Consequences of Implementing the buildingSMART Data Dictionary

From a construction company’s perspective

Author: Erik Jönsson

Supervisor: Väino Tarandi, KTH
Maria Freeney, NCC
Construction Sverige AB

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<tr>
<td>Authors</td>
<td>Erik Jönsson</td>
</tr>
<tr>
<td>Department</td>
<td>Architectural Design and Construction Project Management</td>
</tr>
<tr>
<td>Master Thesis number</td>
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<tr>
<td>Supervisor</td>
<td>Väino Tarandi</td>
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Abstract

Building Information Modeling is a topic widely discussed in construction research today. It is a concept that potentially could benefit the construction industry in several different ways. Many believe that BIM will revolutionize the industry in the future. The buildingSMART data dictionary (bsDD) is an international standard developed by the neutral organization buildingSMART. It is a standard that defines the terminology surrounding BIM objects. Much research has been done on the potential benefits of BIM in general. However, no research has been made on the immediate consequences of an implementation of the buildingSMART data dictionary.

The purpose of this thesis is to determine how a property development and construction company, that already works with BIM in many of its projects, would be affected by an implementation of the bsDD. The possible consequences of bsDD implementation are mapped out and analyzed through a literature review. In addition to this, a simulation is conducted with the purpose of showing how object libraries can be created on an organizational level.

The findings of this thesis show that the consequences of a bsDD implementation can be summarized into three categories; technological, operational, and contractual consequences. The main consequences of the implementation would be that the employees would have to be provided education and continual support, through guidelines and internal BIM standards etc. The consequence with the largest impact, however, would be the task of creating an object library. This task is required since the bsDD does not have any Swedish content yet.
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**Abbreviations**

AEC – Architecture, Engineering and Construction

BCF – BIM Collaboration Format

BIM – Building Information Modelling. Definition is provided in chapter 3.2

BIMMI – BIM Maturity Index

bsDD – buildingSMART Data Dictionary

GUID – Globally Unique Identifier

IDM – Information Delivery Manual

IFC – Industry Foundation Classes

IFD – International Framework for Dictionaries. The old name of the bsDD

LOD – Level of Detail/ Level of Development

MVD – Model View Definitions

VDC – Virtual Design and Construction

2D – Two Dimensions

3D – Three Dimensions
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1 Introduction
This chapter explains why this master thesis is relevant and necessary for the construction industry. It also describes the purpose of this paper and how the scope of this research subject has been limited.

1.1 Background
Building Information Modeling is one of the most debated concepts in the construction industry today. Many believe that it will revolutionize the industry and increase its falling productivity in the future. BIM implementation has been slow in the industry in the past, but is now seriously starting to accelerate. In the UK and in Scandinavia public projects will be required to use BIM in a couple of years. This shows that there currently is a paradigm shift in motion. (McGraw Hill, 2014)

The buildingSMART Data Dictionary (bsDD) is an international standard that defines the terminology used in building information models (Bell et al. 2008). buildingSMART is an international and neutral organization that works with developing BIM and BIM standards (buildingSMART, no date-a). The bsDD makes information understandable for people of different nationalities and for different software applications. It is a standard that still is being developed, and it is not yet widely used. Therefore, the effects of implementing the bsDD are relatively unknown. This shows the relevance of this thesis.

NCC is one of northern Europe’s largest construction and property development companies. The company works with BIM in many projects, mostly when they construct apartment buildings. NCC has been working with BIM for many years and use it for many different tasks, e.g. visualization, quantity take-offs, analysis etc.

1.2 Purpose
The purpose of this thesis is to investigate what the possible consequences of implementing the bsDD are. This issue is analyzed through the perspective of NCC. How will they be affected by the implementation of the bsDD? The possible consequences are mapped out and then analyzed with the goal of providing an overview of how construction companies would be affected by implementing the bsDD.

In addition to this, a simulation is made to demonstrate how an object library can be created on an organizational level. In other words, the simulation shows how NCC could construct their own object library to fit their specific needs. This is a relevant addition to the purpose of this thesis since there is not yet any Swedish content in the bsDD. The simulation simply demonstrates how object libraries can be created and the possibilities that this brings.

1.3 Research Question
In addition to the purpose, a research question has been formulated in order to more explicitly show what this thesis aims to study.

- What would the consequences be for NCC if they chose to implement the buildingSMART Data Dictionary?
1.4 Limitations
To narrow the scope of this study certain limitations have been made. This has been necessary since the thesis is limited to 20 weeks of studying. Also, the purpose of the thesis is quite general, which means it would be impossible to comprehensively analyze all conceivable consequences of bsDD implementation in detail. This means that consequences discussed in the results of this paper are meant to give a general view of what kinds effects an implementation of the bsDD would bring.

The consequences that are discussed in this thesis have been limited to only include those that directly affect NCC’s organization. This means that subcontractors or other stakeholders in NCC’s projects may find other consequences than those stated in this paper. Also, the economic consequences of the implementation have been excluded from this thesis. In other words, how much money the implementation will cost and the economic benefits of using the bsDD will not be discussed in the thesis.
2 Method

This chapter describes the methods used in this thesis. This is included so that the reader will understand how the results in the thesis have been attained and to provide a basis for assessing the validity and reliability of the results.

2.1 Research Design

The research conducted in this thesis is qualitative and inductive. The first part of the study is based on a literature review. In this part, existing theories and research provide the foundation for exploring the consequences of an implementation of the bsDD. The literature review is based on scientific articles that explore the consequences of BIM implementation. The second part of the research is the simulation, which can be considered to be exploratory. The research conducted is qualitative since the results in this thesis are based on empirics and literature review, and since the purpose is to explain how one organization will be affected by a bsDD implementation.

2.2 Literature Review

For the purpose of finding the consequences of the bsDD implementation a literature review has been conducted. This has been done by analyzing scientific articles concerning BIM implementation. There are many articles on this subject, often including case studies from actual BIM implementation processes. However, there are no scientific articles concerning implementation of the bsDD specifically. It could be argued that this could have a negative effect on the reliability of the results of the literature review. However, these negative effects should be limited since the bsDD can be seen as a part of BIM. Therefore, the consequences of BIM implementation are closely related to the consequences of a bsDD implementation.

A literature review is suitable for this part of the thesis since this provides experience from BIM implementation from a scientific perspective. Also this shows the current state of the knowledge in this area. The results in chapter 5.2 are therefore derived from the literature review.

2.3 Simulation

The method used in the simulation part of the thesis is purely empirical. It is done as a demonstrative experiment to show how to create a BIM object library. This should provide a sufficiently appropriate basis for drawing some conclusions.

For the simulation, a classification system for door types was created in Microsoft Excel. The classification system, and also a BIM model, was then imported to the software bimsync. This makes it possible to apply the created classification system to the model. This provided the basis for the analysis.

2.4 Method Discussion

Since this thesis only discusses the possible consequences of bsDD implementation specifically for one construction company you could argue that the results are not very general. The results seen may only be relevant for this specific company. However, since the many articles on BIM implementation agree on certain consequences that BIM brings, the
consequences of the bsDD implementation should also be generalizable. Though some organizations may find that certain consequences end up being more dominant than others, bsDD implementers should find that the results of this paper, more or less, reflect the consequences that they should expect.

The literature review conducted is based on scientific articles on BIM implementation. This could possibly have a negative effect on the internal validity of this thesis. In other words, it is possible that the results of the literature review are only valid for BIM implementation and not bsDD implementation. The reason for conducting the literature review this way is because there is no research done on the immediate effects of an implementation of the bsDD. Since the bsDD is still being developed there are no scientific articles dedicated to studying its effects. However, since the bsDD can be seen as a part of BIM, the consequences of implementing them should not be that different from each other. Therefore the internal validity of the literature review should not be low, and it should not have a negative effect on the results.

The reliability of the study should be high since it is largely based on a literature review. Therefore, the data collected from the scientific articles will be the same for other people trying to repeat this study. The same study should pretty much yield the same results if it was conducted again.

In order to perform a successful and reliable simulation there are several factors that need to be taken into consideration. The most important thing when conducting a simulation is that its conditions must reflect the conditions of the actual process. The fundamental properties of the real context should be incorporated into the simulation scenario. If the conditions of the simulation are not realistic, the conclusions drawn from it is not representable.

The strength of conducting a simulation is the possibility to explore different phenomenon that have not yet been seen. This means that you can gain experience and draw conclusions from it in a controlled environment.
3 Theoretical Background

This chapter presents the theoretical background necessary for the purpose of this thesis. It describes some of the concepts linked to BIM and what some of the benefits and challenges of BIM are.

3.1 Introduction to BIM

Building Information Model or Building Information Modeling (BIM) is a topic that is widely discussed in the construction business today. It is a concept for managing building information before, during and after construction projects. As Jung and Joo (2011) put it, the purpose of BIM is to improve “construction effectiveness by better utilization of construction information systems in an integrated way.” Howard and Björk (2007) write that many researchers believe that having one single building information model could benefit construction projects in several different ways. They explain that having a single building information model, with the purpose of integrating as much data as possible, has been a goal for 30 years among researchers.

BIM is still a relatively new technology and it is still continually evolving. It is new in the sense that it hasn’t actually been used in practice on any large basis in the construction industry until a few years ago (McGraw Hill, 2014). This is despite the fact that much research has been done on the subject for many years. There are several reasons why BIM adoption in the industry has been slow. On reason is the industry’s unwillingness to change. Another is that the roles and responsibilities are often unclear. Another is that the distribution of the benefits of BIM is sometimes unclear, i.e. which actor should receive the benefits (Gu and London, 2010). BIM is now at a point where it is used more and more frequently in projects, and it will continue to grow more in the future (Succar et al., 2012). Succar (2009) claims that studies about the consequences and components of an information model, with properties similar to BIM, were made long before BIM emerged as a recognized term.

3.2 Definition

BIM technology will possibly completely change the construction industry in the future; due to the different positive effects that it has on performance and project cost (Azhar, 2011). However, it can cause some confusion due to the fact that the term is somewhat ambiguous. As Aranda-Mena et al. (2009) writes “for some, BIM is a software application; for others, it is a process for designing and documenting building information; And for others, it is a whole new approach to practise and advancing the profession which requires the implementation of new policies, contracts, and relationships amongst project stakeholders.” There are multiple definitions of what BIM actually is, most of which only have subtle differences. This shows the quick development that the BIM area has experienced during the past years, both academically and in the construction industry.

Penttilä (2006) defines BIM as processes and technologies that make up a method for digitally managing project data and the building design. Woo et al. (2010) describes BIM as “an intelligent, 3D, virtual building model that can be constructed digitally by containing all aspects of building information.” NBS (2013) defines BIM as a ”process for managing the information produced during a construction project, in a common format, from the earliest feasibility stage through design, construction, operation and finally demolition.”
The National BIM Standard’s Project Committee (2015) presents the following as the definition of BIM: “Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.” For clarity’s sake, this is the definition that will be used for the purposes of this paper.

3.3 How Does BIM Work?

BIM is essentially a digital representation of a building, which can be used as a way of collaborating and communicating as well as for several types of analyses. With the use of BIM technology a model is produced digitally. The purpose of the model is to support the project during all of its phases. The model supports intelligent tools for analysis and control. (Eastman et al., 2011) There are several key features that make BIM a potentially useful tool. The most apparent feature is naturally the three-dimensional visualization of the models. However, 3D modeling is only one part of BIM. Smart and structured databases as well as exchange of information in common formats are equally important parts of BIM. (NBS, 2013) Another key factor is increased collaboration between different disciplines within the industry. Engagement in the whole building life cycle should also improve with BIM. Taylor and Bernstein (2009) conclude that firms with increasing experience from BIM projects evolve from just visualization, to coordination, to analysis, and finally to also include supply-chain management.

BIM technology could potentially lead to very positive effects during the design phase, production phase, as well as for the Facility Management (Becerik-Gerber et al., 2012). The model supports tools for cost estimation, quantity takeoffs, clash control, performance simulations, etc. The time required for these types of tasks could significantly be reduced with the utilization of BIM. The precision can also be affected positively, which leads to a lower number of errors. (Love et al. 2011)

3.4 Benefits of BIM

An organization can potentially gain many positive outcomes of utilizing BIM in their construction projects. Much research has been done in the area of finding the benefits of BIM. Azhar (2011), for example, presents several ways in which BIM could have extremely possible effects on the AEC industry in the future. He writes that BIM helps to find design errors and clashes between building elements. These types of errors can be extremely expensive if they are not discovered in time. Love et al. (2011) agrees that BIM is a valuable tool for discovering errors. They write, however, that BIM cannot be the single error detection method, since that would make error creation embedded in the work processes. They conclude that BIM is not the answer to completely reducing design errors. Organizations also need strategies for error reduction and error containment cooperation to succeed.

Azhar (2011) also writes that BIM will visualize the model so that collaboration and understanding is increased during the construction phase of the project. In a study conducted by Bryde et al. (2012) the production phase of 35 projects that used BIM were studied. The results showed that cost reduction and improved cost control were stated as being the most
common benefits that these projects experienced. They also saw that many projects were better at keeping to the schedule and sometimes even finished before schedule.

According to the McGraw Hill Construction SmartMarket Report (2014) the most common benefits that contractors receive from BIM are reduced errors and omissions, better collaboration with owners and design firms, reduced need for rework, reduced construction cost as well as better cost control and predictability. Many firms have already experience benefits from adopting BIM technology. However, it is most likely that the potential benefits of BIM will increase in the future when BIM technology is developed further (Eastman et al., 2011).

Barlish and Sullivan (2012) have in their case study tried to measure the benefits if implementing BIM. They have acknowledged that there isn’t a generally accepted method of calculating the benefits of BIM. Therefore, they have derived a model from a case study, which can be used to calculate the value of BIM. They conclude that the benefits of BIM in a project depend on a number of things. Things that are recognized to have an effect on the value of BIM are project size, communication in the project team, BIM proficiencies within the team, etc. This means that BIM is not automatically successful. The people in the organization also need to have the right competencies. Aranda-Mena et al. (2009), write that due to the large differences between companies (when it comes to company size, experience with IT, etc.) it is impossible to create a general business model for BIM implementation. Each individual company needs to develop goals for the implementation process that are unique to the company. Generally, an organization needs to have three things. First, they need a technical ability in order to produce and exchange models. Second, organizations need an operational ability to produce designs while minimizing errors in 3D. Lastly, companies need to have business ability so the projects will be more efficient and have higher client satisfaction.

3.5 The Current state of BIM

As Succar et al. (2012) writes, “BIM is at a tipping point.” The usage of BIM is accelerating and is becoming more and more common in the industry. According to McGraw Hill (2014) one of the major drivers for the rapid increase in the number of BIM users over the last years is the demand from both governments and large private owners.

In the UK BIM will be a requirement for all government projects with a value of at least £5m by 2016 (Withers and Matthews, 2011). The UK government has also created a BIM Task Group with the purpose of assisting the government, as well as the contractors, in the transition period. The BIM Task Group is currently working on bringing all government projects up to Level 2 BIM, on the BIM Maturity Model (McGraw Hill, 2014). This level is defined as “file based collaboration and library management” (BIMTalk, 2014).

In Sweden, Trafikverket (the Swedish transport administration) will require BIM in their projects from 2015 and forward (Trafikverket, 2013). Similarly, several government-owned property owners in Norway, Denmark and Finland also require BIM in their projects. (McGraw Hill, 2014)
Singapore was the first country to implement a model-based submission system. With BIM project groups only need to submit one model containing all required information about the project. The government authorities accept E-submissions of this kind for architectural, structural and also MEP BIM models. (McGraw Hill, 2014)

All of the above shows that the paradigm shift towards BIM is currently in motion.

3.6 BIM Challenges
Even though many researchers have showed that adopting BIM could lead to several positive outcomes, BIM adoption in the industry has been slow (Azhar, 2011). As mentioned in the introduction there are a number of reasons for this, and the problems with BIM are mainly managerial and technical. There is not a clearly defined way of how to implement BIM and how to use it. This is a risk that adopters of BIM would have to take. Another problem with BIM is that the learning curve for people who are new to BIM is too large. Also, the roles and responsibilities concerning the BIM models are often vague. Who is responsible for developing the models and how should the costs be distributed among the stakeholders.

Gu and London (2010) describe a number of other aspects that has inhibited BIM adoption. For example, the market readiness varies a lot between different geographic areas. The construction industry has historically been unwilling to change. There is a lack of knowledge about BIM and what it actually can do for a project. These are all reasons why the adoption of BIM among players in the construction industry has been slow.

3.7 BIM Capability
According to a model by Succar (2010) there are three stages when evaluating BIM capability for an organization. The first is object-based modeling. The second is model-based collaboration. The last stage is network-based integration. These three stages are the most important milestones that organizations need to reach in their mission of implementing BIM (Barlish and Sullivan, 2012). The BIM capability stages are pretty straightforward. An organization utilizing software tools such as Revit and or ArchiCAD have reached stage 1. If the organization has the ability to share models with other disciplines in projects they have reached stage 2. Stage 3 requires the ability to share object-based models with several other disciplines by linking external databases to the project server. (Succar et al., 2012) A project server, or an information hub, is a place where the project information is centrally stored. The project server should be accessible from all of the stakeholders in a project. The information should ideally be in standardized formats (Tarandi, 2011). An organization that decides to implement BIM into their business strategy will pass through all of these three stages at some point in time. The stage of an organization prior to reaching stage 1 is often called pre-BIM. The pre-BIM stage is the starting point for organization before the BIM implementation.
3.8 BIM Maturity

The term BIM maturity can be defined as the “quality, repeatability and degree of excellence within a BIM Capability”, where the capability should be seen as the minimum ability to performing a BIM service that an organization possesses (Succar 2010). In other words, capability is whether or not an organization can perform a specific task; maturity is how well the task is actually performed. Figure 2 describes five different levels of maturity within each stage of capability. The model in figure 2 is what is called the BIM Maturity Index (BIMMI).

For example, an organization may be capable of model-based collaboration but the process may not be defined. Then the organization is only at maturity level 1, according to the BIM Maturity Index (Barlish and Sullivan, 2012).

As Succar et al. (2012) describes, many organizations that adopt BIM expect to obtain significant benefits and increases in productivity even though they are inexperienced BIM users. The BIM maturity levels show a simple explanation why this can happen. An organization cannot just adopt BIM technology expecting that to lead to higher productivity etc. There needs to be a clear strategy how the organization can increase its capability and maturity. The higher level that an organization achieves on the BIM maturity index the better results they will experience from BIM.
The BIM Maturity Index is not the only way of assessing the BIM maturity of an organization. Another way of measuring maturity is by using the BIM Maturity Model or the Capability Maturity Model. The BIM Maturity Model was created by M. Bew and M. Richards (Sackey et al., 2013) and consists of four levels of maturity. It is often illustrated with figure 3 below. The index can measure BIM maturity in individual projects, as opposed to measuring maturity on an organizational level. As mentioned above, UK government has decided that all of its construction projects should use BIM level 2 by 2016. Below is a description of the different levels in the model.

3.8.1 Level 0
This level of the maturity model should be seen as the starting point for an organization about to adopt BIM. This level is defined as unmanaged 2D drawings either in paper-based or digitally. (Designing Buildings, 2014)

3.8.2 Level 1
Level one is the first step for an organization trying to adopt a BIM strategy. This level means a more managed CAD, usually in both 2D and 3D. 3D models are typically used for concept work, while 2D drawings are used for the approval process as well as for the production. However, the models are not shared between project team members. Each discipline maintains and manages its own data. (NBS, 2014)

3.8.3 Level 2
In this level the models have become managed 3D environments with data tied to BIM objects are included in the model. This data makes it possible to perform scheduling and estimation with the model. The different disciplines create individual models, which are then combined into one, but without any loss of data. This means that the different disciplines have started to collaborate more and more through more structured information exchange. However, as mentioned above, the different disciplines do not collaboratively create a single shared model.
They still create individual models. A common file format should be used to share design information between the different actors. (Out-Law, no date.) The IFC is one example of a neutral file format that is compatible with different software. (Eastman et al., 2011) This allows you to combine the design models with other models in order to perform different analyses.

3.8.4 Level 3
Data is integrated into one single project model, which is collaborative and located online in a shared server. Cost analysis, construction sequencing and project lifecycle information is integrated into the model. This level represents full collaboration between the different actors in a project. The single share project model can be accessed and modified at all times by the actors involved. This means no more inconsistent models. (Designing Buildings, 2014)

3.9 BIM Objects
Traditionally, construction information has been communicated through the use of paper drawings. With the help of the computer these drawings could be produced digitally, and then printed to paper. This simplified the process of constructing the drawings. Then came the idea of using digital objects to add information to the illustrations (Ibrahim et al., 2003). To include objects in the models is a function of the building Information model that potentially can have beneficial outcomes (Eastman et al., 2011). BIM objects are entities with properties and not only a geometrical shape. According to Halfawy and Froese (2002) “AEC objects typically involve large, complex, and dynamic information structures.” The authors explain that these objects include not only a geometrical representation, but also information that describes properties of the objects. Eastman et al. (2011) describe BIM objects as “digital components of parametric or static geometry, and information describing the state (for example, materials, dimensions) and behavior (for example, energy performance, price), that are aware of their relations to other objects”. Some examples of these properties can be the structural characteristics and functional features, maintenance, cost, design etc.

The data connected to these BIM objects can be used for cost estimation, scheduling, and maintenance plans, for example. (Wang et al., 2013) Objects can be connected with each other by assigning relationships to each other. This makes it possible to perform for example design checks. Also, the use of smart objects allows for the possibility of including cost estimation as well as scheduling in the model. This increases the information sharing between actors in the project in a simple way. (Halfawy and Froese, 2002)

BIM objects can also be used as a representation of a specific product from a specific manufacturer. This means that the objects’ properties represent the actual characteristics of a product. This will naturally lead to higher accuracy for some of the data in the model, for example cost. Manufacturer specific objects make it possible to include a new set of data connected to the objects in the model. For example, maintenance plans and installation guides can be included in the model. Also, information about the supply of the products can be included, which makes it possible to incorporate supply chain management info the model (Eastman et al., 2011). The model can then show if the products are made to stock, made to
order or possibly engineered to order. This means that the data on the model can show how long it will take to deliver the products.

Manufacturer specific objects can potentially have some useful advantages, e.g. adding supply chain management to the model (Eastman et al., 2011). Including manufacturer specific information in a model is not yet very common. However, manufacturers are becoming increasingly involved in BIM technologies. (Weygant, 2011)

An object library is where the objects, both generic and manufacturer specific, are stored. The library contains all object data, as well as the geometry of the objects. When creating the building information model the library is accessed and the desired products are inserted imported into the model. (Stangeland, 2013)

3.10 BuildingSMART
BuildingSMART, previously named International Alliance for Interoperability, is a neutral international organization that works with developing BIM and BIM standards. Their focus is on “standardizing processes, workflows and procedures for BIM” (buildingSMART, no date-a). buildingSMART has developed five basic open international BIM standards: the buildingSMART Data Dictionary (bsDD), Industry Foundation Classes (IFC), the Information Delivery Manual (IDM), BIM Collaboration format (BCF), and Model View Definitions (MVD). (Chapman, 2013)

In simple terms IFC is a standard for sharing information, the bsDD (previously known as IFD) is a standard for interpreting what the information means, and IDM is a standard that defines which information should be shared and when it should be shared. The BCF is a tool for sharing comments attached to building elements when issues in the design have been found (Mogollon, 2014). The MVD specifies what is required from the model in order to perform what is in the IDM. (See et al., 2011) The bsDD and IFC will be described more in detail in the following two chapters.
Technical Principles: Basic Standards

There are five basic methodology standards

<table>
<thead>
<tr>
<th>What it does</th>
<th>Name</th>
<th>Standard</th>
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<tbody>
<tr>
<td>Describes Processes</td>
<td>IDM Information Delivery Manual</td>
<td>ISO 29481-1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ISO 29481-2</td>
</tr>
<tr>
<td>Transports information / Data</td>
<td>IFC Industry Foundation Class</td>
<td>ISO 16739</td>
</tr>
<tr>
<td>Change Coordination</td>
<td>BCF BIM Collaboration Format</td>
<td>buildingSMART BCF</td>
</tr>
<tr>
<td>Mapping of Terms</td>
<td>IFD International Framework for Dictionaries</td>
<td>ISO 12006-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>buildingSMART Data Dictionary</td>
</tr>
<tr>
<td>Translates processes into</td>
<td>MVD Model View Definitions</td>
<td>buildingSMART MVD</td>
</tr>
<tr>
<td>technical requirements</td>
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Figure 4. BuildingSMART Basic Standards

Connected to buildingSMART are their members, known as Chapters. The Chapters are national organizations who work locally to support and encourage the use of the buildingSMART standards. Since the Chapters are national, or sometimes regional, organizations they have better knowledge about the individual markets including their opportunities and issues (buildingSMART, no date-b). There are currently 16 Chapters working with buildingSMART. They can be seen in figure 5.

<table>
<thead>
<tr>
<th>BuildingSMART Chapters</th>
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<tbody>
<tr>
<td>Australasia</td>
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<tr>
<td>Canada</td>
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<tr>
<td>China</td>
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<tr>
<td>France</td>
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<td>Germany</td>
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<td>Hong Kong</td>
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<td>Japan</td>
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<td>Korea</td>
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<tr>
<td>Netherlands</td>
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<tr>
<td>Nordic (Finland, Denmark, Sweden)</td>
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<tr>
<td>Norway</td>
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<tr>
<td>Singapore</td>
</tr>
<tr>
<td>Spain</td>
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<tr>
<td>United Kingdom</td>
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<tr>
<td>United States</td>
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</tbody>
</table>

Figure 5. buildingSMART Chapters.
3.11 buildingSMART Data Dictionary

At an ISO meeting in 1999, attended by various organizations connected to the AEC industry, it was agreed upon that there was a need for a standardized terminology that could function globally (Bell et al., 2008). This resulted in the buildingSMART Data Dictionary (referred to as the bsDD for short), an international standard for terminology. It was previously called the International Framework for Dictionaries (IFD).

The bsDD is an open, shared object-oriented database where the terminology about the BIM objects is defined. It is a library where concepts and terms are defined, but also where the meanings of the terms are described (Bell et al. 2008). There are two types of information in the dictionary. Firstly, the naming of concepts are defined in the different languages so that they are can be understood by people from different nationalities. The terms are also given a unique number each, a Globally Unique ID (GUID). This number makes it possible for anyone to identify objects that are named in a foreign language (Bjørkhaug & Bell, 2006). Second, characteristics are assigned to each concept. These characteristics can for example describe the measurements of the object or their function. Figure 6 shows how the dictionary can look like. Figure 7 shows an example of the attributes that can be connected to windows in the data dictionary.

Let's say a designer has named objects in Japanese, a non-Japanese speaking person can simply look at the GUID and get the definition of the object in his or her own language. The use of GUIDs in the bsDD lowers the impact of language barriers. The GUID also makes it possible for computers to understand the meaning of the concepts, which is important when using the model for different kinds of analyses. When exchanging the model between different programs the objects can still be recognized. This increases the interoperability between different software and different actors. (Bell et al., 2008)
It is important to stress that the bsDD makes a distinction between the naming of an object and the actual object. This means that it does not simply provide a translation of the words in an object definition. For example, a word in English is not only translated into Swedish. The bsDD makes sure that the words in English and Swedish have the same definition (Bjørkhaug & Bell, 2013). The bsDD standard provides structure for object information as well as a method for uniquely identifying objects. As Weygant (2011) describes it, depending on the context, words can have several meanings. This means that standardization of the terminology is needed so that the computer understands the concepts correctly.

It is important to note that the data dictionary is not a classification system, nor is it a place where you store project information. However, it can store a number of classification systems in it. The purpose of the dictionary is to simplify information exchange by providing a structure for the definitions of object data. (Palos, 2012)

**3.11.1 Uses**

The stand-alone uses of the bsDD are like any other dictionary. Basically it can be used in three different ways. First of all, the bsDD can be used for identifying object properties in any file format. Second, the dictionary can translate property names, descriptions, values and units between different languages. Lastly, is can be used for mapping between different classification systems. (Stangeland, 2013)

The bsDD can, however, have a whole new set of benefits when used for exchanging model information between different software (Watson, 2008). The bsDD makes sure that data is exchangeable between similar and dissimilar software. This means that no information is lost when exchanging the model, but it also means that all software will be able to understand the information tied to the BIM objects. The example bellow shows why this is of importance.

“For example: A user selects a particular "column" from an object library in the BIM software, and the user wishes to add performance data to that object. If there is no established provision for adding such data, then the user must add a text "note" or other unstructured means to identify the requirement.” (Watson, 2008)

This would mean that the added data in the text note cannot be used by analysis software, and the full potential of the data in the model would not be achieved. The software will not
recognize the meaning of the data. To have properties tied to objects means that the model can be imported to different simulation software. For example, this makes it possible to automatically calculate fire-resistance ratings. (Watson, 2008)

It is important to note that the bsDD can be used to define object properties independently of whether or not they are defined in IFC. This means that IFC is not a substitute for the bsDD, they complement each other. (Bjørkhaug & Bell, 2013)

3.12 IFC
As mentioned above, IFC is another international standard created by buildingSMART. IFC, however, is not a standard for terminology. Instead, it is a standard for how information should be shared. IFC is a file format that is both open and neutral. The purpose of IFC is to increase interoperability between all actors involved in the whole lifespan of the project. (NBS, 2013)

As Laakso & Kiveiniemi (2012) writes, BIM data is often exchanged in formats compatible only with one software-vendor. In most construction projects the people involved use the same software, and they share data in a format that works exclusively with that software. Actors who do not use the specific software will not be able to acquire the data. This means that proprietary software can cause problems when it comes to the ability to collaborate. The IFC format was created in order to solve this problem. Its purpose is to make it possible for different actors and different disciplines in all phases of a project to share information with each other, even though they all are not using software from the same vendor. This means that data is shared and that it will flow easily between all of the phases in the project, thereby facilitating communication and collaboration. However, IFC does not automatically lead to a higher compatibility. It depends on software vendors to make their software compatible with IFC. Most of the large software companies today have chosen to make their systems compatible with IFC.

The IFC format can handle geometric representation in 2D and 3D, as well as BIM objects with both geometrical representation and information about its properties. The format covers information regarding relations between objects as well. There are many different types of relations that objects can have to each other, for example the way a window is linked to a wall, and IFC covers almost all of them (Eastman et al., 2011). IFC also has the capacity to depict other things than object information that are relevant to construction project. For example, scheduling, cost estimations and organizational charts can all be stored in IFC models (Wei et al., 2010). However, the amount of information types that may need to be exchanged between actors in the construction industry is massive. This means that IFC will require continual development in order to increase the information that it can hold. (Eastman et al., 2011)

The first version of IFC was launched in 1997. This was called IFC 1.0. Since then the format has been further developed and updated several times. The newest version of IFC was released in 2013 and is called IFC4 (Liebich, 2013). With each update the IFC format has gained functionality and increased its compatibility. It is only recently that the IFC format has
started to gain popularity in construction projects. So why has it taken so long for IFC to have become accepted in the industry? Drogemuller (2009) presents several explanations why this is. Firstly, software vendors have no incentive for making their products be compatible with software from other developers. Second, contractors and designers often feel satisfied with their current way of working, making them reluctant to take on the risk of changing their technical systems. Third, many organizations in the industry have not known if they would reap any benefits from adopting a work process with high interoperability. Lastly, new technology requires practice in order for people to understand how to use it. This means that organizations have been reluctant to invest in teaching people, especially when they are uncertain whether or not the investment in interoperability will have positive effects or not.
**4 NCC**

*Here is explained some background to NCC and their history. This chapter also describes how they currently work with BIM and what they use it for. This is relevant background information for the result and analysis chapters.*

**4.1 Background**

NCC is a Swedish multinational construction and property development company. The organization was founded in the late 80s when the two construction companies ABV and JCC merged. It has approximately 18 000 employees and 57 billion SEK in sales, which makes NCC one of the largest organizations of its kind in northern Europe. NCC develops, designs and constructs everything from residential properties, to commercial real estate, to roads and bridges. NCC holds a very strong market position in Sweden but is also present in Norway, Denmark, Finland, Germany, Russia, and the Baltic states. (NCC, 2015)

**4.2 BIM Practices**

Here follows a brief description of how NCC uses BIM and what they use it for. For this, an interview with Maria Freeney, leading project control specialist [ledande specialist projektstyrning] at NCC, was conducted (Freeney, 2015). This is the source for the rest of this chapter.

NCC has been working with VDC and BIM since 2007 and they are continually working on improving their BIM ability. The ambition is to use BIM during the entire life-span of the project, from the early stages to after its completion. They currently have BIM platforms for apartment buildings. The most common type of project where BIM is used is when they themselves develop the design of the product. This means that they take the initiative to develop a BIM model and that they are the ones who will eventually use the model once the construction starts. It is not very common, but it does happen that a client will hand out a BIM model in projects where NCC is hired to do the construction.

The BIM models are used for several things. Each stage in the life of a project has its own set of BIM applications. For the planning phase of a project BIM is used for quantity take-offs, tender preparation, clash control, analysis of alternatives, etc. During the production phase BIM is used for purchasing, deliveries, planning of the site, etc. Also, one of the most important uses of BIM for NCC is for visualizing. To use a 3D model to visualize a product is a way of improving communication, and this is beneficial in all stages of the project. It is used for communicating with the client and to show them how the product will look. This is beneficial since people often find it difficult to visualize how something will look in reality when reading off a paper drawing. This is not only beneficial when communicating with client. Also when communicating with subcontractors and other project stakeholders is the visualization aspect of BIM valuable. Sometimes, in projects where they are hired to construct, NCC will even create a 3D model for the sole purpose of visualizing the model. This shows how useful NCC finds the visualization feature BIM.

The models are used in different software for different tasks. For coordination the software that NCC uses are Solibri Model Checker and *Navisworks*. *SketchUp* and *Infrawork* are used
for traffic control planning [TA-planering] and site planning [APD-planering]. *Revit* is used for the bidding process as well as for MEP and structural planning. Apart from this, *Rhino, Novapoint*, and *Civil 3D* are used in infrastructure projects.

BIM is still used together with 2D drawings in most projects, and BIM is often seen as a complement to the paper drawings.

As mentioned above the desire is to have a model during the whole project. To support this NCC have developed a document stating the Level of Detail (LOD) that they wish to have in the model in the different stages of the project. This document specifies what information that the model should have depending on the stage of the process. It states the level of detail for both the visual information and the other information in the model, for example the properties of objects. The purpose of the LOD document is to make sure that the model always will contain the right amount of information at any time, and at the same time avoid any unnecessary information. The struggle, however, is to know what information you want to have in the model.

The models are created by external consultants who specialize in modelling. NCC shows what they want and the consultants then develops the required models. This means that there needs to be continual communication between NCC and the consultant so that the model holds all right information when it is needed. This dialog is required so that the model develops accordingly along the development of the project, during its whole life-span. *IFC* is not the primary file format that is used. Instead, the models are handled in software specific formats.

Once the models are finished NCC uses a kind of online archive where the models, and other important documents, are uploaded. This means that all the people who are involved in a project can access all the information at any time. The tool *Buzzaw*, a cloud based collaboration software, is also used for model sharing.
5 Empirics
This Chapter presents the findings of the literature review and summarizes them into three categories of possible consequences.

5.1 Literature review

5.1.1 BIM Standards
Previous studies have been made about standards in BIM, but not much research has been made specifically on bsDD.

Weygant (2011) writes that standardization in BIM is crucial. He argues that no matter how much information you put in a model, it will be useless unless that information can be accessible and understandable.

The process of developing standards can be either formal, semi-formal or de-facto (Björk and Laakso, 2010). Formal standards are created through collaboration between different stakeholders. This is done through discussions and negotiations between many actors. The opposite of formal standards are de-facto standards. These are developed by a single organization in the market. This often leads to several emerging standards in the same field, resulting in harsh competition and a selection process in the market. The standard discussed in this paper, the bsDD, is an example of a formal standard. Björk and Laakso (2010) write that formal standards do not automatically become successful. There are a number of standards that have been developed formally that have been really successful, but there are also many that have been flops.

5.1.2 Implementing BIM
Research concerning the implementation process of BIM has been conducted several times in the past. Though these studies discuss the implementation of BIM in its entirety, and bsDD is only one small part of a BIM implementation, the findings in such studies can still be relevant to this study. The focus of the literature review in this chapter is on the consequences of BIM implementation. More specifically, what challenges the adopters experienced, in what way did they have to change their procedures, what new skills were required etc.

Arayica et al (2011) writes that there are several challenges with implementing BIM. Firstly, existent workflows need to be changed in order to be compatible with BIM oriented processes. Second, employees need the right training in BIM. Third, there needs to be collaboration and interoperability between the different disciplines. Lastly, the roles and responsibilities for the actors involved needs to be clear.

Roorda and Liu (2008) found that software limitations are a common issue when implementing BIM. This could mean that different software are not compatible with each other or a considerable amount of information is lost when files are converted between different formats. Also, hardware limitations can lead to problems after the implementation.

According to Manning and Messner (2008) a lack of knowledge about the parametric concepts is an issue for organizations in the process of adopting BIM. This leads to the issue
of a lack of parametric objects in the model. This means that the full potential of BIM is not being realized.

Azhar (2011) writes that BIM can lead to legal problems such as who actually owns the model and who is responsible for its accuracy. Also, when several people can access the model and make adjustments in it issues can arise.

To conclude this chapter, the findings in the literature review show that the challenges and consequences with BIM adoption can be summarized into the three categories below.

These three categories will be the basis for the results of this paper. As we have seen, the implementation of BIM often leads to challenges within these three categories. An adoption of the buildingSMART data dictionary should reasonably also lead to consequences within these areas. Therefore the following chapter will investigate what possible consequences adoption of the bsDD would lead to within these three categories.
5.2 Results

This chapter maps the possible consequences that an adoption of the buildingSMART data dictionary could have. Firstly the technological consequences will be discussed, followed by the operational consequences and the contractual consequences. The results found in this chapter are an extension of the literature review. They are based on previous research on BIM implementation.

5.2.1 Technological Consequences

The technological consequences of bsDD implementation are perhaps the most obvious ones. Since the data dictionary actually involves a new piece of technology there are certain possible changes in this area. The possible consequences that will be discussed in this chapter are listed below.

1) Guideline and monitoring requirements
2) Software compatibility
3) Document of the information structure
4) Education, training and support
5) New possible applications

1. Guideline and Monitoring Requirements

The buildingSMART data dictionary is an information structure. This means that the models contain more information with the bsDD than without it. The amount of possible information that could be added to the model with the bsDD is huge. So what information should be added to the model? How should this information be used? These are questions that need to be described when implementing the bsDD. The organization needs to define some guidelines how it should be used. Also, there might be a need for monitoring that the models are developed properly and that they are sufficiently accurate.

2. Software Compatibility

One of the first questions that need to be answered is whether or not NCC would have to change their way of work after an implementation of the bsDD. One part of this is if the software that NCC currently uses is compatible with the bsDD. This is a fairly straightforward question. As described in chapter 4.2, the software that NCC uses for BIM are Revit, Solibri Model Checker, Rhino, Navisworks, SketchUp, Infraworks, Novapoint, and Civil 3D. They work primarily in file formats that are proprietary.
Since the bsDD can be used in non-IFC formats these eight software should all be compatible with the bsDD. This means that NCC would not have to switch their software for others from other manufacturers just to be compatible with the bsDD.

3. **Document of the Information Structure**
This bullet will be discussed more in detail in chapter 7 regarding the simulation. To be brief, there needs to be a document defining the structure of the information in the object library. This is needed since there currently is no Swedish content in the bsDD. In the future when the bsDD has been developed further organizations can still feel that an object library created specifically for the organization would be of value. If an organization wishes to create their own library they will need to create a document showing the information structure.

Creating an object library means that all the different types of object are defined in a document. Also, all the properties that these objects might have can also be defined in this document. The simulation conducted in this paper shows an example of how this is done and what the contents of the library might look like.

4. **Education, Training and Support**
New technology always requires time for the people to learn how it works. This is also true for the bsDD. The organization needs to educate the employees who are to use the bsDD so that they know how to use it and what possibilities it brings. The quicker the transition period is the faster the company can start to benefit from it. The employees need to learn how to use the bsDD and its functions properly. One way of doing this is by having classes that teaches this for employees working with BIM. Also, employees need to be able to access manuals where they can read about the bsDD.

Apart from the initial need for educating the employees, the organization continually needs to be able to provide support for the users. This could mean that the organization may need to introduce a helpdesk service with the purpose of providing support for employees working with BIM and the data dictionary.
5. New Possible Applications
There are a number of new possibilities with the bsDD as a part of the BIM practice in the company. This has already been discussed to some extent in chapter 3.11. These are applications that the organization has not used BIM for in the past. However, bsDD opens the door for future applications of BIM.

5.2.2 Operational Consequences
When implementing the buildingSMART data dictionary there will be operational consequences. In other words, there are some ways in which the company will have to change how they work with BIM. The list below shows that operational consequences that will be discussed in this chapter.

6) Level of Detail document
7) Requires new skills, new roles
8) New BIM standards
9) Changes in requirements of how the models are produced

6. Level of Detail Document
In the process of implementing the bsDD there is a need for specifying the Level of Detail since the bsDD increases the amount of information in the model. For NCC this would mean that they would have to incorporate the bsDD into their existing LOD document. This document specifies how the model should grow more and more detailed as the project progresses. It is important to specify what information is needed and when it is needed in the process. For example, it probably is unnecessary to add information about the acoustic properties of objects during the projects’ feasibility study. But later in the project this information might be essential. For NCC this would mean that they would have to incorporate the bsDD into their existing LOD document.
7. Requires New Skills and New Roles
Since NCC hires external consultants to create the models they would probably not need to hire a new employee to handle the bsDD. There would not be a need for a new role at NCC dedicated only to the bsDD. It would probably be the consultants who would work with the library and apply it to the models. This means that the new skills required for producing the model with the bsDD applied to it would mostly affect the consultants. This is unless NCC plans to do most of the new tasks required for the bsDD in-house. The new skills that NCC would need are more connected to how to use the new information. This is discussed above in the technological consequences section.

8. New Internal BIM standards
As described above the adoption of bsDD will lead to new possibilities for how BIM can be used. The BIM capability of an organization that has implemented the bsDD immediately increases. The organization is now capable of doing new things with BIM. The organization is now capable of adding classification systems and properties to the objects in the model. Being capable of this, however, is not the same as actually doing it. This means that the organization also should make sure that they increase their BIM maturity after the bsDD implementation. The organization needs to manage and integrate the bsDD into the existing BIM process in the company.

The possible benefits of BIM increase now that the bsDD is implemented. This means that more projects could benefit from BIM. After implementing the bsDD and after teaching the employees how to use it the organization needs to set the standards for when and how it should be used. In what type of projects should BIM and the bsDD be used, and what should it be used for? Some projects might not yet receive the full benefits that BIM possibly can bring. But many projects might benefit greatly from BIM and the bsDD, and it is important that you make sure that BIM is used in these projects.
To avoid confusion the whole company should work with the bsDD more or less in the same way. The terminology in the dictionary is meant to increase the understanding of the terminology, but if it is not used in a unison way there is a risk that the implementation of the bsDD only will cause misunderstandings and frustration. One part of coordinating the organization to work with the bsDD in the same way is to have defined the internal BIM standards. The standards need to specify how the organization should work with BIM and the bsDD. It is important to make sure that the whole organization works with BIM in unison. For example, there should be an organizational standard for how to name objects in the model, and the whole organization should work with the same set of properties in all projects.

9. Changes in requirements of how the models are produced
Since NCC’s BIM models are created by consultants and not in-house they need to know what to ask of the consultants. What new tasks do they want the consultants to perform after the implementation of the bsDD? What NCC needs to show the consultants is how BIM objects should be named in NCC’s models, and what properties should the different objects have. It is important for NCC to know what they want for the models to be as useful as possible. This also relates to the new organizational BIM standards of the organization. This shows how the models should be used and what information they should have. But NCC needs to know what they want the consultants to do and what they want to do themselves.

5.2.3 Contractual consequences
What the data dictionary does is essentially to make data understandable for a large number of software, making it possible to use the model for a new set of tasks, simulations for example. This naturally requires an accurate model; otherwise the results of the simulations will also be inaccurate. The responsibilities regarding the accuracy of the model need to be clearly defined. This raises the question if there are any contractual consequences of bsDD implementation. Below are the consequences that are discussed in this chapter.
10) Who is responsible for the accuracy of the model

10. Who is responsible for the accuracy of the model?
Working with BIM raises the question of responsibility. Since the models are used for a number of different purposes it is important that the model is sufficiently accurate. Errors could possibly lead to serious issues. This means that the responsibilities regarding the modelling need to be clear, especially when working with modelling consultants.

NCC already works with BIM and therefore should already be familiar with the question of responsibility. The question is if, and how, a bsDD implementation will change the responsibilities in any way. There are two parts in this question; who is responsible for the accuracy of the information provided for the model, and who is responsible for the accuracy of the model? These are questions that need to be discussed between the consultants and NCC. Also, if it is decided that NCC will create an object library there needs to be a discussion about who is responsible for that it is created correctly and that it is used correctly.

Consequences?
- Possibly.

How?
- Can be worth considering.
- However, the responsibilities are probably similar to the current situation.
5.3 Simulation

In this chapter the simulation conducted in this thesis is described in detail. It explains how the simulation was performed, what tools were used and what the final results were.

5.3.1 Introduction

Aside from the literature review a simulation has been conducted. As mentioned in the beginning of this paper the purpose with the simulation performed in this thesis is to show an example of how an object library can be constructed on an organizational level. This is a relevant addition to the object of study in this thesis since there is no Swedish content in the bsDD. If an organization would wish to implement the bsDD now they would have to develop a library themselves, and the library constructed in this simulation shows how this can be done. Also, organizational specific object libraries can possibly still be of interest in the future when the buildingSMART data dictionary has been developed for Swedish markets. Organizational specific libraries can contain all possible types of information, and it can therefore also be used as a complement to the bsDD. This makes it possible for organizations to create libraries that are specifically suited for the way that they do business. The object libraries can be custom made for any organization and their specific needs. A library like this would require a lot of work and research. However, the simulation in this paper shows the principle of how it can be done.

Below is a description of how the simulation was conducted, followed by the results.

5.3.2 Method

To narrow the simulation part of this thesis, doors have been chosen as the only type of objects in the library. To narrow down the library to only one object type should not have a negative effect on neither the reliability nor the validity since the principle for creating a library is the same for all objects. This simulation shows a miniature library, but the procedure of expanding it by adding objects and properties is just the same.

For this simulation a Microsoft Excel spreadsheet was used for creating the information structure in the library. The model used in the simulation was provided by NCC from one of their current projects. Bimsync, a web browser-based BIM collaboration platform (Catenda, 2015), was used for classifying the objects in the model with the objects in the created library.

5.3.3 Procedure

5.3.3.1 Model

For the purpose of this simulation NCC provided a model to work with. The model was created for one of their current projects; a multi-tenant apartment building that is being constructed in Uppsala, Sweden. Only the architectural model is used for this simulation. The objects in the model did not have any classification assigned to them previous to this simulation. Figure 8 shows the model in bimsync.
5.3.3.2 Classification

As mentioned above the information structure for the classification was created in a spreadsheet. The goal was to build a classification system so that you could categorize different door types. Therefore a list of different types of doors was created. The door types were sorted into two main categories:

- Interior Doors
- Exterior Doors

These two categories were in turn divided into subcategories. After this a number of door types were assigned to each of these categories, for example glass doors and Interior door type A. Figure 9 shows what the spreadsheet looked like. This classification structure contains four types of information: Level, Code, Name, and description. These four are separated by commas ("," in the spreadsheet.

First, all the different door types and door levels were each assigned a number that represents the hierarchy of the classes. Door (1) is highest level in the hierarchy; this is followed by Interior doors (1.1) and Exterior doors (1.2) and so on. This is represented by the number in the first position in each line.
Second, every object in the spreadsheet was given a unique code (this is the second position in each line). To make it as simple as possible the objects’ codes were named 1 through 14. The third position in each line of the spreadsheet represents the name of the object. This name is what will be visible in the different BIM software when objects have been tagged. Lastly, all the different classes were assigned a text clarifying what is meant by the names. This can be useful because sometimes the names can be somewhat vague.

An assumption made in this example is that there are a number of standard doors that are often used. For example, for interior doors it is assumed that there are two different standard doors (type A and type B). You could, however, be more specific with these two door types and write their manufacturer and model name etc.

When the library classification system was finished in the spreadsheet it was exported as a CVS file and imported in bimsync as a new user-defined library.

5.3.3.3 bimsync

After both the model and the library were imported into bimsync it was time for assigning tags to all the doors in the library.
As can be seen in figure 10, all doors were tagged as “Doors”. Then the doors were tagged as either interior or exterior doors, and so on. With the tags in place you can easily sort the doors after their type.

5.3.4 Simulation Results
The simulation conducted in this part of the thesis shows how object libraries are created in principle. All the desired information is simply inserted into an Excel file. Here you can insert information specifically adapted to fit the need and preferences of the organization.

The objects in the model are then tagged after the classification system made in excel. For this simulation bimsync was used for tagging the objects. There are, however, other software that can be used for the same purposes. When all objects are assigned to appropriate classes a large number of applications can use this information. A simple example of an application is quantity take-offs. You can instantly calculate the number of glass doors in the design which in turn can be used for many things (e.g. purchasing and bidding).

5.3.5 Simulation Analysis
The principle of creating an object library is simple, as this simulation shows. The technical knowledge required for this task is not very high. What is more challenging, however, is knowing what to put in your library, i.e. what content you want to have in it. This raises the question: what is the model actually going to be used for? Also, in what stages of the construction process will it be used? The answers to these two questions will direct what type of information you would want to have in the model. These questions are, however, more difficult to answer than you would think. BIM is a new technology and its users are often not very experienced. Organizations do not know how to make the most out of it. Therefore, there is not yet a clear vision of how BIM should be used. This makes it difficult to know what information is needed in the model. Too little information in the model will inhibit the project team from achieving the full potential of BIM. Not having enough information in the model will make it impossible to use the model for all of the desired functions. Having too much information on the other hand is unnecessary. This could mean that a company has paid consultants for something that they don’t have any use for. The benefits of BIM will not be achieved simply because there is a lot of information in the model. The benefits of BIM are achieved when this information is used in an efficient and valuable way.

To create a library, such as the one created in this example, should be an iterative process. In other words, you start by creating a library with some object types and some properties, and then you try it out. From using the library you gain experience which should then be used as feedback for the library. You rework the library over and over until it is somewhat complete, and even then there will be a need for revising it regularly. This will eventually lead to an understanding of how the object library can be used in the different stages of the project. Also, what properties and object types are needed in the library? There may even be a desire to have manufacturer specific products in a product library. The process of creating object libraries leads to incorporating more and more information into the model. This will in turn lead to more and more possible applications of BIM. An organization should also find that
having organizational specific object libraries can be especially useful since they are made to fit the exact needs of the company.

To create an object library requires a lot of work. All object types that can possibly be desired should have a representation in the library. If some objects cannot be tagged with a class the lower will the precision of the model be. This means that the model cannot be used properly and that its full potential will not be reached.

5.3.5 Simulation Criticism
The purpose of simulation conducted in this thesis was simply to demonstrate the principle of creating an object library. The simulation did manage to achieve this. However, if this simulation were to be conducted again there are several things that would need to be improved in order for it to give better results.

In this simulation, the library created was limited to only contain door types. This could be considered to be too limited. In reality, you would never use a library containing only door types. This would be of no use. This means that the validity of the simulation would be improved if more object types were included in the library, i.e. windows, wall types etc. Also, the simulation would improve if the library also contained some properties for each type of object. This would represent more realistic conditions since if you would create an object library it would contain several object types and properties for these.

Another way to improve the simulation would be to actually use the library for some real applications. This would yield actual experience from using object libraries. This experience would then be used for improvements of the library. In other words, using the object library would result in more knowledge about what things that work and what in the library that needs to be improved. This would replicate the iterative process that creating object libraries should have in reality. This would be a useful addition to the simulation in this thesis since it is hard to evaluate the quality of the created library.
6 Analysis

In this chapter the results of the literature review and the simulation are analyzed more in detail. These are compared to each other to give an indication of what consequences are the most challenging and what consequences that will not have a very high impact on the organization post bsDD implementation.

6.1 Evaluation of the consequences

Since the buildingSMART Data Dictionary has no Swedish content there is a limitation to what an organization can do with it in its current state. This means that if an organization was to implement the bsDD now they would have to create a product library on their own. The simulation conducted in this research shows that it is quite simple to do this in principle. However, in reality, this task can turn out to be more difficult. To create the library you need to know all the object types that possibly can be needed when creating a model, and also what properties you want to use. This task is difficult, time consuming and would require a lot of research. You would need to revise the library continually when you have experience from using it in actual projects.

When it comes to the ten possible consequences listed in the results chapter, it is apparent that the company would have to change in two ways when implementing the bsDD. Firstly, NCC would need to educate its employees. This involves both teaching them how the tools work and what new possibilities that the bsDD brings. This could be done through providing the employees with bsDD-classes that teaches the different functions of the data dictionary and what it can be used for. Manuals can also be useful to show employees how it can be used and what it can be used for.

Second, the organization would need to provide support to the employees. A support function, specifically devoted to the bsDD, would have to be implemented so that employees would have somewhere to turn when issues arise. But this is only one part of providing the employees with the support that they need. Documents regarding the Level of Detail and the information structure would need to be developed. Also, the organization need establish a new BIM standard and share this with the entire company. The purpose of this is to work with BIM and VDC in the same way in the entire company. This means that NCC would work with BIM in the same way in all of its projects. This is very important since it avoids confusion and increases understanding. To do this, the organization needs to establish documents that specify in which projects that BIM should be used, and to what extent it should be used. Some projects still benefit less from having extensive VDC procedures than other projects. The BIM standard within the company should take this into account and give direction to how BIM could be used in that project. This also involves creating guidelines so that employees are confident how BIM should be used in each project. The organization should also establish a monitoring function to make sure that the employees use the model in the correct way and also so that the models are up to NCC’s standards.

Since NCC already has been working with BIM for several years, they already have experience from the things described above. However, when implementing the bsDD much of
the existing documents and established processes would have to be adapted to incorporate the bsDD. This means that the organizational BIM standard should be further developed so that employees know how the bsDD should be incorporated into the existing BIM processes. BIM guidelines should be updated so to incorporate what objects and what properties should be used in the models in various types of projects. LOD documents should be updated to show what bsDD information should be in the model in the different stages of a projects’ life span. Monitoring requirements should be reviewed to see that this information actually is in the model. The internal BIM standards should be updated to incorporate all of this, and also to show what the bsDD should be used for in the different projects, and in different stages.

The consequences of not educating and supporting the employees in the ways stated above will simply be that the bsDD is not used, or possibly used in wrong and uncomfortable ways. The result of this is quite simply that the full potential of the bsDD is not achieved. This will in turn lead to maintaining the status quo of the BIM processes. The organization will simply work with BIM and VDC like they did before implementing the bsDD. The investment in the data dictionary will end up being a bad one.

However, providing the employees with education and support should not be that difficult. Especially after a few years when the organization has acquired some experience from working with the bsDD and when they better know what support is required. The more challenging part of this process is the initial task of creating an own product library. Knowing what information to have in the library is very difficult. It is probably a task that would require work for many years. This would mean that the organization probably could not start with immediately implementing the library in the whole organization at once. It would be more reasonable to create a library and then use it in a pilot project to gain experience from it without the risk of huge losses. Then the library could be developed further with the experience from the pilot project. After this the library could once more be tested in a real project. Developing a library that works would require an iterative process like this for a number of projects before the library can launched in a larger scale in the organization.

The biggest consequence of the implementation process if simply that the size of the commitment of creating an organizational object library is very large. To create a library requires research and testing for many years to come. The organization would need to know exactly what the library will be used for and when in the process that it will be used.

Since starting to create an object library is such a big commitment, the decision to take on this assignment probably needs to be taken by the top management. This is simply because it is a long-term strategic decision which requires a large workload. This assignment will take up a lot of time and resources for many years to come. Obviously the team working with research and development of BIM will need to be onboard with this decision since they are the ones who will lead the work of creating the library. There needs to be a consensus about the goals and importance of this project between the specialists working with BIM and the management team.

The possible gains of having an organizational specific object library could however potentially evolve into a competitive advantage, if it could be used correctly. The
organizational specific library would mean that the models could be made more specific to the ways that the organization constructs its buildings. With models more accurately tuned to the organizations’ construction processes the models will have a more positive impact on the business. The company could then e.g. create more accurate cost projections which would result in lower risk.

When discussing the creation of an organizational object library it should be worth mentioning that the responsibilities might be affected. When an organization has an own organizational object library, they are themselves responsible for making sure that it is made correctly. If an issue would arise they themselves would be the ones responsible. Even if the organization hires consultants to create the actual models, they need to be certain that the object library that they use in the modelling is accurate. This is pretty obvious, but it could be worth thinking about. This means that there could be large risks involved with creating object libraries. This shows that it is important that the library has been thoroughly developed when it is first tried in a real project.

Another issue that needs to be examined before taking on the project of creating an object library is how it should be used in projects where other organizations are involved. Construction project often involve a number of actors, with different roles, depending on the form of delivery of the project. This means that understanding what role the object library plays in projects with other actors is essential. For example, other actors will need to be able to access the library information in order to have a successful information exchange. How do you make this possible technically? How can people from other companies know how NCC’s library works? Also, if other actors start creating their own object libraries, how will this affect the cooperation between actors? How should the library interact with other object libraries? There is a risk that multiple object libraries will lead to different work processes in every project, since the actors involved will need to adjust to different object libraries in different projects. There is a risk that libraries will start to compete with each other, and the different actors will want to use their own. How can you solve these issues? These are all very important questions that need to be discussed.
7 Conclusion

This last chapter of the thesis is meant to summarize the results and to describe, in short, what the consequences of implementing the bsDD will be. The intention of this is to unite the analysis with the purpose of the thesis stated in the introduction of this paper.

The results of this thesis show that the possible consequences for an organization planning to implement the buildingSMART Data Dictionary can be summarized into three categories; operational consequences, technological consequences, and contractual consequences. The results describe ten more specific types of consequences that each can be connected to one of these three categories. The analysis shows that the main consequences are educating the employees and continually supporting them. This requires guidelines, clearly defined internal BIM standards and LOD documents. For organizations that already work with BIM and VDC, the bsDD would have to be incorporated into its existing BIM documents. Therefore, these consequences would not have a severe impact on the organization.

The most important of all consequences, however, is the level of commitment that would be required to create an organizational object library. It would be necessary for a company to create their own object library if they would want to adopt the bsDD in its current state since it does not have any Swedish content. To create an object library would require a lot of effort and research during a long time period. An organization planning on implementing the bsDD needs to be conscious of this and it needs to be certain that they are willing and able to invest in an object library.
8 Further research

The results of this thesis raise new questions that are interesting when discussing the future of BIM and the buildingSMART Data Dictionary. These are subjects that would be relevant for further research. Some of these are listed below.

- How can different object libraries (national libraries, libraries from different organizations etc.) interact and cooperate with each other in a project? How can you make libraries interoperable with each other?
- How do you make sure that different object libraries do not compete with each other in the same project?
- How do you know what contents to have in organizational object libraries?
- How do the responsibilities change when more and more information is added to Building information models?
- How does a construction company benefit from having their own object library?
9 Sources

9.1 Written sources


Manning, R., & Messner, J. (2008), Case studies in BIM implementation for programming of healthcare facilities. *ITcon special issue – Case studies of BIM use*, 13, 246–257.


**9.2 Interviews**

## Appendix – Excel spreadsheet

<table>
<thead>
<tr>
<th>Level, Code, Name, Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,1, Door, Doors general</td>
</tr>
<tr>
<td>1.1,2, Interior doors, All doors within the building</td>
</tr>
<tr>
<td>1.1.1,3, Hinged, Hinged doors</td>
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<tr>
<td>1.1.1.1,4, Apartment door, Apartment doors</td>
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<tr>
<td>1.1.1.2,5, Type A interior, Standard interior door A</td>
</tr>
<tr>
<td>1.1.1.3,6, Type B interior, Standard interior door B</td>
</tr>
<tr>
<td>1.1.2,7, Sliding, Sliding doors</td>
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<tr>
<td>1.1.3,8, Rotating, Rotating doors</td>
</tr>
<tr>
<td>1.2,9, Exterior, All doors separating the inside of the building and the outside</td>
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<tr>
<td>1.2.1,10, Hinged, Hinged doors</td>
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<tr>
<td>1.2.1.1,11, Glass doors, Glass doors to balconies</td>
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<td>1.2.1.2,12, Type A exterior, Standard exterior door A</td>
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<tr>
<td>1.2.2,13, Garage, Garage doors</td>
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<tr>
<td>1.2.3,14, Rotating, Rotating doors</td>
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