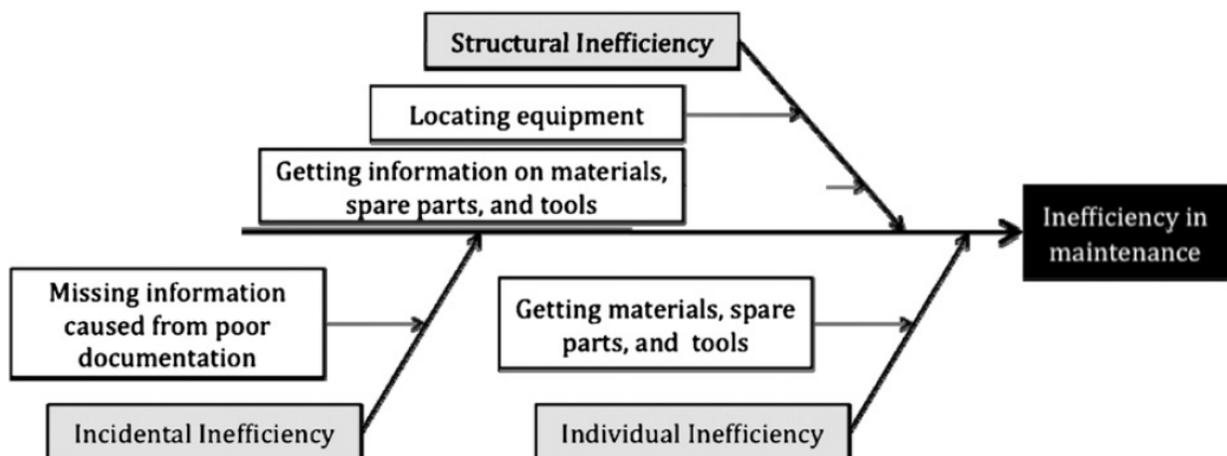
Figure 3 Root-Cause Diagram of Inefficiency in Maintenance (Lee 2009)

It might be surprising then, that any person who has produced or used construction handover documents knows the information provided within cannot be trusted. Interviews with representatives from one well known US federal government facility owner have documented how one of the first paid tasks for every facility management contractor is to conduct a building equipment survey. Taken alone, large owners with deep pockets may consider a duplication of

effort on the order of $100,000 per project. However, consider the cost across this owner's portfolio. The same duplicated effort has been identified as a widespread practice in the UK.

One unpublished benchmark of a major US engineering university estimated that over 40% of the equipment requiring regular maintenance was not captured in maintenance management systems. When maintenance technicians were asked how the building systems continued in operation, the technicians answered that since they have worked in these buildings for as many as three decades, they were familiar with all the changes that had taken place. Consider the implication for that facility management office upon the eminent retirement of such experienced technical staff.

To illustrate the cost of recollecting existing information about building equipment, one US federal facility owner was required to issue a $40,000,000 contract to re-survey every mechanical room in every building on every installation. The reason why? An incompatibility in versions of their regional and enterprise maintenance management software.

Having established that improving the timeliness and quality of traditionally created construction handover documentation could provide an estimated 20% increase in the efficiency of maintenance technicians, decrease the start-up cost of maintenance activities, and eliminate the ongoing impact of losing experienced personnel, let us turn to consider why the information is currently delivered in this way.

In addition to the costs to collect building information, there is also a significant cost associated with loading such information into maintenance management and other needed systems. In one example, three person-years of overtime were needed to load basic equipment information into a commercial maintenance management system. Responding to these non-reimbursable costs, some large portfolio owners have created proprietary information handover specifications.

Proprietary information handover specifications do give the appearance of providing a solution to the data entry problem. However, over time proprietary solutions cannot provide a cost-effective alternative to the adoption of open standards. To comply with proprietary specifications, contractors must specialize (or hire specialty subcontractors) to fulfill niche requirements. Thus, costs are driven up and competition is reduced. Proprietary approaches are not likely to be adapted by other organizational stakeholders who also need to capture as-built building information. Thus, each organizational "stovepipe" continues to run its own proprietary solutions. A comparison of databases at any such organizations demonstrates the lack basic agreement between organizational elements on the number, naming, tenancy, and function of rooms of buildings on every campus or installation.

Finally, proprietary information handover specifications result in standard operating procedures that lock-in such requirements and increases an organization's reluctance to adopt less costly and more efficient solutions. Unless there is higher level oversight of such matters within an organization it is also unlikely that implementing offices will deviate for many decades. Why? Because of the misinterpretation of the sunk costs, the bureaucratic inertia of internal teams backing such proprietary systems, and the pressure of commercial software vendors who maintain proprietary standards as barriers to competition.

2.2. CONSTRUCTION MANAGER'S BUSINESS CASE

Traditionally, either by contract, convention, or regulation construction handover data is created at the fiscal completion of a building project. The information, delivered in paper boxes and folders, three-ring binders, or equivalent PDF files, is compiled by a person who has typically never visited the site and may not be able to distinguish between information available across tens of thousands of contractual communications, forms, and documents.

In most cases, the capture of project data is accompanied by manual surveys to collect equipment manufacturer names and model numbers. This process is known not to yield reliable data because many pieces of equipment will, at the end of the job, be covered by insulation, installed above ceiling panels, or physically occluded from view. One study of traditional construction handover data demonstrated that almost half of the information provided was incomplete or inaccurate because it would not have been possible to collect the cited information due to physical obstruction or coverings (Lin 2018).

To the outside observer it can be surprising to learn that everyone involved in these end of project activities privately knows that their work is inaccurate and inefficient. The surprise is even strong when one considers that the practice of construction is the practical application of engineering and trade knowledge and skill to create a facility which conforms to the scope and quality standards defined by contract, convention, or regulation. Those who help manage time, cost, and scope on projects have significant personal experience knowing the steps needed to reduce waste and increase profit. The rapid self-acceptance of 3-D clash detection allowing the off-site prefabrication formerly stick-built building systems is a case in point. Construction companies want to be efficient because reduced cost and time makes them money.

Nowhere else in the execution of a construction project is such a wasteful set of activities permitted. One estimate of the cost of producing traditional operations and maintenance manuals or their electronic equivalents is shown in Figure 4 (FFC 1995). The top line in Figure 4 identifies the expected cost of operations and maintenance manuals for complex projects, such as hospitals and research labs. The bottom line in Figure 4 illustrates the expected cost for less complex projects, such school or residential facilities. While individual projects can afford to include the cost of producing inaccurate information from a general overhead account, the real question to be asked is the value of wasted human labor. This waste is not only in creating inaccurate information that is rarely, if ever used, it is also in the need for those coming later in the project to repeatedly recapture, lose, and recapture the information each time it is needed.

Direct discussion with construction company executives and managers about improving the quality of construction handover information demonstrates a reluctance to change since improved construction handover efficiencies are said to decrease the fees billed to the owner. Set programs such as undergraduate internships have been created to produce construction handover documents in some firms. One company with such a program indicated that they could not change the content of the internship since, "what else would they do?"

In addition to construction handover information being of poor quality, the timeliness of the delivery of the information is problematic. That is because the owner has typically taken occupancy of the building and is responsible for efficiently operating and maintaining the building months prior to the project's fiscal completion. Several problems result. First is that equipment warranty

terms are likely to be violated as the facility manager is not aware of the contractor completed and future required maintenance work. Next, when that maintenance work is accomplished, those performing the work may have no references as to the type of equipment installed and manufacturer authorized maintenance requirements. Finally, facility management staff must try to take information received from the maintenance staff and integrate that information into their maintenance management program. One facility manager reported having a paid CADD operator assigned to taking hand-drawn sketches of systems made by maintenance technicians who do not have access to information when it is needed.
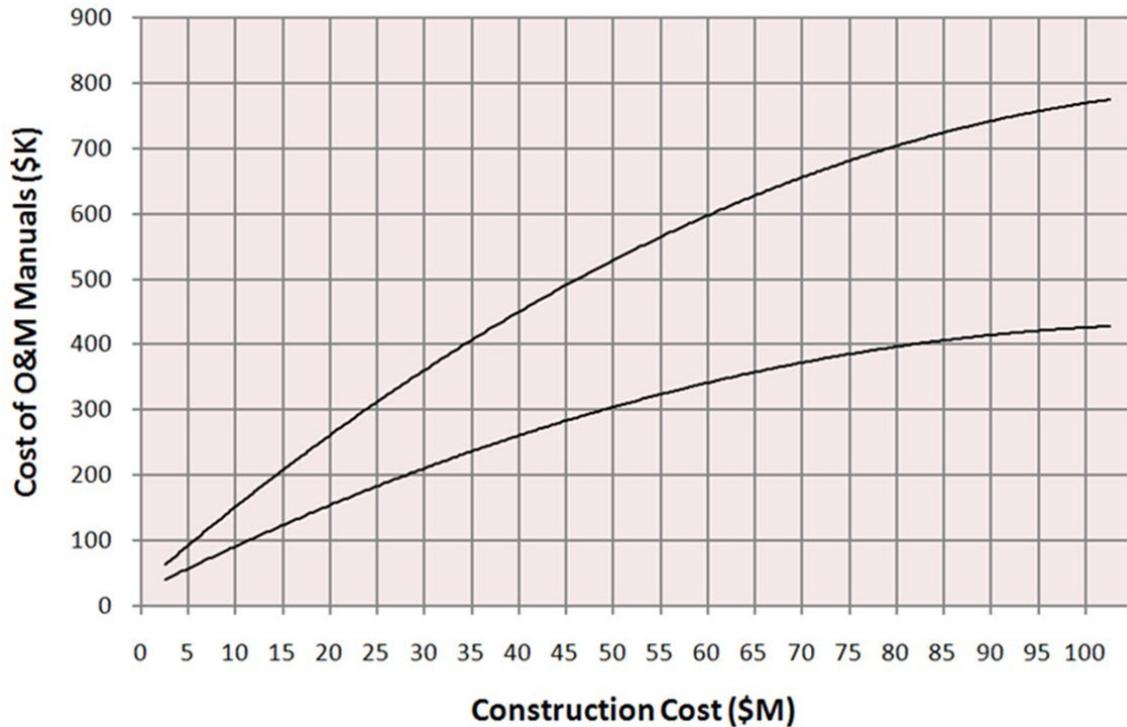
Figure 4 Cost of O&M Manuals (FFC 1995)

For owners with established building portfolios, anecdotal evidence shows a significant discrepancy between basic building facts such as the number of major pieces of equipment in a building. Interviews with one university facility management official described a benchmarking study that was conducted to identify the extent of this missing information. It was discovered that 40% of the equipment in existing buildings surveyed was not identified in the owners' maintenance logs or asset inventories.

Not only does the facility maintenance department have a problem establishing ground-truth, but other organizational elements do as well. One US state agency interested in improving facility maintenance information quickly realized that they had twelve different legacy information technology systems that each contained legacy building information that was likely in conflict. Two separate reviews of large US government data systems also revealed significant gaps in both the number, categorization of assets, and ownership of fixed building assets.

Following a 2010 presentation about construction handover to the US Construction Industry Institute's annual conference, the president of that organization flatly stated, "We know we have a problem." However, nothing was said about how the matter would be rectified.

Some owners and even national governments have attempted to solve the construction handover data problem by issuing mandates for the delivery of data in specific standards. For example, the US national specification was mandated in 2013 as part of British Standard PAS 1192-2:2013 based on the UK's 2012 as the UK BIM Level II requirement. Without training and testing programs for owners and contractors, the result of the mandate has been inconsistent because most UK contractors simply add a handover data requirement to the list of end-of-job tasks to subcontract. A survey of UK contractors demonstrated that while 100% of contractors delivered electronic O&M manuals, half were required to deliver paper O&M manuals, and 40% were required to deliver nationally specified handover data as well (Matarnech 2018). Clearly the UK BIM rollout did not demonstrate that given correct data, electronic and paper O&M manuals could be eliminated.

For there to be any chance of resolving these issues, careful identification of causes and effects must be accomplished. Lack of technology is not a cause. Technology, such as open standards, may facilitate the answer but technology alone cannot solve systemic problems. Forcing top-down technology solutions is not effective without an underlying change to process. As has been demonstrated by the UK BIM Level II experiment, leaving the matter to the building industry to solve by themselves has also not been effective.

The problems being faced are widespread across all types of buildings, all sizes of owners and contractors. The causes of problems behind the construction handover are the result of the traditional design and construction management processes and systems that we all use daily. Until those systems of production are changed, we will not see widespread improvement. Supporting a Herculean effort is only sustainable for one or two pilot projects. After the pilot project is complete, business returns to normal. After a government mandate changes, the entire endeavor can be ignored. Worse yet is the desire by some to create a new effort, with a new high-tech name, that does nothing to solve the systemic process issues causing poor quality facility management handover data.

The questions that must be answered to discover how to improve the delivery of construction handover data are: "Where does this data come from? and Who is responsible to create it?"

2.3. PROCESS MODELS

The development of rigorous process-based business case documentation, that would be used to document the facility management handover - equipment maintenance process, began from a need to document the general benefits predicted from the use of any information technology (East 2011b). A key concept in this evolution was derived from the Total Quality Management movement. Many current readers will recognize the current incarnation of TQM as "Lean Construction." Essential to being "lean" is to fully document the work people currently undertake. By documenting those processes the analyst may identify activities that add to the value of the overall product, and those that do not (Trischler 1996). Activities that contribute to this value, might include installing a pump. Such activities are called "value-added" activities. Activities that do not directly contribute to the value of the project, such as surveying the project at the end of the job to transcribe already known information about a pump's model number, do not add value to the project. Such activities are called "non-value-added" activities. Creating business process models that differentiate between value-added and non-value-added activities allows those interested in improving profit and quality to redesign processes to specifically eliminate such waste.

From the start of the construction handover data exchange project in 2007, the goal of the project has been to capture construction handover data when it is first created, by the party contractually obligated to provide that information. In 2010, every process creating or updating building equipment information was documented (East 2010a) (Figure 5).

In each step in Figure 5, the common name for the activity was identified along with the party who is most often required to create or update that information. For example, the party with design responsibility provides a list of each type and count of equipment in that discipline. Such information is documented on contractually required design drawings in the form of equipment schedules. Floor plan drawings for each discipline also document the number and location of each specific instance of every type of manufactured piece of building equipment or product.

Once the list of equipment has been identified, the products must be purchased. Creating the list of products that are planned to be purchased is the responsibility of the contractor or subcontractor who is contracted to complete the scope of work in a bid package or specification section. Such information today is delivered to the project team as a submittal. The submittal is seen as a contractual obligation of the purchaser to provide products meeting technical requirements.

For traditional building procurements the "submittal register" is first a list of documentation requirements. In many design-build projects the submittal register is the list of the documents that have been provided. Regardless of the building's procurement method, consider that the complete list of equipment and the expected product manufacturer and model number to be installed is known before that section of the building has been constructed.

If that information is available before anything is even built, why is it that we must pay to conduct a site survey at the end of a project and then hire someone to recollect submittal data and bind those PDF files into construction handover deliverables. Isn't the primary information needed by the facility manager available before the building is built? If this is the case, would not capturing the information when it is created be more effective than the end-of-project mechanical room survey?

To directly quantify non-value-added activities present in the creation of construction handover data, business process models were created for each life cycle process where building equipment information is added or updated (Figure 6). This set of process models went beyond the typical Business Process Modeling Notation used for bSI Information Delivery Manual. The goal of these models was to document information exchange requirements in each process and predict the impact of having the information may make on the process itself (Fallon 2013).

By providing information about the size and complexity of a project and relevant labor rates, a quantitative model was created from these process models to predict the impact of changes to that process. The resulting business process calculator delivers this prediction. At each step of the life-cycle process, the waste reduction possible can be predicted if accurate information was available.

While a quantification of the construction handover business case had been requested early on, the production of a calculator to measure the current non-value-added activities to help reengineer each process, has been largely ignored. A primary reason for the lack of objective change management in the construction industry (even when the change is publicly acknowledged to increase profitability, improve the quality and timeliness of outcomes, and provide greater owner satisfaction) is the Information Technology (IT) departments technology decision making process.

Project Phase	Contracting Phase	Contracted Exchanges	OmniClass Table 31–Phase	OmniClass Table 34–Actor	OmniClass Table 32-Service
Criteria	Criteria	Facility Criteria	not provided	34-21 14 00 Owner	not provided
		Discipline Specifications	not provided	34-21 14 00 Owner	not provided
Initiation	Definition	Project Definition	31-10 11 14 Description Phase	34-21 14 00 Owner	32-11 11 15 Development
Requirement	Programming	Space Program	31-10 14 21 Programming Phase	34-21 17 00 Planner	32-11 14 24 Programming
		Product Program	31-10 14 21 Programming Phase	34-21 17 00 Planner	32-11 14 24 Programming
Design	Documents	Design Early	31-20 10 14 Conceptual Design	34-25 21 00 Architect	32-11 14 00 Designing
		Design Schematic	31-20 10 17 Schematic Design	34-25 21 00 Architect	32-11 14 00 Designing
		Design Coordinated	31-20 20 11 Detailed Design	34-25 21 00 Architect	32-11 14 00 Designing
		Design Issue	31-20 20 21 Engineering Analysis	34-25 21 00 Architect	32-11 14 00 Designing
	Specification	Product Type Template	31-20 20 24/37/31 Product, Material Equipment Selection	34-25 41 00 Specifier	32-11 45 00 Specifying
		Product Template	31-20 20 24/37/31 Product, Material Equipment Selection	34-25 41 00 Specifier	32-11 45 00 Specifying
Construction	Bidding	Bid Issue	31-30 30 21 Proposal Preparation	34-35 14 00 Contractor	32-21 21 11 Bidding
	Selection	Product Type Selection	31-40 20 27 Submittal Processing	34-35 14 00 Contractor	32-21 00 00 Execution Services
		System Layout	31-40 20 27 Submittal Processing	34-35 14 00 Contractor	32-21 00 00 Execution Services
	Installation	Product Installation	31-40 40 11 17 Installation	34-35 14 00 Contractor	32-21 17 41 Installing
		Product Inspection	31-40 40 91 17 Evaluation	34-35 14 00 Contractor	32-21 17 00 Constructing
		Construction Issue	31-40 40 91 17 Evaluation	34-21 14 00 Owner	32-21 17 00 Constructing
	Commissioning	Product Type Parts	31-40 50 00 Commissioning	34-35 17 00 Sub Contractor	32-21 00 00 Execution Services
		Product Type Warranty	31-40 50 00 Commissioning	34-35 17 00 Sub Contractor	32-21 00 00 Execution Services
		Product Type Maintenance	31-40 50 00 Commissioning	34-35 17 00 Sub Contractor	32-21 00 00 Execution Services
		System Operation	31-40 50 00 Commissioning	34-35 17 00 Sub Contractor	32-21 00 00 Execution Services
O & M	O & M	Space Condition	31-50 20 21 Facility Inspection	34-41 11 00 Facility Manager	32-41 51 11 Inspecting
		Product Parts Re-placement	31-50 20 11 Facility Operation	34-41 21 00 Maintenance	32-41 47 11 11 Facility Repairing
		Space Occupancy	31-50 10 17 Use	34-41 11 00 Facility Manager	32-41 47 21 Space Planning
		Space Activity Renovation	31-50 30 11 Facility Renovation	34-41 11 00 Facility Manager	32-41 47 21 Space Planning
Repurpose	Programming	Remodel	31-50 30 14 Facility Remodeling	34-41 11 00 Facility Manager	32-41 47 11 17 Facility Upgrading
		Expand	31-50 30 17 Facility Expansion	34-41 11 00 Facility Manager	32-41 47 11 17 Facility Upgrading
		Demolish	31-60 35 00 Recycling	34-41 11 00 Facility Manager	32-41 47 11 17 Facility Upgrading

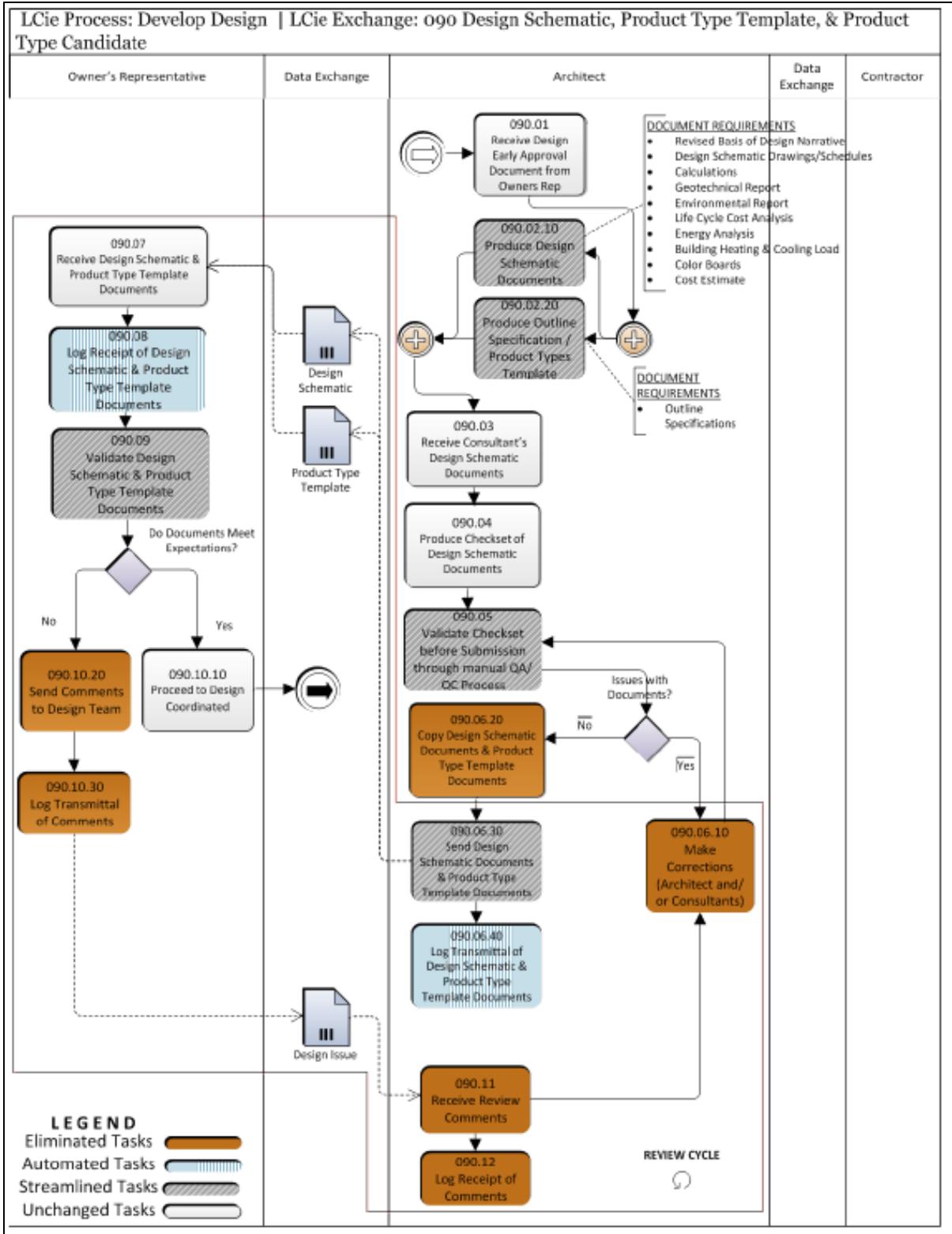Figure 5 Contracted Information Exchanges (East 2010)

Figure 6 Business Process Model Example (Fallon 2013)

Without understanding and acting on transformation of underlying business processes, information technology decisions today are based on "what software do our competitors use." This drive forces projects into applying whatever general capability can be provided by commercial software products. Such decision making can only see such decision making as "putting the cart before the horse." The result is that back-office IT integration has not been a driver of increased construction industry profitability. Something that has been understood and implemented in every other industrial market sector.

2.4. EXCHANGE REQUIREMENTS

The business process models documenting the sources and uses of construction handover information not only differentiated between value-added and non-value-added activities, these models also directly identified the information needed to make those improvements.

From the "data exchange" columns in enhanced business process models, Figure 6 (Fallon 2013), the content and timing of contracted information exchanges were derived. The set of diagrams taken together are the first published examples of a complete life cycle picture of building equipment maintenance information exchange requirements. Although the enhanced business process models were based on a traditional design-bid-build procurement process, experience has demonstrated that the same information is also exchanged in other building procurement methods. The only difference between these methods is in the allocation of responsibility to produce the information, typically shifting initial data creation from the traditional design responsibility to subcontractors.

One of the key goals of the bSI FM Handover - Equipment Maintenance project is to confirm these exchange requirements and their responsibility. Documentation of our industry's lessons learned, to date are described later in this report.

The need to document information exchanged during a business process is not unique to the FM Handover - Equipment Maintenance MVD. There is now an international agreement that such documentation is needed in every aspect of our construction industry. A main goal of ISO 19650 is to define information exchange requirements beyond owner information delivery specifications to include information exchanged throughout the project. Only after there is an agreement about the information to be exchanged at each point, can there be an objectively testable specification for that information. Applications of bSI's Basic FM Handover MVD were the first specification to demonstrate such an objectively testable deliverable.

Only when there is an objectively testable specification of exchange requirements can payment be withheld for non-compliance. Perhaps it is understanding that objectively testable information delivery specifications can result in non-payment for performance, that has design and construction companies reluctant to deliver complaint data sets. Luckily, some companies have begun to recognize that their ability to meet objectively defined and testable information delivery specifications provides an advantage, both in the marketplace and in their own profitability.

2.5. SIMULATING THE PROCESS

During the testing process it was recognized self-selected and small models (e.g. Duplex Apartment) were insufficient to ensure proper data import and/or export testing (Johnson 2011).

In addition, the large building (e.g. Medical/Dental Clinic) was too large to be provide a representative test across all disciplines. What was needed was a complete building, of reasonable size, whose content could be fully modeled to provide simulate the contribution of all design disciplines and construction subcontractors.

To move the conversation from a business process model into artifacts closer to design and construction practice, a new test model was created by an international team of designers, contractors, and technologists. The goal of the "East Dormitory Project" is to simulate the delivery of a complete set of building information through planning, early design, construction documents, and construction handover (Prairie 2021). The Dormitory is a small two-story building with single residential spaces on the second floor and shared kitchen, recreation, and storage space on the first floor, Figure 7. It should be noted that this project is a simulated application of a real set of standard design documents made publicly available to support this specific project.

The East Dormitory was created as a test bed upon which many people can test and evaluate ideas about the processes of delivering building information at different process stages. These files have been used to investigate the exact setup, implementation, export, and quality control checking needed when using commercial design BIM software (East 2016b)(East 2017).

These files have also been used to simulate processes within design and construction ignored by national derivations of the 2009 bSI Basic FM Handover MVD. During the simulated design process, models have been created for all significant disciplines. The resulting data files can be used to demonstrate why every design consultant needs to configure and test their own data. Rules for merging design data from multiple disciplines have also been tested with these files. The result of that activity has demonstrated the lack of commercial software testing for products claiming to merge open standard data.

Although the design models were created using BIM-based design authoring tools, many specialized design disciplines use Computer Aided Design and Drafting (CADD) or simply technical drawing software (such as Visio). While the East Dormitory Project files demonstrate the ease with which data files conforming to national specifications of the bSI 2009 Basic FM Handover MVD can be accomplished, they can also be used to demonstrate the process of collating, merging, and testing data from smaller design consultancies who do not have the advantage of BIM-based design authoring tools.

Information created by those with a design responsibility, from the point of view of the Basic FM Handover MVD, identifies the required spaces and expected equipment. During construction that outline is "filled in" by contractors and subcontractors. The East Dormitory Project files have also demonstrated how to capture and collate information between contractors and subcontractors prior to creating real-time as-built equipment information. Identifying the information required in the process of creating and using FM Handover information should be a key point of any ISO 19650 implementation.

A common step in every construction administration process is the production and distribution of submittal documents identifying the specific products to be purchased. In some cases, these products must be reviewed, and possibly approved, by designers. In most cases, however, if the identified product can meet its design requirements, then several different products could be selected based on cost, time, and quality criteria relevant to the individual contractor or subcontractor.

Figure 7 East Dormitory Project Cross-Section (Prairie 2021)

Information from the product selection process is the first and most critical set of construction handover data created during construction. From the design point of view, this is "filling in the outline" of scheduled building equipment. Such information is created by administrative personnel who simultaneously work on many projects for many different clients. As the information systems across hundreds of suppliers and contract partners who must be managed are necessarily proprietary, these decisions are today documented using a variety of different types of forms. In most cases, the forms used also differ for each project party. An example data-driven product selection form, shown in Figure 8, demonstrates the authorship of design and construction content. The subcontractor provides information found in yellow form boxes . This type of data-driven form can be generated from the design or construction data set directly.

The ability to capture construction handover data by those who create submittals, in lieu of the traditional "wait until the end of the project and hire it out" method, has been dubbed Lean Handover™ (East 2019). In this approach, there is no need to hire someone at the end of a project to collect handover data and no need to visit the site to identify manufacturer and model numbers. One simply must provide forms to capture the data when it is "naturally" created.

The Lean Handover™ approach allows project teams to collect construction handover data in real-time by those legally responsible to ensure that the data is correct. As that process unfolds, those who receive and use the data the context of a construction quality control process ensures the data is accurate. That is part of their existing job. No one needs to take on a new role to capture information that is already part of the construction administration process.

While this approach was clearly present in the original MVD (bSI 2009)(East 2013), those writing and bidding contracts that require handover data delivery have not understood the need to reengineer underlying business processes to collect data as it is created. Instead, most contractors are operating under an incorrect assumption there is a spreadsheet that must be loaded after the fact.

DATA-DRIVEN TRANSMITTAL FORM		DATE:	11-Jan-2019	TRANSMITTAL NO.:	23 57 10 - 01

SECTION 1. HEADER

TO:	Galliford Try		FROM:	Prairie Sky Consulting LLC
	(ATTN:John Ford)			
	C&I North Scotland, Shand House			
	Derbyshire, Matlock DE4 3AF UK			
	0752 222 7897			
	John.Ford@Gallifordtry.co.uk			

SECTION 2. SUBJECT

Project:	Four Dormitory Complex		Product Type:	Pr 60 60 96 Water heaters
ID:	East Dormitory			

SECTION 3. ACTION

Action Reqd.:	Contractor Certified
Comments:	O&M Plan for Electric Hot Water Heater - By File Reference
Action:	Initial
Submitted By:	Bill East

		Date Submitted:	25-Feb-19

SECTION 4. PRODUCT TYPES AND O&M DATA (one sub-section required per product type)

Section 4.1	Action:	Product Type:	Manufacturer	Model Number	Supplier
	Initial	Water Heater (Water Heater_380 L)	AO Smith	DEN-120 Series 110	AO Smith - Supply

Attached Data Files	
Maintenance Manual:	AOSmith-322055.pdf
Replacements Parts List:	AOSmith-322055.pdf
Warranty Certificate:	AOSmith-322055.pdf
Safety Instructions:	n/a
Troubleshooting Instructions	n/a

Lean Handover(TM) Templates	(c)2016-9 Prairie Sky Consulting	www.prairieskyconsulting.com

Figure 8 Data Capturing Transmittal Form Example (Prairie 2020)

Beyond the direct demonstration of creating, capturing, checking, merging, and delivering equipment operations and maintenance data, the East Dormitory Project data set is also being used to demonstrate the delivery of similar but related handover information. For example, members of the United States Institute of Building Documentation (USIBD), supported a project to show how to incorporate jobsite photography as linked "documents" associated with spaces and installed equipment. Another project being conducted at University of Florida is investigating why the original bSI Basic FM Handover MVD, and derived national specifications, are insufficient to support architectural programming.

3.   LESSONS LEARNED

Despite the extensive research, development, and testing that went into the development of an IFC MVD supporting the open-standard delivery of construction handover data, the practical understanding and impact of national specifications based on the bSI Facility Management Handover - Basic MVD have failed to live up to the expected benefits.

What has been discovered during the first dozen years in which handover data has been required as a contract deliverable on projects, is that the current specification requires significant "data wrangling" by those preparing or using related deliverables. A root cause for needing to manually "tweak" deliverables is the inconsistent application of data typing in national specifications as well as the original Basic FM Handover MVD itself. For example, non-printing characters in manually created handover data provided by subcontractors are not prohibited. As a result, what visually appears to be the same information, may not be the same to the computer systems checking the file or consuming the data.

The first lesson learned is the need to directly address this issue by specifying low-level character sets that shall be required for each language. In addition, reserved characters that have different meanings in different language settings will also need to be defined proscribed. A clear example of this situation is the "decimal point" character used to represent decimals numbers such as one and one half. In English, this number would be presented as "1.5". However, other countries use the comma character",", as the delimiter. Thus, the set of allowed numeric characters for most languages would be the encoding for characters zero through nine, and one symbol identifying the delimiter. Once character sets have been mapped participants in international projects may use these character mappings to significantly reduce the need for "data wrangling."

The next issue to be addressed is the random addition of scope by local (national) implementations of the original Basic FM Handover MVD.

In four instances, use cases were added to local (national) specifications without the required business cases and exchange requirements documentation. In another instance the original specification has been force-fitted to support infrastructure projects to the confusion of all involved. Given the importance of refocusing the FM Handover - Equipment Maintenance MVD to deliver a core set of non-geometric building equipment data, each of these, and related scope, topics are discussed in subsections below.

Another issue to be addressed with the original Basic FM Handover MVD, has been to focus technical documentation exclusively for a technical audience. For example, the original MVD limited the delivery of maintenance information only to those items not on an "exclusion list." While this is the most correct technical presentation of what should be included in a compliant deliverable, such a presentation was not understood by those performing the work. As a result, the FM Handover - Equipment Maintenance project's documentation, will explicitly identify allowed objects and include a software implementation requirement to provide a default setting limiting information to that set of allowed objects.

Unfortunately, local (national) implementations have also been inconsistent in referencing the underlying IFC object schema. This resulted in the additional need to define and translate objects already defined in ISO 16739. The FM Handover - Equipment Maintenance project will refocus object and semantic names derived directly from the IFC Schema.

The next issue to be addressed, has been the reluctance to act on predicted beneficial business processes improvements that would provide real-time building equipment visibility through the entire project. The perverse incentive keeping these inefficiencies from being methodically rooted out was expressed by one construction company executive in 2016, "Why would I want to reduce my fees. To do so would reduce my profit."

Another important lesson learned from use on real world projects demonstrates that without a change to underlying incentives, there will be no change to process. This bSI project will provide an Implementor's Guide to demonstrate how owners can "nudge" improved processes within the context of current construction administration practice. These examples will be created using the current East Dormitory test bed project (Prairie 2020).

3.1. NARROWED SCOPE REQUIRED

In the initial report on construction handover requirements (East 2007) three sets of information were found to be present in traditional handover documentation. Equipment maintenance information was one of these sets and the place where the FM Handover - Base MVD was focused. Operational data found in traditional handover documentation included systems manuals and troubleshooting procedures. Fiscal asset accounting information was found in a much smaller but essential component of traditional handover data.

A review of the practical use of local (national) adaptations of the original FM Handover - Basic MVD, have been conducted in the academic literature and have demonstrated that not only have the expected benefits not been obtained by contractors and owners, but in many instances, there have been increased costs. For example, one case study project encountered difficulties with implementing national handover standards using commercial software that claimed compliance (Pishada-Borzorgi 2018). Unfortunately for this project the action taken was not to require qualified staff and pre-test exchange protocols using small sample files but to hire staff to implement proprietary exchange requirements.

A more detailed review of national implementations of the FM Handover - Basic MVD has demonstrated scope over-reach with respect to asset management (Patacs 2015). In this paper, requirements for service life planning outlined in ISO 15686-1 were compared to the required national deliverables. While information corresponding to the list of installed equipment in a building, referred to as an asset register, was largely covered, information needed to evaluate the total cost of ownership based on service life planning was largely missing.

Implementers of the original MVD also identified missing information related to the management of replacement parts inventories (East 2012). While the original specification contains information related to the list of parts, an entire class of data related to needed quantities and reorder cycles is not present.

Another lesson learned with respect to scope has been that despite the original aspirational goals that prove, over time, beyond the ability of software to fully implement and practitioners to fully deliver. The new name for the requirements addressed in this document and the related project is, therefore, focused directly on the one of the original three goals of the FM Handover - Basic MVD, building equipment maintenance.

To emphasize the need to solve specific problems correctly, bSI has outlined a strategy which can directly support and address many questions of "handover" between builders and owners. The scope of that strategy will be described in separate communications from bSI.

3.2. PROCESS FOCUS REQUIRED

During a review of construction contractors, it was learned that the MVD was not easily adaptable to changing information during the project (Abdirad 2019). In this case, the project team was unaware that the purpose of the original FM Handover - Basic MVD was not to be the historical repository for the project but an information exchange format. Such a format implemented within commercial process-based commercial software, would be able to display the entire history of all the equipment in the building from basis of design through to construction handover.

Implementations of the FM Handover - Basic MVD focused on two primary deliverables. One consolidated design deliverable and one consolidated construction handover deliverable. Unfortunately, a review of the related business process models (Fallon 2013) demonstrates that information is not created at the end of design or construction and somehow delivered. Information must be captured during the process of design and construction.

The FM Handover - Equipment Maintenance MVD will directly address questions of process by returning to key business processes and providing examples and implementation guidance. During design, for example there is a need for mechanical disciplines to incorporate architectural information for the resulting mechanical equipment to be placed within the correct architectural space. There is also a need to make small changes to equipment schedules to allow data from design authoring tools to directly produce the required design deliverables (Bose 2020).

During construction there are several times when the prime contractor and subcontractors each update information that should be provided from designers. These stages include submittals, changed submittals, installation, start-up, testing, commissioning, and operation prior to handover. At each of these stages team members at many different levels, and working for different companies, may have a requirement to contribute new data or change existing information. Although these processes are well understood the identification of the information exchanges needed are hiding in plain sight as illustrated in the recent description of the Lean Handover™ approach (East 2018).

The lesson to be learned for the FM Handover - Equipment Maintenance MVD project is to provide as much focus on the workflows necessary to capture the required information during design and construction as was previously paid on the evaluation of data collected at the end of the construction stage.

3.3.   REMOVE ARCHITECTURAL PROGRAMMING

Geometry representations for boxes, lines, and points were forced within the original scope (East 2007) to demonstrate the potential for creating a separate MVD related to architectural programming (East 2008a). The resulting "coordinate" data required in the US/UK national specification for building handover was said to support consideration of building massing, in particular "blocking and stacking" diagrams. Unfortunately, the analysis of the requirements, beyond room data properties, was not demonstrated. Had there been a demonstration, then it would have been obvious that any spatial shape other than a rectangular box could not be represented.

The lesson to be learned is the need to clearly distinguish between non-geometric data and geometric data. The FM Handover - Equipment Maintenance MVD will remove the requirement to deliver coordinate information and instead clearly specify the linkage between non-geometric information and geometric models.

3.4.   REMOVE FIXED PROPERTIES

Understanding the need to include the means to capture product properties, prompted an additional set of research projects aimed at creating a list of Specifiers Properties information exchange (SPie) (East 2010b, 2011a). The project was ultimately joined by large manufacturers,

such as General Electric, as well as professional and trade associations, such as the Construction Specification Institute, Specifications Consultants in Independent Practice, and the National Electrical Manufacturers Association. The work was deemed so important by the Construction Specification Institute, that in 2009 they issued their first "Excellence in Construction Information," award to the project's leaders. Ultimately, however, many attempts to create a local (national) infrastructure for the exchange of building product data were not successful due to US national construction industry sector structure.

Despite the lack of success in establishing a path by which manufacturers could directly provide product properties that could be validated by the traditional construction administration process, local (national) implementations a fixed set of product properties were assigned for every type of product delivered.

After more than a decade's use of these local (national) implementations, it has been clearly established that, in general, it is not possible, at this time, for owners to force the transcription of non-contractually required product properties into construction handover data deliverables. In addition, the fixed list of properties cannot be generally identified across all product classes.

Today, there is at least one European and one Scandinavian example of frameworks created by a large product supplier and a major healthcare owner, where electronic equipment product data is available. The properties provided are not, however, the same across all product types.

There are several lessons learned regarding product property sets to be incorporated into the FM Handover - Equipment Maintenance MVD. First, there is not one set of product properties applicable to all products. Thus, the generic set of properties that are current identified in the US national specification should be removed. Second, the updated MVD must be flexible enough to allow the delivery and testing provided (or required) product properties for specific classes of products or equipment. This flexibility can be provided to allow those who pay for the data to be transcribed to capture and test the needed information.

Finally, should product property definitions be identified in the buildingSMART Data Dictionary (bSDD), the flexibility built into the FM Handover - Equipment Maintenance MVD and later testing program may, demonstrate how to deliver transactional non-geometric product information from manufacturers and validate that information against defined product property requirements.

3.5. INDEPENDENTLY CONSIDER HEALTH AND SAFETY

The lesson learned pertaining to the efforts in the UK to add health and safety deliverable requirements to the original MVD is that it has failed to achieve its intended effect. While these requirements are clearly important to those working in every building, obtaining the information cannot be solved by technical specification knowingly ignored by project team members.

The lesson to be learned in this instance is that these requirements should be taken up by a future project that reflects the international communities' consensus.

3.6. INDEPENDENTLY CONSIDER ENVIRONMENTAL IMPACTS

The lesson learned pertaining to the efforts in the UK to add environmental impacts is to acknowledge the failure of this national specifications to achieve its intended effect. While these

requirements are obviously important, they cannot be solved by creating a technical specification that is knowingly ignored by project team members.

The lesson to be learned in this instance is that these requirements should be taken up by a future project that reflects the international communities' consensus.

3.7. SPECIFY ALLOWED ASSET TYPES

A very important lesson learned has been the incorrect and widespread assumption that every element in a design is relevant to the capture of equipment maintenance. Prior attempts to create a list of every IFC object type that must be excluded as an "inverse" specification, while more technically correct, did little to address the noted incorrect and widespread misunderstanding.

As a result, the FM Handover - Equipment Maintenance MVD will provide the list of allowed asset types, as well as the list of excluded asset types. One example of an included asset type is the IFC Entity "IfcPump". Clearly pumps are a class of building equipment that have maintenance requirements, thus can be delivered through the FM Handover - Equipment Maintenance MVD.

One example of an excluded asset type is the IFC Entity is "IfcDistributionFlowElement." This IFC object includes physical building elements such as ducts, pipes, wires. Clearly these products are not individually identified manufactured products that have model and serial numbers. Nor do such products typically have scheduled maintenance requirements in the same way that pumps, fans, and other such unitary building elements require for efficient operation.

3.8. SUPPORT OVERALL BUILDING MAINTENANCE

Experience from real world projects has also identified several types of excluded building objects that do have regular preventative maintenance requirements. Such elements are typically assemblies of parts or layered materials, such as curtain walls or roofing. The FM Handover - Equipment Maintenance MVD will support a practical accommodation to deliver maintenance requirements for assembly- or material-based building assets.

In addition to the maintenance requirements, there are also bulk materials provided to the owner at the end of the project. Not all these materials can be directly tied to manufactured equipment. Examples of such contractor-provided handover materials are extra boxes of suspended ceiling, carpet, ceramic tile, or cleaning supplies.

To support consolidated delivery of maintenance and on-site spare parts information for all types of products in the building, the FM Handover - Equipment Maintenance MVD has learned its lesson and will allow a linkage between maintenance tasks and parts at the building, floor, space, and system.

3.9. REJECT OUT OF SCOPE APPLICATIONS

The issue of scope creep also exists in the attempted application of building equipment maintenance specification to projects that are not buildings. One of the important implications of having a bSI-based project, is the potential to reduce the applications of the FM Handover - Equipment Maintenance MVD in out-of-scope domains. That does not, of course, mean that other domains, such as infrastructure projects, do not have maintenance requirements. They do, of

course! What this does mean is that such requirements must be defined in the context of infrastructure projects - not building projects. In fact, there is ongoing discussion at bSI with teams interested in infrastructure maintenance requirements.

3.10.   PROVIDE LIFE CYCLE EXAMPLE

A key lesson has been the need to provide and use example models of a reasonable size and scope. The first test model (Duplex Apartment) attempted to use toy projects. Use of simple such models resulted in implementations that were not representative of problems encountered on full scale projects. Testing the same software on larger projects caused the software to crash.

The second test model (Medical/Dental Clinic) was a larger project developed from publicly released redacted drawings and operations and maintenance manuals for a real project (Johnson 2011). The benefit of this larger model was that it could be used to test situations that were more like those encountered in practice. The weakness of such a large example was that Medical/Dental Clinic was tool larger to have ever software tested create a complete solution.

Since 2015, a new set of test files has been developed whose goal is to demonstrate the complete, life cycle set of building data for a project that can be developed in the same way, using the same software, used on much larger projects. Prairie Sky Consulting has organized the creation of this test model created with practicing designers, contractors, subcontractors, construction managers, and BIM technicians through. The project is one of four fictional residential buildings, the "East Dormitory," built adjacent to the campus of the University of Illinois, Champaign-Urbana campus (Prairie 2020).

The first information provided by the Dormitory project set illustrates the consolidated delivery of the complete design and construction handover data sets. A key lesson-learned from testing of national specifications was that such full file-exchange testing did little to help explain and motivate and support the capture, testing, and merging and of construction handover data during the process of design and construction. During design, issues related to merging data provided from each design consultant were not previously explored. During construction, support for the capture of building equipment data, along with manufacturers' files, or equipment installation information, along with subcontractor daily reports, were not tested. Furthermore, software claiming to merge and/or test files from multiple consultants or subcontractors was not tested.

In the FM Handover - Equipment Maintenance MVD project, we will extend the Dormitory project file set as needed to create testing files supporting the life cycle delivery of what could be a real-time set of as-built equipment information. During Phase 1A of this project, the initial set of example files will be produced.

3.11.   DEFINING TESTABLE SCOPE

Essential to the success of the original Basic FM Handover MVD was that from its first presentation the quality of information provided could be quantitatively assessed. The quality control procedure was formally defined as testing a deliverable for conformance with the internal consistency of data in a deliverable based on the technical specification (i.e. verification testing) and the evaluation of the data in the file to determine if the correct project data was provided (i.e. validation testing). It

should be noted that the definitions of these two stages are provided based on the ISO Quality Management standard (ISO 9001).

Testing software was used from the very first test of software implementations. The numeric criteria used to evaluate software implementations was based on the expected time required to correct information provided in the file that was inconsistent with the specification's technical requirements. These verification testing rules were eventually packaged in two software products produced by the U.S. Army, Corps of Engineers, Construction Engineer Research Laboratory. Testing software was publicly released from the U.S. Army, Corps of Engineers in 2015. Those working with spreadsheet-based data files could run a command-line checking tool (Bogen 2015a). Those working with STEP Physical File Formatted files could also run the same core checking routines against their files using a plugin to the open source BIMserver software (Bogen 2015b). Documentation for these two testing tools was published by Prairie Sky Consulting (East 2016c).

While bSI certified professionals know how to correct design and construction data to deliver test reports showing zero errors with every deliverable, in practice most deliverables are not tested in any way.

The key take away with respect to testing is that the FM Handover - Equipment Maintenance MVD project must provide for verification of testing software itself.. Today, there are several products that claim to test deliverables conformance with national specifications. In addition, software consuming conformant data also must verify data prior to loading.

While discussion of the specific requirements needed to verify FM Handover - Equipment Maintenance MVD data files will be addressed during Phase 2 of the project. It is enough, during this Phase 1 process, to document the need to test testing software.

3.12.   SOFTWARE TESTING PROCESS

The traditional role of bSI with respect to software testing has been to evaluate the delivery of information from design authoring software. While the delivery of the outline of building equipment required by the FM Handover - Equipment Maintenance MVD, is available during the design stage, most of the content of a complete deliverable is created by construction subcontractors. The use of the resulting complete deliverable is used in database software tools whose purpose is to schedule maintenance work orders.

Even when considering information provided from design authoring software, lessons learned have demonstrated the variety of approaches to creating the needed deliverables. Some design software vendors overload the required design data onto existing MVD's in STEP Physical File Format. However, not one of the independently tested software systems to date can consume data in this file format. To deliver the information required in the spreadsheet format that has been implemented by all but two of the over thirty products tested, a third-party application that was not developed or under the control of the STEP-providing products must be used. This situation has proven ineffective as the one 3rd party software claiming to be able to provide the capability to test, merge, and transform data into the physical file format needed downstream has not itself been tested.

There are several essential lessons learned to be gained from this experience. First, the delivery of data conforming to the FM Handover - Equipment Maintenance MVD during design must be

provided in spreadsheet format. Vendors cannot be forced to rely on 3rd party software that has not been tested. For most vendors, this would require the incorporation of format translation code within their own products.

The next lesson learned is that vendors have allowed users to make choices that conflict with the requirements of national specifications. While there may be many good reasons to use the basic capability provided by exporting a tabular listing of building information, that general capability must, in the case of the FM Handover - Equipment Maintenance MVD export have fixed default settings that keep users from making incorrect choices.

Next, all 3rd party vendors claiming to correctly merge and test FM Handover - Equipment Maintenance MVD data must themselves be tested.

During construction testing of "common data environments" that claim to support the capture of required data by contractors, subcontractors, and suppliers must be accomplished to evaluate both the transactional capture of information related to submittals, equipment, installation and testing and the delivery of the resulting full data set. By documenting these processes with example data and providing testing for the resulting exchanges, bSI may be able to help establish predicted process improvements.

Data conforming to the FM Handover - Equipment Maintenance MVD standard is ultimately used by maintenance management (and similar) software. Testing of this software cannot be done by evaluating the accuracy of the software's proprietary internal data representations but only by the case-by-case consideration of the expected and actual use of the information provided. What has been done to support national specification implementations during the previous dozen years of testing has been to allow downstream vendors to identify the objects found in the standard that fit within their products and then to run test scripts that validate the expected use of that information within the system. Lessons learned from this experience will be applied to create a new set of test scripts based on updated test models.

One final lesson learned is that waiting to test files by software intended as the final location for FM Handover - Equipment Maintenance MVD data often occurs after the completion of the construction contract. As a result, any changes needed must be done at additional cost by facility maintenance and information technology staff. The production of an independently created checking software tool that can be provided at limited cost to all project team members is essential. The current approach of using open-source software has not been widely adopted, therefore alternative approaches for independent software testing must be considered in this project.

3.13. REPEATABLE FIELD TESTING

Since 2015, testing of commercial software implementations has been accomplished by knowledgeable end-users, not representatives of the software companies themselves. Such testing has the benefit of (1) only allowing the use of existing commercial products, (2) having significantly less chance that specialized workflows and settings were used, but not documented, and (3) supporting the rapid updates to products to ensure full conformance with the standard.

Given the availability of a complete set of standard test models provided through this project, it is now possible to test that software is "made well" and "used well". The results of the software testing provide the detailed documentation needed to provide this demonstration.

Furthermore, the provision of these test models allows any project team member to repeat the tests to ensure that they can reproduce the results. The lesson learned is that testing on this project must be accomplished to support the repetition of local testing by users without direct knowledge of the project. Without this level of testing and the clear definition of all required software default settings, the practical impact of this project will remain an academic exercise.

Data conforming to the FM Handover - Equipment Maintenance MVD standard is ultimately used by maintenance management (and similar) software as well as many enterprise software systems present. A review of a regional transportation authority in the US identified 12 different systems that were required to consume data conforming to their national specification. It is also critical that those who would specify and obtain proper data understand how they may use test files to evaluate their own internal system's capabilities.

3.14. EDUCATION, QUALIFICATION, AND CERTIFICATION

NOTE: As the bSI FM Handover - Equipment Maintenance MVD project progresses from initial draft to Candidate Standard, bSI will be updating educational, qualification, and certification activities.

Educational curriculum for building equipment data handover was developed by a bSI subcommittee using requirements established by the bSI Professional Certification Committee. This curriculum identifies four levels of knowledge and outlines specific areas where bSI can assist. The requirements and process necessary to become a bSI Registered Training Provider at either the Foundation or Practitioner level, based on coverage of the identified curriculum, is also provided by bSI.

The bSI Foundation individual qualification process requires potential exam candidates to complete a specified course of study against known learning objectives. Following an additional minimum of three years of delivering handover data, candidates may then sit for the Practitioner exam.

3.15. SUPPORTING IMPLEMENTATION

In many instances those writing specifications are unfamiliar with the full impact of their requirements. While some specifications writers assume that because a requirement is in a contract the resulting deliverable will be delivered, that is not the case. In most cases, the qualifications of the project team and the penalty for non-compliance factor into any decision to meet, or not meet, a contract requirement, even when there is a national government mandate to provide that deliverable.

The bSI education, qualification and certification programs assist in the development of staff with demonstrated capabilities, the impact on construction contracts or business process convention leading to the effortless and streamlined production of the required information must be considered as part of this overall effort. Workshops lead by Registered Training Providers and Certified Professionals can support bSI Chapter's implementation planning. A key aspect of those workshops would be to ensure bSI Chapter personnel are qualified to translate documentation produced during this project.

3.16. PROVIDING BACKWARD COMPATIBILITY

Regardless of the changes made to the underlying FM Handover - Equipment Maintenance MVD, or its mapping between presentation formats, one key value that must be kept is to respect the dozen years of effort that went into software and enterprise-wide implementations based on the original Basic FM Handover MVD. While the lessons learned identified above clearly demonstrate the need for a simplified international standard, the project team shall provide a change management guide that directly identifies the mapping of the IFC 4.3 FM Handover - Equipment Maintenance MVD to IFC 2x3. In addition, changes to the spreadsheet mappings will be documented allowing software to refactor existing import and export routines.

3.17. CREATING VALIDATION FRAMEWORK

The complete set of rules to verify the internal integrity of each deliverable conforming to a complete or partial exchange of data under the FM Handover - Equipment Maintenance MVD will be fully documented in this project. That however is only part of the quality control activity required by those receiving a full or partial data set. It is quite possible that even though a technically correct set of data is provided, that the information is simply incorrect. Unless information is captured during the process of construction, then it is virtually guaranteed that the resulting data set will be invalid.

A key learning is that a framework for validation testing must also be provided and demonstrated in this project. The implementation of such a framework must be accomplished based on regional, country, or owner specifications. However, this project will put in place a framework, or approach, to document and enforce valid data exchanges. Examples of such requirements might include:

- "All major pieces of equipment must identify their installed model number and serial numbers."
- "All instances of a given type of equipment must have a property called 'Fan Belt Size'."
- "All rooms of a given type are required to have identified finishes."

There is no way for the computer to be able to interpret such a requirement without first translating these rules into a specific set of instructions. The instructions provided in this project's Implementation Guide will demonstrate how to specify the applicable building element subset and then how to document the test to be conducted. An example would be to select a specific IFC Object Type (or equivalent classification), and then to test if each instance of that type has a non-NULL value of "SerialNumber."

Moving from an ad-hoc set of validation rules that may or may not be checked across all applicable deliverables to a commonly defined and implement style of testing will be a major set forward to ensure that both the content and the quality of files claiming to conform to the FM Handover - Equipment Maintenance MVD can be objectively tested to the greatest extent possible.

Should work to collect, test, collate, merge, and deliver FM Handover - Equipment Maintenance MVD data be efficiently and accurately accomplished when that information is first created, our industry can move forward from relying on those coming years after the project is over to manually recreate data ignored by those who receive it. Instead, each party can test their work as that work is

being done for the first time. Corrections take place by the people who caused the error or change of information, when those changes take place.

If that sounds like real-time information quality control supporting design and construction back office work, you would not be wrong. Providing such capability to project teams represents a major step forward, and a new major market, in design, construction, and facility management software capability.

4. BUILDING FM DOMAIN REQUIREMENTS

During the initial stages of this project, bSI identified the opportunity to create a strategic alignment of several potential projects supporting the FM domain and those who "handover" information required to support the FM domain. This project, the FM Handover - Equipment Maintenance MVD, is the first such project to support this alignment. As was identified earlier in this report, however, this is not expected to be the only FM Handover MVD to be produced. Examples of other projects include, but are not limited to, the following:

> Spare Parts Inventory
> Industrial Control System Management
> Key Management
> Janitorial Requirements
> Fiscal Accounting
> Total Cost of Ownership
> Sustainability Program Compliance
> Environmental Program Compliance
> Health and Safety Program Compliance

To illustrate the difference between FM and FMH, within the context of building equipment maintenance, consider the following. If a building owner wants to hire a new facility management contractor of software, they need to have full and open access to the information about their existing building. Without a full and open accounting of list of as-maintained equipment, the list of completed work orders, and the number and types of on-site spare parts, the owner will be forever locked into one vendor. The cost of such a 'lock-in' can be considerable. In one example, a major US government owner with an extensive international portfolio was forced to pay approximately $40,000,000 to resurvey all equipment rooms on every campus. Why? Because the information in an earlier version of vendor's software was not compatible with the new enterprise version. Without the facility manager and building owner having open access to FM information, significant future hidden costs can be predicted.

Of course, during a construction (or renovation) project, there is only the need to provide the initial input to the ongoing FM process. In each of the possible future projects identified above, it will be the case that the building project team delivers information needed to start the FM process. From the point of view of building operators receiving as-built equipment information is the start, and not the end, of their jobs.

5. INFRASTRUCTURE DOMAIN MAINTENANCE

While the scope of the FM Handover - Equipment Maintenance MVD is building equipment maintenance, there are other types of projects for which regular maintenance, inspection, and

testing are required. A key aspect of the development of the requirements for the FM Handover - Equipment Maintenance MVD is to identify how and where projects other than buildings might be supported.

The first consideration that should be made is that infrastructure projects often contain buildings. In those cases, maintenance information about the equipment in each building can be defined and delivered through the FM Handover - Equipment Maintenance MVD.

The delivery of maintenance requirements pertaining to the horizontal elements of building projects, such as roads, pipes, or railways can, however, not be delivered in the same way as FM Handover - Equipment Maintenance. This is because references used to identify the location of items to be maintained on infrastructure projects do not conform to the spatial decomposition for buildings. To explain, consider the schematic diagram of the FM Handover - Basic MVD shown in Figure 9 (East 2013).
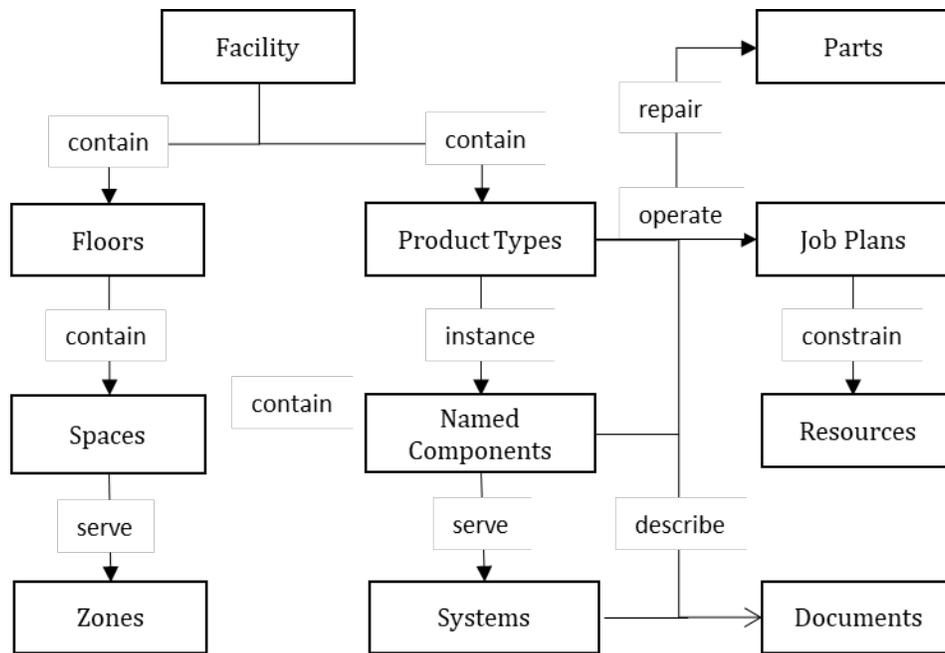
Figure 9 Handover Data Model (East 2013)

In reviewing the schematic diagram for the original FM Handover - Basic MVD, one can see that there are four elements to the right of the diagram that do apply to both building and infrastructure projects. These elements are parts, job plans, resources, and documents.

It is not the case, however, that the specification of this maintenance data can be linked, on infrastructure projects, to floors, spaces, and zones which are used to define buildings. These building items are provided in the MVD to ensure that someone can locate the room in which a maintainable component is found. For infrastructure projects, these "spatial decomposition" elements must be replaced with representations that match the context of the specific type of infrastructure project under consideration.

The middle tier of objects with the handover data model, Figure 9, are the objects that require maintenance. The list of objects within buildings can be clearly defined as building equipment elements. However, for infrastructure projects, the required elements may be individually

manufactured products, such as expansion joints or sensors, and project elements best described by material layers, such as roadway surfaces.

It is not the intention of this report to begin the process of adapting the FM Handover - Equipment Maintenance MVD to infrastructure projects. It is the intention, however, to identify the potential for shared representation, particularly when it comes to the establishment of a common spreadsheet mapping, for some of the elements shared by both vertical and horizontal projects.

The accommodation that is being made to support any changes to the "middle" of the resulting data file is to include a "ProjectDomain" field in the header of the file provided. This field can then be used to identify the later contents of the file as being to a specific IFC domain.

6.   COMMON IFC SPREADSHEET SERIALIZATION

An additional requirement for this project will be to consider the wider need for a common rule set for compressing needed elements within the IFC schema for viewing in spreadsheet formats. While changes introduced in the FM Handover - Equipment Maintenance MVD may take such considerations into account, the essential requirement for backward compatibility shall take precedence during this project.

7.   CONCLUSION

Equipment maintenance handover data requirements have been included in contracts for over a dozen years. During this time, academic studies and practitioners have provided extensive feedback demonstrating the need for bSI to update its original 2009 MVD (bSI 2009).

The new bSI project, FM Handover - Equipment Maintenance MVD, will re-establish a common international specification for the delivery of building equipment maintenance that will respond to this feedback and incorporates the lessons learned to date. The focus on process-based implementation, will support the real-time capture of building equipment information during design and construction. These efforts will assist commercial design and construction software to implement international standard complaint business processes that reduce costs and increase profits.

In the wider sense, bSI's strategic implementation of this project demonstrates how to define a series of non-geometric FM Handover data sets to initialize and harmonize long-term FM process requirements. In addition, the specification of a common IFC model compression rule set, developed under this project, supports a many more life cycle software implementations than are likely with traditional STEP-based specifications.

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