

INVESTIGATING THE CURRENT STATE OF INDUSTRY FOUNDATION
CLASSES IN THE CONSTRUCTION INDUSTRY

A Thesis

by

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ABSTRACT

Interoperability is of high significance in the U.S. construction industry because most construction projects demand multi-disciplinary team efforts that combine inputs from several stakeholders throughout the building life cycle. Industry Foundation Classes (IFC), a standardized and structured data model for Building Information Modeling (BIM), has emerged as a neutral platform to solve the existing inadequate interoperability issues among the project participants. Lately, IFC has grown tremendously and more than 180 software applications currently provide IFC compatible data import and export capabilities. It has been expected that IFC would solve the interoperability problems among various processes, but the reality is not known yet.

This study aims to investigate the current state of IFC in terms of its adoption and non-adoption reasons, its use in the project life cycle, industry's evaluation of the IFC's maturity as well as the way general contractors are tackling the non-interoperability problems. To achieve the desired objective, structured interviews with industry experts were conducted to collect the industry's perspective on IFC, and their opinions were further analyzed.

The results show that, despite advancements in the Industry Foundation Classes schema, Architectural Engineering and Construction (AEC) firms are still facing several challenges while implementing IFC in project delivery systems. Nevertheless, some general contractors acknowledged that the ability to exchange the Building Information Models among the project participants enhanced their collaboration among stakeholders.

These research findings are intended to offer the AEC industry with a clearer picture of IFC's opportunities and challenges and to help the IFC development community and software vendors identify the major obstacles in IFC's adoption by the AEC industry.

DEDICATION

To my family for their
continuous support and motivation.

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NOMENCLATURE

BIM	Building Information Modeling
IFC	Industry Foundation Classes
MHC	McGraw Hill Construction
IAI	International Alliance of Interoperability
AEC	Architecture, Engineering and Construction
GT	Grounded Theory
GC	General Contractor
FM	Facility Management

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CHAPTER I

INTRODUCTION AND BACKGROUND

Interoperability problems remained as a major concern in the highly fragmented construction industry which has non-standardized work flow and inconsistent technological implementation by the project stakeholders (NIST, 2004). In the United States, as per a 2004 report published by the National Institute of Standards and Technology (NIST), \$15.8 billion is wasted because of inadequate interoperability among various construction processes. As per a survey conducted by McGraw Hill Construction in 2007, one of the major barrier for exchanging information with project stakeholders is the software incompatibility issues (McGraw-Hill-Construction, 2007).

With the inception of Building Information Modeling (BIM), construction companies are using this tool during the project life cycle for improved collaboration among the stakeholders (Arayici, Egbu, & Coates, 2012). However, in order to realize full advantages of BIM, standardization of information model has become a necessity so that architects, engineers, construction managers and facility managers could share the interoperable project information amongst them seamlessly.

To empower interoperability in the architecture, engineering and construction (AEC) industry, in 1994, Autodesk invited various companies to form International Alliance of Interoperability (IAI). IAI, which is now BuildingSMART, developed and now maintains the Industry Foundation Classes (IFC) exchange file format, which is a neutral and open file format, not controlled by any particular software development

company or vendor. “The IFC data model consists of definitions, rules, and protocols that uniquely define data sets which describe capital facilities throughout their life cycle” (BuildingSMART, 2016b). As per McGraw Hill Construction (MHC) Smart Market Report published in 2007, it is expected that by year 2020, \$200 billion waste in construction shall be eliminated by effective use of Industry Foundation Classes during project life cycle.

Since the release of first IFC version, which was IFC 1.0 in 1997, IFC has advanced immensely in last few years. The most recent version of the IFC is IFC4 and IFC5 is in development phase. Currently, more than 180 software applications provide IFC import or export feature. IFC could be used for seamless data exchange among the project stakeholders. The recent IFC4 release contains scopes of various disciplines such as architecture, structural engineering, MEP engineers, procurement, construction planning, facility management, building permits and approval, and owner’s requirement management (buildingSMART, 2013b).

Despite the advancements in IFC file format, there are several challenges associated with IFC usage in BIM work process (Steel, Drogemuller, & Toth, 2012). While importing an IFC model into various BIM application, the model loses its parametric intelligence (AUGI, 2012). Various other entity based information is lost during the import because not many parameters are mapped currently in the IFC4 (AUGI, 2012). File size of an IFC model is even larger than the file format of the authoring tool (Steel et al., 2012). Some time, IFC import does not produces the exact geometry and rendering which was there before the IFC export (Steel et al., 2012). At the same time,

uncertainty about Transactional Business Process (TBP) evolution is one of the major barriers in any of the technological integration in construction since construction firms do not know whether the technology will integrate with their work process and provide the desired outcome (Autodesk, 2011).

CHAPTER II

RESEARCH QUESTIONS AND SCOPE OF RESEARCH

2.1 Motivation

The initiative for development of a common language for BIM data exchange began in 1994, when International Alliance for Interoperability has been formed for development of an interoperable file format, now known as Industry Foundation Classes (IFC) (Kiviniemi, 2006). Currently, IFC has established itself as a potential tool for data exchange among the architects, engineers, general contractors, specialty sub-contractors, facility managers etc. (Froese, 2003). More than 180 software applications are providing IFC import or export functionality (BuildingSMART, 2016a). With the enrichment of IFC and increased attention towards interoperability, AEC industry is moving towards open BIM culture where the collaboration will not be affected by the type of software platform a particular stakeholder is using.

IFC 1.0, the first Industry Foundation Classes specification, was developed in 1997 by IAI (Kiviniemi, 2006) and at present, IFC 5.0 specifications are under development stage. During the last 20 years, Industry Foundation Classes has made various advancements to improve the interoperability. Despite these advancements, in the existing body of knowledge, one of the major gaps is the lack of researches which have investigated the current state of IFC in construction industry. It has been said that, IFC is for enhancing the interoperability among the various processes, but the reality is not known. Answers to the questions such as how General contractors are using IFC, why they are using IFC, why

they are not using IFC, how they are solving their interoperability problems without IFC etc. are still unknown.

Therefore, there is a genuine need for a study which investigates state of IFC application in the AEC industry. The best approach to achieve this objective is by analyzing the experiences of industry experts who are currently leveraging the Building Information Modeling based collaboration process in the construction project delivery systems.

2.2 Research questions

This study aims to identify the current state of IFC in terms of its adoption and try to find answers to following questions:

- 1) What are the BIM data sharing requirements of the General Contractors (GCs)?
- 2) Are they using IFC for data exchange? If yes, then why they are using IFC for BIM data sharing?
- 3) If no, then why they are not using IFC for BIM data exchange?
- 4) Without using IFC, how the GCs are tackling the non-interoperability problems in BIM processes?
- 5) What are the potential opportunities and challenges GCs are facing while using IFC for BIM data exchange?

2.3 Objective

This study aims to identify the current state of IFC in terms of its adoption and non-adoption reasons, its use in the project life cycle, industry's evaluation of the IFC's maturity as well as the way industry professional are tackling the non-interoperability problems.

2.4 Assumptions

For this research study, followings are the several assumptions which have been made while conducting this investigation:

- 1) It is assumed that interview participants feel encouraged to provide accurate and honest answers to the interview questions.
- 2) The industry experts, who are interviewed, know the entire BIM operating procedures of their company.

2.5 Significance

This research will investigate the current state of IFC usage in the construction project delivery system. Hence, the research findings are intended to serve the AEC industry with a clearer picture of IFC's opportunities and challenges and to help IFC development community and software vendors to identify the major obstacles in IFC's adoption by AEC industry.

CHAPTER III

LITERATURE REVIEW

3.1 Building Information Modeling

Life cycle of a construction project consists of several sequential processes such as feasibility study of the project, design development, construction and facility management. For these processes, various project participants such as owners, designers, general contractors, sub-contractors, vendors, construction managers, facility managers etc. come together to perform their respective tasks as the project progresses. During these processes, starting from inception to operation and maintenance of the facility, information exchange and collaboration efficiency affects the overall success of the construction project (Wikforss & Löfgren, 2007).

In an effort to enhance the collaboration and data management, Architecture, engineering and construction (AEC) firms are embracing various technological tools which are significantly impacting the construction operations. Among the recent advancements in construction industry, Building Information Modeling (BIM) has emerged as the best approach for collaborating and managing the ever increasing data in the construction industry (Azhar, 2011).

BIM is a new approach to design, construct, and manage a facility where a digital illustration, also known as virtual model, of the building is utilized to enhance the information exchange process and facilitate interoperability of digital content (Eastman, Eastman, Teicholz, & Sacks, 2011). It enables 3D visualization, up-to-date

documentation, accurate quantity take-off and all sorts of building analysis easier. There is a growing interest among the construction companies towards using Building Information models for coordination and building data management throughout the life cycle of the building.

3.2 Interoperability

Construction is a process where multiple stakeholders having different scope of work join together for successful delivery of the construction project. Although, Building Information Modeling (BIM) has tried to cater the need of integrated work processes but, non-standardized work flow and inconsistent technological implementation by the project stakeholders in this highly fragmented AEC industry is driving wasteful activities and redundant works (NIST, 2004). As per a report published by National Institute of Standards and Technology (NIST) in 2004, \$15.8 billion per year is wasted because of the inadequate interoperability among these heterogeneous software applications developed by various software vendors (NIST, 2004).

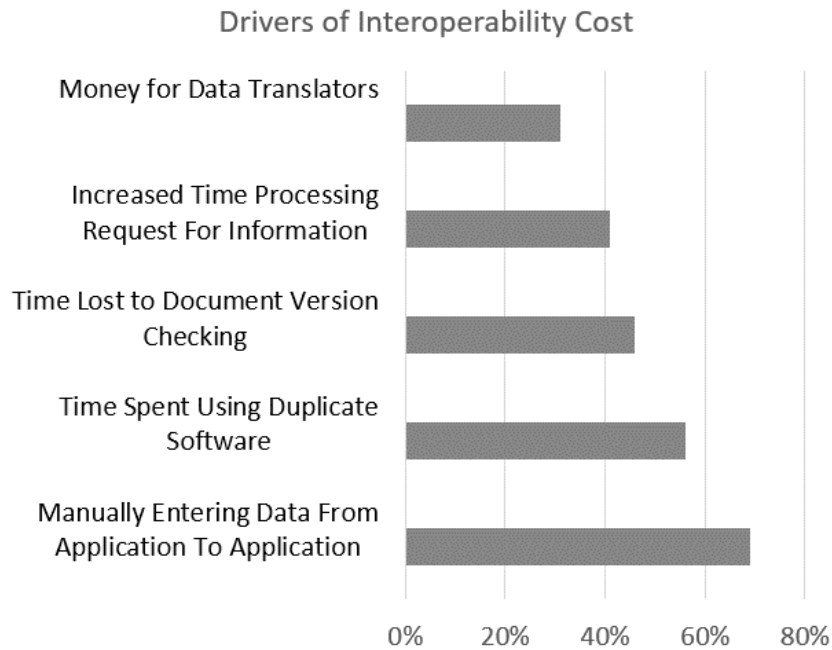


Figure 1- Drivers of non-interoperability costs
Adapted from McGraw-Hill-Construction (2007)

In the era of ever increasing software applications for AEC industry, Interoperability, which is the ability of two or more software systems to exchange the information (Radatz, Geraci, & Katki, 1990), is one of the topic of intense debate. Inadequate interoperability is significantly impacting the budget of a construction project. The McGraw Hill Construction’s SmartMarket report on ‘Interoperability in Construction Industry’ claims that, approximately 3.1% of the construction project budget is associated with non-interoperability among the AEC software applications (McGraw-Hill-Construction, 2007). Figure 1, an extract from the report, indicates that manually entering data from one application to another application is one of the primary drivers of escalating the non-interoperability costs.

Therefore, to fully realize the benefit of BIM by standardization of information model, interoperability has become an obligation so that architects, engineers, construction managers and facility managers could share the interoperable project information amongst them regardless of what software package or BIM platform is used (McGraw-Hill-Construction, 2007).

In construction industry, efforts for open data exchange standards are not new. Till now, various file formats has been developed to promote the integration among the authoring tools in AEC industry.

Following is the list of open data exchange file formats:

- 1) IGES: Initial Graphics Exchange Specification (IGES) is a vector based open source file format released in 1980 by United States NBS (National Bureau of Standards). It allows sharing of digital information among the various existing Computer Aided Design (CAD) platforms (Bhandarkar, Downie, Hardwick, & Nagi, 2000).
- 2) STEP: The inefficacies of IGES file format fueled the demand for development of Standard for the Exchange of Product Model Data (STEP) (Bhandarkar et al., 2000). STEP, a generic structure to define a 3D object, is for representation and exchange of structured product manufacturing information.
- 3) CIS/2: CIS/2 is developed with a mission to efficiently exchange the structural steel design and fabrication information among the stand alone software applications. CIS/2 is a neutral file format to promote interoperability or

communication among steel structure designer, steel fabricators, steel erectors, construction manager and other project participants.

- 4) DXF: Drawing Exchange Format (DXF), a file format developed by Autodesk, is a computer aided design (CAD) file format to empower information interoperability among the widely used AutoCAD and other authoring tools. The first DXF version was published in 1982.
- 5) IFC: Starting from the inception of BIM, demand for a more data rich and construction specific open file format increased to deal with non-interoperability issues increased. In 1997, first IFC version has been released to share the BIM data seamlessly among the various BIM authoring tools.
- 6) agcXML: agcXML, an Extensible Markup Language (XML), is developed to facilitate the sharing of building design and construction information with project participants. The effort to develop agcXML started in 2008. agcXML facilitates sharing of digital information related to transactional data that project stakeholders such as owners, GCs, sub-contractors, architects and engineers exchange during the design and construction phase. These transactional information is schedule of values, change orders, Request for information (RFI), submittals etc.
- 7) ifcXML: ifcXML is basically the data schema of IFC file format. It has been developed with an ambition to reduce the complexity of IFC file extension and hence, simplify the implementation (Liebich, 2013).

3.3 Industry Foundation Classes

Industry foundation classes (IFC) is developed with a mission to provide enhanced interoperability in various construction processes. The initiative for IFC began in 1994, when Autodesk invited group of companies and software makers on development of C++ classes which could support integrated development of applications. This integrated development of C++ classes started by International Alliance for Interoperability (IAI) which is known as BuildingSMART today. Figure 2 shows the sample IFC schema representation of a window. Currently, BuildingSMART, an international organization envisioned at improving the exchange of information among software applications used in the construction industry, develops and maintains the Industry Foundation Classes.

Industry Foundation Classes (IFC) exchange file format is a neutral and open file format, not controlled by any particular software development company or vendor (BuildingSMART 2009). It consists of a standardized data structure model to exchange design, construction and FM related data across various software application platforms during building construction life cycle. “It defines an EXPRESS based entity-relationship model consisting of several hundred entities organized into an object-based inheritance hierarchy and provides a set of definitions for all object element types encountered in the building industry and a text-based structure for storing those definitions in a data file” (IFCWiki, 2011).

The recent version of the Industry Foundation Classes is IFC4. IFC4 release consists of the BIM exchange format definitions which are required by various project stakeholders involved in various phases of the construction life cycle.

Scope of IFC4 release covers following disciplines (buildingSMART, 2013b):

1. Architecture
2. Structural Engineering
3. Building Services (Mechanical, Electrical, Plumbing, Firefighting etc.)
4. Construction Planning
5. Procurement
6. Project Management
7. Facility Management
8. Building permits and approval
9. Owner's requirement management

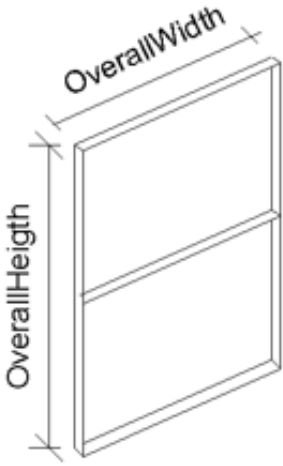
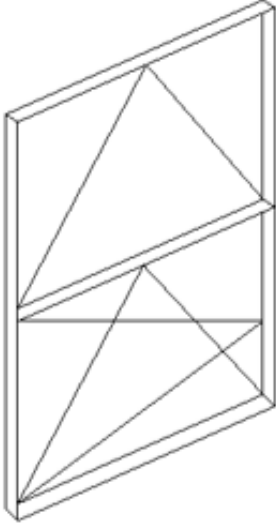
	<p>IfcOpeningElement by creating an instance of IfcWindow.</p> <p>The parameters:</p> <p>OverallHeight</p> <p>OverallWidth</p>
	<p>The final window (DoublePanelHorizontal) with:</p> <p>First panel</p> <p>PanelPosition = TOP</p> <p>OperationType = BOTTOMHUNG</p> <p>Second panel</p> <p>PanelPosition = BOTTOM</p> <p>OperationType = TILTANDTURNLEFTHAND</p>

Figure 2 – Sample IFC schema representation of IfcWindows
 (Inserting the IfcWindowType.PartitioningType = DoublePanelHorizontal)
 Source: (BuildingSMART, 2013a)

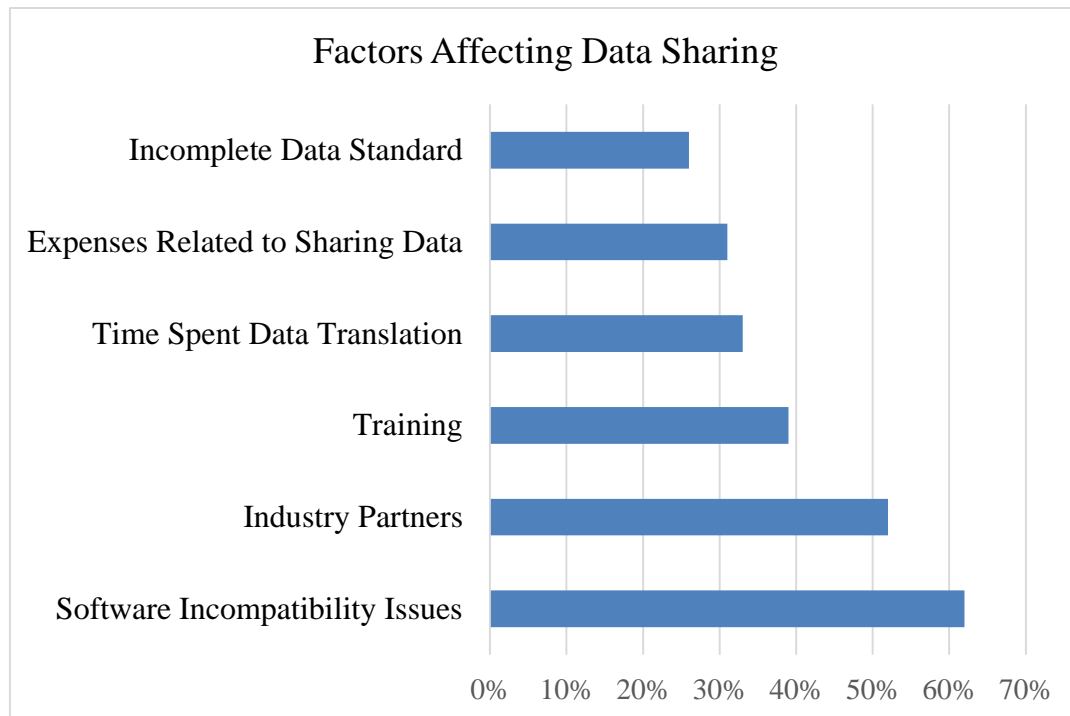


Figure 3 - Factors impacting data sharing
 Source: (McGraw-Hill-Construction, 2007)

As per a survey conducted by McGraw Hill Construction in 2007, one of the major obstacle for data sharing is the software incompatibility issues. Furthermore, almost half of the respondents mentioned that inability to exchange information with other project stakeholders are responsible for inefficient work processes. Figure 3 shows the various factors impacting the data exchange.

Therefore, without IFC, interoperable benefits of BIM, such as sharing information across the stakeholders irrespective of what software applications they are using, cannot be fully materialized. “IFC standard is the key to facilitating this cost-effectively and without becoming dependent on product or vendor specific file formats” (Solibri, 2016).

IFC has emerged as a great tool for exchange of interoperable project information during life cycle. Additionally, over time, IFC is evolving to a point where it can transmit defined computable information (Autodesk, 2011) and can be used for sustainable data management (Jinhoon Lee, 2011).

In summary, IFC has advanced immensely in last few years and construction firms are willing to implement the IFC process for better collaboration (McGraw-Hill-Construction, 2007). But, uncertainty about Transactional Business Process (TBP) Evolution is one of the major barriers in technological integration in construction since construction firms do not know whether the technology will integrate with their work process (Autodesk, 2011).

There are several researches which has been conducted on utilizing IFC for various construction processes. Bazjanac et al. describes a method to make IFC compliant to the existing simulation tools (Bazjanac & Crawley, 1997). Several other researches has been conducted to provide a framework to the use of IFC in project management (Froese et al., 1999) and facility management processes (Wix, Yu, & Ottosen, 1999). Fischer et al. assessed the maturity of the IFC product model for cost estimating purposes and defines the issues of IFC while performing cost estimating (Staub-French & Fischer, 2000). Kamat et al. examined the IFC's maturity by comparing the IFC export from the two leading BIM authoring tools (Golabchi & Kamat, 2013).

3.4 Definitions

Followings are the various terms and their definitions which have been used in this manuscript:

- IFC Schema:

IFC schema is a comprehensive database organization model and specification for information.

- Interoperability:

Interoperability is ability of two independent software application to communicate with each other which is ability to exchange and interpret the data between them.

- Stakeholders:

Project stakeholders are a group or an individual, or an organization who may affect or may be affected by the outcome or course of action in various phases of the project.

- Software Compatibility:

When two software platforms can work together without remodifying or altering the import and export. Software Incompatibility is antonym of software compatibility.

- Open File Format:

Open file format is a standardized specification for storage of digital data which is not controlled by a standalone company or organization. The open file format is usually developed and maintained by standard makers or organizations so that it could be implemented by any of the software developer.

- Authoring Tool:

A software platform or tool which is used to create and build the content or deliverable. BIM authoring tools refers to the tools or applications which has been used to create the building information models of a particular scope of work.

CHAPTER IV

RESEARCH METHOD

4.1 Research approach and rationale for research design

The study aims to understand and investigate the current application of IFC in construction project delivery system along with AEC industry's attitude towards IFC, its place in the construction timeline, as well as the industry's evaluation of the IFC's maturity. To achieve the desired objective, the research conducts a qualitative study by conducting semi-structured interviews with industry experts who are experienced in the usage of IFC in the Building Information Modeling work flow during various construction processes.

The main motivation behind choosing qualitative study is that, there are lack of studies which has investigated the current state of Industry Foundation Classes in construction project delivery system. Additionally, IFC is a fairly new file format having limited use so far in the AEC industry.

For systematic evaluation of the qualitative study, similar to the quantitative analysis, Grounded Theory (Glaser & Strauss, 2009) methodology is chosen (Corbin & Strauss, 1990). Grounded theory methodology has evolved as one the most influential technique for conducting qualitative research to construct theories from data gathered (Strauss & Corbin, 1997). It consists of a systematic procedures, for gathering the qualitative data and thereafter analyzing it to find the theories inherent in the data (Charmaz & Smith, 2003).

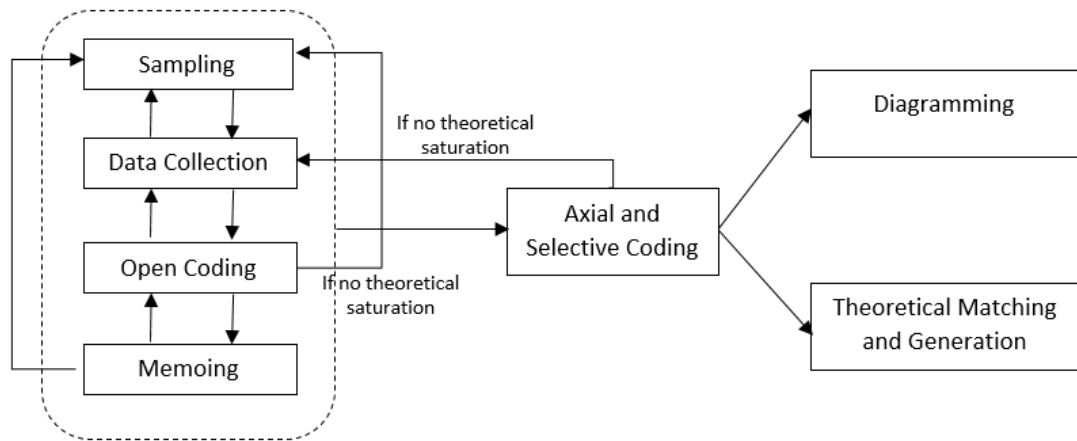


Figure 4 – Grounded theory workflow diagram
Adapted from Rodon & Pastor (2007)

Followings are various steps, as shown in figure 4, in Grounded Theory workflow:

Sampling: In Grounded Theory research, theoretical sampling is the recommended sampling method (Thomson, 2011). Because of the iterative nature of the Grounded Theory, the exact sample size for this study is difficult to define until a theoretical saturation occur (Mason, 2010). Therefore, S. B. Thomson recommends to review the data and look for the emerging patterns after each interview.

Data Collection: There are multiple ways to collect the data for a qualitative study based on Grounded Theory. The main objective of this research is to find out the current application and state of Industry Foundation Classes in the construction industry. To accomplish the desired objective, the research conducts semi-structured interviews with AEC industry professionals who are experienced in utilizing Building Information Tools in their project delivery process.

Open Coding: In the Grounded Theory, open coding is a process of assigning and naming concept, and categorizing the findings to look for emerging patterns (Borgatti, 2005). Through microscopic evaluation of interview content, preliminary codes of comparisons shall be delineated. A framework for concept and various open codes is presented in Table 1. However, the open codes are tentative and might vary based on the responses from the industry experts.

Memoing: Memoing is a continuous process of taking notes and identifying the connections among the various categorical patterns. This process is one of the most important step for finding the underlying and grounded theory in a qualitative data (Glaser & Holton, 2004).

Axial and selective coding: Axial coding is a process to find relationships among the codes. On the other hand, selective coding is the procedure of identifying one main category and connecting all other categories to this core category. This research first finds the relationship among the defined categories using axial coding and then selective coding is used to identify the correlation between core categories i.e. Industry Foundation Classes usage and other categories.

Diagramming: Diagraming is a tool to study the various categories relationships derived from the axial and selective coding. Grounded Theory does not specify any specific way to conduct the diagraming process (Corbin & Strauss, 1990). It is advantageous to find associations among the categories originated from axial and selective coding procedures (Rodon & Pastor, 2007).

Theoretical matching and generation: In the final stage of Grounded Theory based investigation, relevant finding is extracted from the theories developed from the diagramming process.

Concepts / Categories	Open Codes
Interoperability	Problems, Workarounds
Data Exchange	Frequency of data exchange, Participants among which data is exchanged
Adoption	Reason for adoption, Reason for non-adoption
IFC Pros	Interoperability, Sustainable data management, Easy access to the file
IFC Cons	Imperfect, Data loss while export/import, complicated workflow, Non-parametric

Table 1 - Interview concepts along with their various codes

4.2 Data collection method

To achieve the desired objective, this research conducted semi-structured telephonic interviews with BIM professionals in top fifteen commercial general contractors firm. For selection of the top commercial general contractors with extensive

BIM experience, ‘2015 Giants 300 report¹’ is referred. This report provides a comprehensive rankings of the General Contractors based on their BIM expertise and revenue. Table 2 shows the list of top 15 commercial general contractors extracted from this report.

4.2.1 Expert selection criteria

For this research, industry professionals with designations of BIM Engineer, BIM Manager, BIM Coordinator and Technology Team Member with 5 Years of experience in managing BIM processes in AEC Industry are selected for interview.

¹ 2015 GIANTS 300 Report: <http://www.bdcnetwork.com/giants-300-report-robotic-reality-capture-gaming-systems-virtual-reality-aec-giants-continue-tech>

Rank	Contractor's Name
1	Turner Construction
2	Whiting-Turner Contracting
3	Skanska USA
4	PCL Construction
5	Balfour Beatty US
6	Gilbane Building Co.
7	Hensel Phelps
8	Lend Lease
9	McCarthy Holdings
10	JE Dunn Construction
11	Mortenson Construction
12	Clark Group
13	DPR Construction
14	Hoffman Construction
15	Suffolk Construction

Table 2 - Ranking of general contractor based on BIM expertise and revenue²

² 2015 GIANTS 300 Report: <http://www.bdcnetwork.com/giants-300-report-robotic-reality-capture-gaming-systems-virtual-reality-aec-giants-continue-tech>

4.2.2 Theoretical sampling

In this study, to collect the industry perspective, several interviews were conducted. The interview questions were mostly open ended to encourage a complete and meaningful answers. To sample the interview subjects, theoretical sampling method is used. Theoretical sampling is used in the researches where the analysis of qualitative data is performed using the grounded theory. In researches based on Grounded Theory, the exact sample size for this study is difficult to define until a theoretical saturation occurs (Mason, 2010). Theoretical saturation is a point when no new information emerges by further sampling and there are plenty data to come up with an emerging pattern and define theory.

S. B. Thomson gathered all the research papers which consisted interviewing as the technique for data collection and Grounded Theory for analysis (Thomson, 2011). In those studies, the range of the sample size varied from five to one hundred fourteen.

Guest et al. recommends a sample size of six to twelve if the research scope is narrow and subjects are homogeneous, which is our case (Guest, Bunce, & Johnson, 2006). In this study, only the BIM professionals, who have experience in managing BIM processes for at least 5 years, are interviewed to gain the perspective about the IFC and overall interoperability problems. Romney et al. recommends a sample size of four to five if the target audiences are experts and well knowledgeable in the subject of investigation (Romney, Weller, & Batchelder, 1986).

Since, IFC is a fairly new file format and has limited use in the industry, a smaller sample size could be enough to achieve the theoretical saturation. Hence, anything between 6 and 12 is a workable sample size.

4.3 Interview questions design

This study aims to identify the current state of IFC in terms of its adoption, AEC industry's attitudes towards IFC, its place in the project life cycle, as well as the industry's evaluation of the IFC's maturity.

As investigated in Table 1, followings are the various categories of investigation:

1. Interoperability
2. Data Exchange
3. Adoption
4. IFC Pros
5. IFC Cons
6. Maturity

Therefore, based on these categories, the interview questionnaire has been formulated. This semi-structured interview questionnaire has 9 open and close ended questions where industry experts has been asked to share their experiences about interoperability and Industry Foundation Classes. To explore more, sometime auxiliary questions are also asked to the interviewee for better understanding.

4.3.1 Interview questionnaire

Interoperability

Question 1: Do you exchange Building Information modeling data with other project stakeholders during the construction phases?

Data exchange and adoption

Question 2: How frequently the exchange of BIM data happens with project participants?

Question 3: Do you use Industry Foundation Classes file format which is dot IFC file extension?

IFC pros and cons

If answer to question 3 is 'No':

Question 4: How do you exchange the Building Information Data with the project stakeholders?

Question 5: What are the potential reasons for not using Industry Foundation Classes?

If answer to question 3 is 'Yes':

Question 6: How do you use IFC? Is it only for data exchange or you perform several other tasks using the IFC file format?

Question 7: What challenges you face while using IFC file format in to your construction delivery processes?

IFC maturity

Question 8: Overall, are you satisfied with your experience of using IFC file format?

Question 9: Is there anything which has not be asked and you would like to mention?

CHAPTER V

RESULTS AND ANALYSIS OF DATA

Chapter 4 described the research methods used to achieve the desired objective and find the answers to the research questions. It also provides the questionnaire design process, data collection method and then how to analyze the interview data collected from industry experts.

Grounded Theory is used to analyze the qualitative data. The responses are coded using axial and selective coding to find out the underlying theory in the qualitative data. “In speaking about qualitative analysis, we are referring not to the quantifying of qualitative data but rather to a non-mathematical process of interpretation, carried out for the purpose of discovering concepts and relationships in raw data and then organizing these into a theoretical explanatory scheme.” (Strauss & Corbin, 1990)

This chapter is divided into two sections: 1) Description of Interview participants, 2) Data Analysis and Discussions.

5.1 Description of interview participants

To achieve the desired objective, the research conducted a qualitative study by conducting semi-structured interviews with industry experts who are experienced in Building Information Modeling work flow during various construction processes. Table 3 shows the statistics of interview participants.

Approached	Responded	Interviewed	Response Rate
15	8	8	53.3%

Table 3 - Statistics of interview participants

Out of the 15 BIM professionals invited to participate in the research, 8 of them responded and all of them interviewed. The response rate is 53.3%. Interview participants' years of BIM experience is shown in the figure 5 below.

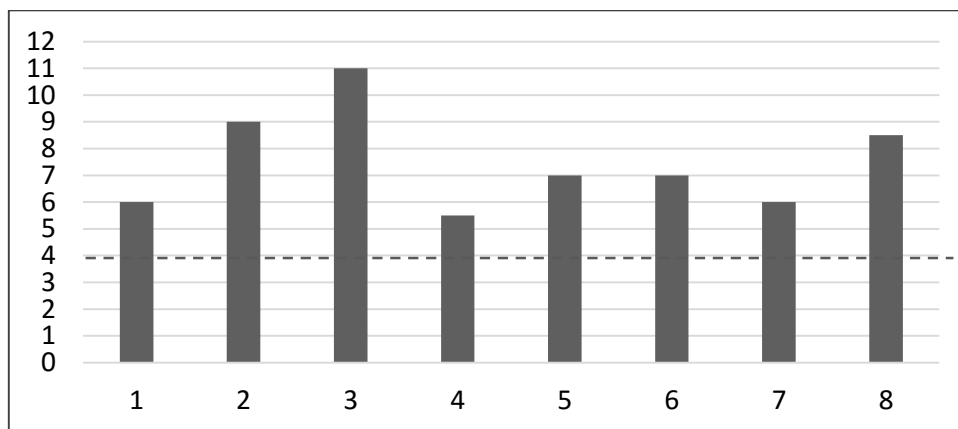


Figure 5 - Interview participants' BIM experience in number of years

5.2 Data analysis and discussions

5.2.1 BIM data exchange

Building Information Modeling Data exchange has become a necessity in every construction project. The project stakeholders share information which are authored using a wide variety of authoring application. One of the responder said that BIM data exchange is highly important for them, because for collaboration, the trade partners send them the model and they compile those models for collaboration.

Table 4 shows the frequency of BIM data exchange in the construction industry. All the eight general contractors who participated in this research, mentioned that BIM data exchange happens almost every week. As one of the general contractor said, “In our business, we have several subcontractors who joins together to accomplish several tasks. If a project is BIM enabled, then we sit together in a coordination meeting which is organized on weekly basis and after discussion, if there are any clashes, then, they have to come up with the revised model which resolves the clashes which has been discussed in the earlier coordination meeting. So, I must say that, data exchange happens at least once in a week”.

Other general contractor quoted, “When we just start with building the model, usually it is two or three uploads per week. And then once we have big meeting when everybody comes together, we compile the models, run the clash detection, make the viewpoints and markups, then we all sit together on weekly basis for an hour or two and

try to see who is going to move and who is going to fix what. So we compile our models into Navisworks once everybody sends their model.”

General Contractors									
Frequency of Data Exchange	1	2	3	4	5	6	7	8	Total
It depends on the stage of project.	X	X	X	X	X	X	X	X	8
At least once every week.	X	X	X	X	X	X	X	X	8

Table 4 - Frequency of BIM data exchange in industry

Furthermore, all the experts who participated in this research also mentioned that, frequency of BIM data exchange totally depends on the phase and status of the project. Sometimes when the project is in initial phase where the sub-contractors are building the model, the exchange could be two or three times per week. As the project reaches to a phase where the GC compiles all the models for coordination meeting, the number of BIM data exchange could vary based on who has to update their Building Information Model and how serious the changes are. As one of the general contractor said, “I cannot say a number (for BIM data exchange). But it depends on type of project and phase of the project. But mostly, the exchange happens if there are any change in the model after the

coordination meeting because the stakeholders have to update their building information model based on the discussion in the coordination meeting. This coordination meeting could be once or twice a week. But at the same time, we do several one to one coordination session and that time also, we have to exchange the updated models so that everybody remains on the same page and using the most updated model.”

5.2.2 IFC usage in industry

IFC adoption

The General Contractors had varied responses when they have been asked if they are using Industry Foundation Classes, which is dot IFC file format, for data exchange. Table 5 shows the various reasons cited by the industry participants for IFC adoption. Out of eight responders, seven of them are using IFC at least for something. However, there are varied motivations behind using IFC in their work process. Most of the general contractors are using IFC for transferring the structure file from the BIM authoring tool of structural engineers to the BIM analysis tools.

General contractors agreed that, many of the steel fabricators are using Tekla for building their information models and it is difficult to import the Tekla file into the Autodesk BIM Authoring tool such as Navisworks, Revit etc. One of the general contractor mentioned that, “We are asking our steel subcontractors to send both IFC as well as DWG file format. The reason for asking both the file format is, because DWG file format is good for performing all kind of clash detection because it is light and smooth, but unfortunately, in DWG, it does not export the all the information related to a particular

object. In this case IFC is a good substitute.” Another GC said that, “All of the three projects on which I have worked, IFC is only for the steel fabricators. Usually the IFC files are very large and that’s the reason I avoid it to use in our workflow. But we do not have any other option when it comes to importing the steel fabrication file from the Tekla BIM authoring tools”.

	General Contractors								
Reason for using IFC	1	2	3	4	5	6	7	8	Total
Only for exchange of Structural BIM Data	X	X	X	X		X	X	X	7
As Part of Sign Off Process		X			X				2
To save snapshot of the project at a particular time		X							1

Table 5 - General contractor’s motivation behind using Industry Foundation Classes file format (.IFC)

General contractors agreed that, many of the steel fabricators are using Tekla for building their information models and it is difficult to import the Tekla file into the Autodesk BIM Authoring tool such as Navisworks, Revit etc. One of the general

contractor mentioned that, “We are asking our steel subcontractors to send both IFC as well as DWG file format. The reason for asking both the file format is, because DWG file format is good for performing all kind of clash detection because it is light and smooth, but unfortunately, in DWG, it does not export the all the information related to a particular object. In this case IFC is a good substitute.” Another GC said that, “All of the three projects on which I have worked, IFC is only for the steel fabricators. Usually the IFC files are very large and that’s the reason I avoid it to use in our workflow. But we do not have any other option when it comes to importing the steel fabrication file from the Tekla BIM authoring tools”

For some of the General contractors, Industry Foundation Classes is the part of their sign off process too. Out of the eight general contractors, two of them mentioned that owners usually ask for IFC file format and hence, for some of the projects, they have to submit the IFC file as part of sign off process. When asked about, why owner requests IFC files of the project, one of the GC mentioned, “That’s because IFC might be useful for their further processes. I do not know what owners do with that file. But for the purpose of general building construction software such as Revit, Navisworks etc., IFC document is not useful”.

One of the General contractor who are using IFC file format for sign off process cited that, “Sometimes we use IFC to save snapshot of the model while it takes shape. The reason for saving the information model into IFC at regular interval is that, IFC files are non-editable and it is therefore, a more reliable source to review the model development through the various construction phases”.

In summary, all the general contractors together cited three potential reasons for using IFC:

- 1) To import the steel structural BIM data exported from the BIM authoring tool Tekla, which currently widely used by the steel structural designer and the steel fabricators.
- 2) For some GCs, IFC has become a part of sign off process where the GCs have to export the BIM data to the IFC format and submit it to owner. Although, what owner does with the IFC file is not known.
- 3) IFC is being also used to save the various stages of model development in different phases of the construction process. That is, IFC is used for sustainable Building Information Model's Data Management.

Why not using IFC?

A number of barriers for IFC adoption and implementation has been cited by the General contractors. All the eight General Contractors had mixed responses when asked about the reasons for not using or limited use of IFC in their construction process.

Table 6 shows the various reasons cited by the industry professional behind limited or no use of IFC in their construction delivery process. Out of all the reasons cited by GCs for not using IFC or limited use of IFC, the most cited reason is the data loss while importing and exporting the IFC file format. One of the GC mentioned that, "The main problem with IFC is that, it is very hard to coordinate with VDC applications. So, actually, when we import the IFC file format into our programs such as AutoCAD, Navisworks and others, there coordinate points are not aligned with our coordinate system, because IFC

file format does not saves the shared coordinate system and it is hard to find the actual coordinate points.” Other GC cited that, “Sometime some model elements do not export to the IFC file format. So the IFC export is useless if we lose information during the export”.

General Contractors									
Reason for not using or limited use of IFC	1	2	3	4	5	6	7	8	Total
File size is large.			X			X	X	X	4
Geometry changes while importing.		X	X						2
Making changes in IFC file is difficult.		X							1
IFC file loses parametric intelligence.		X						X	2
Some data is lost or do not export.		X			X	X		X	4
We prefer not to use IFC.	X						X		2

Table 6 - General contractor’s reasons behind not using Industry Foundation Classes file format (.IFC)

Out of all the reasons cited by GCs for not using IFC or limited use of IFC, the most cited reason is the data loss while importing and exporting the IFC file format. One of the GC mentioned that, “The main problem with IFC is that, it is very hard to coordinate with VDC applications. So, actually, when we import the IFC file format into our programs such as AutoCAD, Navisworks and others, there coordinate points are not aligned with our coordinate system, because IFC file format does not saves the shared coordinate system and it is hard to find the actual coordinate points.” Other GC cited that, “Sometime some model elements do not export to the IFC file format. So the IFC export is useless if we lose information during the export”.

Four of the responders out of eight cited that, IFC file size, which is usually larger than the file type of their parent BIM authoring tool, is the reason behind no or limited use of IFC into their BIM process. As one of the respondent said, “The subcontractors are embedding lots of constructible information into their Building Information Model and hence, the file sizes are getting bigger and bigger day by day. Exporting their models into IFC is further increasing the file size and hence making the entire process slow. Therefore, file size of IFC format is a concern for us. We cannot afford to lose the time wasted in slow performance of our models.” Other respondent mentioned that, “File size of IFC is a real problem for us because it takes lots of time uploading and downloading the files. Once it has been downloaded, we have high power computers to handle any file size. But still we try to avoid using IFC because it takes forever to download and upload the files”.

Some responders mentioned that inability to modify the IFC file is one of the reason behind no or limited use of IFC in their work process. The GC said, “IFC files are

difficult to modify. So after coordination, if we have to modify a particular element, the process is really difficult and if we submit our IFC models to owners, then they cannot do anything with the model. Also, the IFC model loses the parametric intelligence, because of that also the modification in IFC file is time consuming.” Other GC cited that, they do not need IFC to be parametric intelligent because as GC, their role is just to facilitate coordination and all the modifications into the models are performed by the subcontractor who are responsible for procuring their scope of work at jobsite.

Two of the general contractors expressed their reluctance to use IFC for any process. One of the GC said, “All of the three projects on which I have worked, IFC is only for the steel fabricators. But for all other subcontractors, .DWG and .RVT works best for us because most of our subcontractors are working on Autodesk authoring tools”.

In summary, GCs have varied reasons behind not using IFC for data exchange or any other process. But, some of them were just reluctant to use IFC without providing any reasons behind their reluctance.

5.2.3 Interoperability problems in industry

Table 7 shows a snapshot of the workarounds adopted by industry to avoid the non-interoperability problems. Despite the promises of Industry File Format to solve the interoperability problems in construction industry, some GCs has their own way of dealing with the existing interoperability problems. Some of the workarounds to avoid non-interoperability problems which GCs are using, to build the entire sub-contractors model

in parallel with them and restrict the subcontractors by a contract to submit a particular file format only.

General Contractors									
Workaround for Interoperability Problems	1	2	3	4	5	6	7	8	Total
We build our model in parallel with the subcontractors.		X							1
We specify the BIM data exchange file format in our contract.	X		X						2
Our sub-contractors are using Autodesk BIM Authoring tools.					X				1

Table 7 - Workarounds adopted by GCs to the interoperability problems

As one of the GC mentions that building a model in parallel with the subcontractors is the solution to their interoperability problem, “we rebuild our model for all sort of analysis and visualization. For example, our trade partners have separate model for prefabrication. So, we build our model for construction delivery in parallel with them. I know this is an efficient process, but we do not have a solution for this. Also, most of our

trade partners work on Autodesk products mainly AutoCAD and Revit for building their model. In that case, the 3D model exchange is easy for us because almost all the BIM tools have the capability to import these file formats. If not, then we prefer to make our models in parallel with our sub-contractors.”

Some GC uses the binding contract for their subcontractors to submit some specific file formats which the GCs could easily import and export into their BIM authoring tool. One of the GC who does so cites, “Most of our subcontractors are using Autodesk software. If they are using anything else, then it’s always been bound in the contract that they have to use one of those. If they want to use some other third party application then the sub-contractors have to somehow convert their files so that it could be usable in our BIM Authoring tool which is Navisworks by Autodesk”.

Only one out of the eight general contractors has mentioned that, they are not facing interoperability problems because all of their sub-contractors are using Autodesk BIM authoring tools. As the GC quotes, “Currently, most of them (sub-contractors) are exporting NWC or DWG file format because almost every Autodesk software now have an export option to those formats. So, once they export, we are able to easily import that information into our Navisworks platform and BIM 360 Glue platform”. This general contractor also mentions about the ease of file sharing by using cloud BIM platforms where instead of exchanging the BIM data, the project participants could easily upload and update their scope of work. As the GC mentions, “After we moved to the cloud platform i.e. BIM 360 Glue, we provide access to the files to owners too. Owners can see the progress in real time. So, no more sending the BIM data to owners every time. Also,

sub-contractors can upload their model into the cloud and BIM 360 Glue does everything for us”.

CHAPTER VI

CONCLUSIONS AND FUTURE WORK

6.1 Conclusions

This study aims to identify the current state of IFC in terms of its adoption and non-adoption reasons, its use in the project life cycle, industry's evaluation of the IFC's maturity as well as the way industry professional are tackling the non-interoperability problems. To achieve the desired objective, the research conducts a qualitative study by conducting semi-structured interviews with industry experts who are experienced in the usage of IFC in the Building Information Modeling work flow during various construction processes. The qualitative data received from the industry experts are analyzed using Grounded Theory to form the theories inherent into the data.

The study reveals that, despite the advancements in the IFC structure and increasing number of tools which provide IFC import and export capabilities, there are still limited use of Industry Foundation Classes in the construction Industry. Industry is reluctant to use the IFC files for data exchange because of the various challenges which they face while using IFC in their construction delivery process.

6.1.1 BIM data exchange

BIM data exchange has become an integral process during the coordination process. The sub-contractors shares their Building Information Model authored using a wide variety of BIM authoring tools. There is no definite frequency for exchange of the BIM data since it depends on the stage of the project.

6.1.2 IFC usage in industry

Despite the advancement in IFC schema, GCs are still facing several problems which using IFC in their work process. The loss of data during the import and export of IFC files remains the biggest reason for limited or no-use of IFC by the general contractors. Furthermore, few GCs are still reluctant to use IFC without providing any specific reasons behind their reluctance. But, there are still some application of IFC in the industry such as for exchange of steel structural BIM data, sign off process and sustainable data management.

Seven out of eight GCs said that, they are using IFC for exchange of steel structural information because they their sub-contractors are using Tekla for building the steel structural model. Two out of eight GCs mentioned that, IFC file submission is part of their sign off process. While one of the eight said that, they are using IFC for saving the project snapshot and development timeline of their Building Information Model.

Four out of eight GCs mentioned that, huge file size of IFC and data loss during import and export of IFC files are the main reasons behind non-usage or limited usage of IFC. Two of the eight GCs said that, loss of parametric intelligence in IFC file format is a problem for them. While, others argued that, since as a GC their role is just to facilitate coordination, so even if the IFC file loses the parametric intelligence and they are difficult to update, it is not a problem for them because they are not the ones who are going to update the model. It is the responsibility of sub-contractors to update the models of their scope of work.

6.1.3 Interoperability problems in industry

Inefficiency because of the non-interoperability of BIM data still exists in the industry. To avoid these interoperability problems, some of the GCs are forming a binding contract with the sub-contractors to submit only specific file formats which are interoperable to their BIM authoring tools. At the same time, wide application of Autodesk authoring tools is helping the industry to lessen the non-interoperability problems.

Two of the eight GCs interviewed mentioned that, they are forcing their sub-contractors by a binding contract to work on a software platform which is easily interoperable to their BIM tool. While one of the GC mentioned that, since all of their stakeholders are using Autodesk's BIM authoring tools, their data exchange process does not need IFC.

6.2 Limitations

Followings are the limitations of this study:

1. The scope of study is targeted only to the top fifteen Commercial General Contractors in the United States.
2. The findings presented in the research are compiled based on the individual opinions provided by the industry professionals.
3. The research findings are presented based on the eight interviews conducted. It cannot be generalized for the entire construction industry.

6.3 Future work

This research is targeted to only the top commercial general contractors. In order to find a comprehensive overview of the IFC state in terms of adoption and interoperability problems, the sample of the research could be extended to more General contractors along with engineers, sub-contractors and facility managers.

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APPENDIX A: IRB APPROVAL

DATE: February 04, 2016

MEMORANDUM

Title: INVESTIGATING CURRENT STATE OF INDUSTRY FOUNDATION CLASS
(IFC) IN CONSTRUCTION INDUSTRY

Date of Determination:

Approval Date: 11/17/2015

Continuing Review Due: 10/15/2016

Expiration Date: 11/15/2016

Documents Reviewed and Approved:

- Only IRB-stamped approved versions of study materials (e.g., consent forms, recruitment materials, and questionnaires) can be distributed to human participants. Please log into iRIS to download the stamped, approved version of all study materials. If you are unable to locate the stamped version in iRIS, please contact the iRIS Support Team at 979.845.4969 or the IRB liaison assigned to your area.

Document of Consent: Written consent in accordance with 45 CF 46.116/ 21 CFR

50.27

Submission Components			
Study Document			
Title	Version Number	Version Date	Outcome
Sachin Singh_Revised proposal	Version 1.0	02/01/2016	Approved
Email copy	Version 1.0	02/01/2016	Approved
Study Consent Form			
Title	Version Number	Version Date	Outcome
Consent form	Version 1.0	02/01/2016	Approved

Comments:

- Change in protocol approved. Enrollment changed from 1200 to 15, signed consent now necessary.
- Research is to be conducted according to the study application approved by the IRB prior to implementation.
- Any future correspondence should include the IRB study number and the study title.

Investigators assume the following responsibilities:

1. **Continuing Review:** The study must be renewed by the expiration date in order to continue with the research. A Continuing Review application along with required documents must be submitted by the continuing review deadline. Failure to do so may result in processing delays, study expiration, and/or loss of funding.
2. **Completion Report:** Upon completion of the research study (including data collection and analysis), a Completion Report must be submitted to the IRB.

3. **Unanticipated Problems and Adverse Events:** Unanticipated problems and adverse events must be reported to the IRB immediately.
4. **Reports of Potential Non-compliance:** Potential non-compliance, including deviations from protocol and violations, must be reported to the IRB office immediately.
5. **Amendments:** Changes to the protocol and/or study documents must be requested by submitting an Amendment to the IRB for review. The Amendment must be approved by the IRB before being implemented.
6. **Consent Forms:** When using a consent form or information sheet, the IRB stamped approved version must be used. Please log into iRIS to download the stamped approved version of the consenting instruments. If you are unable to locate the stamped version in iRIS, please contact the iRIS Support Team at 979.845.4969 or the IRB liaison assigned to your area. Human participants are to receive a copy of the consent document, if appropriate.
7. **Post Approval Monitoring:** Expedited and full board studies may be subject to post approval monitoring. During the life of the study, please review and document study progress using the PI self-assessment found on the RCB website as a method of preparation for the potential review. Investigators are responsible for maintaining complete and accurate study records and making them available for post approval monitoring. Investigators are encouraged to request a pre-initiation site visit with the Post Approval Monitor. These visits are designed to help ensure that all necessary documents are approved and in

order prior to initiating the study and to help investigators maintain compliance.

8. **Recruitment:** All approved recruitment materials will be stamped electronically by the HRPP staff and available for download from iRIS. These IRB-stamped approved documents from iRIS must be used for recruitment. For materials that are distributed to potential participants electronically and for which you can only feasibly use the approved text rather than the stamped document, the study's IRB Study Number, approval date, and expiration dates must be included in the following format: TAMU IRB#20XX-XXXX Approved: XX/XX/XXXX Expiration Date: XX/XX/XXXX.
9. **FERPA and PPRA:** Investigators conducting research with students must have appropriate approvals from the FERPA administrator at the institution where the research will be conducted in accordance with the Family Education Rights and Privacy Act (FERPA). The Protection of Pupil Rights Amendment (PPRA) protects the rights of parents in students ensuring that written parental consent is required for participation in surveys, analysis, or evaluation that ask questions falling into categories of protected information.
10. **Food:** Any use of food in the conduct of human research must follow Texas A&M University Standard Administrative Procedure 24.01.01.M4.02.
11. **Payments:** Any use of payments to human research participants must follow Texas A&M University Standard Administrative Procedure 21.01.99.M0.03.

12. **Records Retention:** Federal Regulations require records be retained for at least 3 years. Records of a study that collects protected health information are required to be retained for at least 6 years. Some sponsors require extended records retention. Texas A&M University rule 15.99.03.M1.03 Responsible Stewardship of Research Data requires that research records be retained on Texas A&M property.

APPENDIX B: INVITATION LETTER FOR INTERVIEW

Date:

Subject: Invitation to participate in the research

Dear [NAME],

Since you are construction industry professional with at least 5 years of experience in who Building Information Modeling / Virtual design and construction tools, you are invited to participate in a study evaluating the IFC usage in project delivery systems. The interview will not take more than 25-30 minutes and it's very informal. Your responses will be kept confidential by using a number code. Participation to the interview is voluntary. Your participation to the interview will be a valuable addition to our research and findings.

This study is conducted by Sachin Singh, a construction science department's graduate student at Texas A&M University. The study involves a survey questionnaire and you should be able to complete it within 15-20 minutes or less. Compensation is not available.

If you are willing to participate then please suggest a date and time that suits you. If you have any question, please do not hesitate to ask.

If you have any questions or concerns about the research, please feel free to contact us.

APPENDIX C: PARTICIPANT CONSENT FORM

Project Title: INVESTIGATING THE CURRENT STATE OF IFC APPLICATION IN CONSTRUCTION INDUSTRY

You are invited to take part in a research study being conducted by Sachin Singh, a researcher from Texas A&M University. The information in this form is provided to help you decide whether or not to take part. If you decide you do not want to participate, there will be no penalty to you, and you will not lose any benefits you normally would have.

Why Is This Study Being Done?

The purpose of this study is to investigate the current state of IFC (Industry Foundation Class) in terms of adoption and usage percentages, AEC (Architecture, Engineering and Construction) industry's attitudes towards IFC, its place in the construction timeline, as well as the industry's evaluation of the IFC's maturity.

Why Am I Being Asked To Be In This Study?

You are being asked to be in this study because you are a construction professional having at least 5 years of industry experience using BIM and VDC in your project delivery systems.

How Many People Will Be Asked To Be In This Study?

15 industry experts will be invited to participate in this study locally.

What Are the Alternatives to being in this study?

No, the alternative to being in the study is not to participate.

What Will I Be Asked To Do In This Study?

If you volunteer to participate in this study, you will be asked to answer structured questions regarding IFC and how your firm uses IFC in its construction project delivery process. It will take 20-25 minutes.

Are There Any Risks To Me?

Although the researchers have tried to avoid risks, you may feel that some questions/procedures that are asked of you will be stressful or upsetting. You do not have to answer anything you do not want to.

Will There Be Any Costs To Me?

Aside from your time, there are no costs for taking part in the study.

Will I Be Paid To Be In This Study?

You will not be paid for being in this study.

Will Information From This Study Be Kept Private?

The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely. Information about you will be stored in computer files protected with a password. Information about you and related to this study will be kept confidential to the extent permitted or required by law.

Who may I Contact for More Information?

If you have any questions or concerns about the research, please feel free to contact:

Sachin Singh, Texas A&M University, College Station, USA

Phone Number: (469) 767 9279, Email: sachin2411@tamu.edu

For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research, you may call the Texas A&M University Human Subjects Protection Program office at (979) 458-4067 or irb@tamu.edu.

What if I Change My Mind About Participating?

This research is voluntary and you have the choice whether or not to be in this research study. You may decide to not begin or to stop participating at any time.

By participating, you are giving permission for the investigator to use your information for research purposes.

Thank you.

Sachin Singh

SIGNATURE OF RESEARCH PARTICIPANT

I have read the information provided above. I have been given a chance to ask questions. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Name of Participant

Signature of Participant

Date

SIGNATURE OF INVESTIGATOR

I have explained the research to the participant and answered all of his/her questions. I believe that he/she understands the information described in this document and freely consents to participate.

Name of Person Obtaining Consent

Signature of Person Obtaining Consent

Date

APPENDIX D: INTERVIEW TRANSCRIPT

GC Code: GC01

Interviewer: Do you exchange Building Information modeling data with other project stakeholders during the construction phase?

Interviewee: We have a contract with the sub-contractors to provide their model and send it to us. As a General Contractor, we facilitate the coordination of all the individual models. So, we do exchange the BIM models with other sub-contractors.

Interviewer: How frequently the exchange of BIM data happens with project participants?

Interviewee: When we just start with building the model, usually it is two or three uploads per week. And then once we have big meeting when everybody comes together, we compile the models, run the clash detection, make the viewpoints and markups, then we all sit together on weekly basis for an hour or two and try to see who is going to move and who is going to fix what. So we compile our models into Navisworks once everybody sends their model.

Interviewer: Do you use Industry Foundation Classes file format which is dot IFC file extension?

Interviewee: All of the three projects on which I have worked, IFC is only for the steel fabricators. Usually the IFC files are very large and that's the reason I avoid it to use in our workflow. But we do not have any other option when it comes to importing the steel fabrication file from the Tekla BIM authoring tools. But for all other subcontractors,

.DWG and .RVT works best for us because most of our subcontractors are working on Autodesk authoring tools.

Interviewer: How the collaboration happens if your sub-contractors do not use Autodesk software?

Interviewee: Well, most of our subcontractors are using Autodesk software. If they are using anything else, then it's always been bound in the contract that they have to use one of those. If they want to use some other third party application then the sub-contractors have to somehow convert their files so that it could be usable in our BIM Authoring tool which is Navisworks by Autodesk.

Interviewer: Apart from the file size problem, have you faced any other challenges while using IFC?

Interviewee: No, they still import the exact same. File size of IFC is a real problem for us because it takes lots of time uploading and downloading the files. Once it has been downloaded, we have high power computers to handle any file size. But still we try to avoid using IFC because it takes forever to download and upload the files

Interviewer: What is your signoff process? Which type of file formats are preferable?

Interviewee: We have actual sign off sheets that both the subcontractor and we sign together. We also have the meeting with the owner. When everybody completes their scope of work, we have a form saying our models are complete and 100% free, also there are no pending RFIs etc. Then we present all the signed documents to owner. We do a quick model fly through and then we do a discussion. So, if the owner has any concern then we give our sub-contractors five days to comment on those concerns.

Interviewer: So, what format of documents they ask for?

Interviewee: In the end they ask for NWD file formats. They also want editable file formats too, that is the native file, the original sub-contractors model.

Interviewer: What happens ones you submit the models to owner? Do you coordinate with facility managers so that they can utilize your models for facility management?

Interviewee: What happens is we also walk with all the Facility Managers. We fly through the model with them we provide them training. We do not want to give them something which they do not know how to use.

GC Code: GC02

Interviewer: Do you exchange Building Information modeling data with other project stakeholders during the construction phases?

Interviewee: Yes, BIM data exchange is highly important for us, because for collaboration, the trade partners send us the model and we compile them for collaboration. We typically use a wide arrays of software, few of them are Navisworks Manage, Synchro Pro, Autodesk Revit etc. We see various challenges while importing the information from our sub-contractors or trade partners while performing collaborative tasks.

Interviewer: How frequently the exchange of BIM data happens with project participants?

Interviewee: I cannot say a number. But it depends on type of project and phase of the project. But mostly, the exchange happens if there are any change in the model after the coordination meeting because the stakeholders have to update their building information model based on the discussion in the coordination meeting. This coordination meeting could be once or twice a week. But at the same time, we do several one to one coordination session and that time also, we have to exchange the updated models so that everybody remains on the same page and using the most updated model.

Interviewer: Do you use Industry Foundation Classes file format which is dot IFC file extension?

Interviewee: Well, we use IFC but the use is limited. Sometimes we use IFC to save snapshot of the model while it takes shape. The reason for saving the information model

into IFC at regular interval is that, IFC files are non-editable and it is therefore, a more reliable source to review the model development through the various construction phases. Sometime, IFC is part of our sign off process along with 3D PDF. But, for data exchange we still see various challenges with Industry Foundation Classes. Even, IFC is not solving our interoperability problems.

Interviewer: Then, how do you deal with interoperability problem?

Interviewee: Well, we rebuild our model for all sort of analysis and visualization. For example, our trade partners have separate model for prefabrication. So, we build our model for construction delivery in parallel with them. I know this is an efficient process, but we do not have a solution for this. Also, most of our trade partners work on Autodesk products mainly AutoCAD and Revit for building their model. In that case, the 3D model exchange is easy for us because we almost all the BIM tool has the capability to import these file formats. If not, then we prefer to make our models in parallel with our sub-contractors.

Interviewer: You mentioned about the challenges while using IFC in your collaboration process. Could you please highlight those challenges?

Interviewee: There are many. First, some of the information does not get exported while writing an IFC file. Also the geometry of the model changes when you import it into some other software application even if the software provides import option of IFC. Second, IFC files are difficult to modify. So after coordination, if we have to modify a particular element, the process is really difficult and if we submit our IFC models to owners, then they cannot do anything with the model. Also, the IFC model loses the

parametric intelligence, because of that also the modification in IFC file is time consuming. So IFC is not the solution to the interoperability problems which we face day to day in our process.

Interviewer: Would you like to add anything which I have not asked?

Interviewee: Well, currently IFC is just part of our sign off process. Even, if you want to look through the model, 3D PDF does a better job than IFC. 3D PDFs are easy to visualize and walk through.

GC Code: GC03

Interviewer: Do you exchange Building Information modeling data with other project stakeholders during the construction phases?

Interviewee: We do. As a GC, we just assemble the model for coordination. All the subs (subcontractors) build their model and send their models to us. So, we compile the models and do all sorts of analysis, mostly clash detection.

Interviewer: How frequently the exchange of BIM data happens with project participants?

Interviewee: Well, the sub-contractors provides their updated model once we raise a concern or we send them a markup. So, I must say, the exchange twice or thrice in a week. At the same time, it totally depends on the number of clashes and deadline to resolve them.

Interviewer: So, do you use Industry Foundation Classes file format which is dot IFC file extension?

Interviewee: We usually do use IFC for exchange of steel structure files only.

Interviewer: How about the other trades?

Interviewee: For all other trades, they send us NWD files or DWG files. This is mostly because for mechanical, electrical, fire and plumbing subcontractors, they are using Revit for modeling.

Interviewer: Then, how do you deal with interoperability problems if you face any?

Interviewee: As I said, other than the steel subcontractor, all our sub-contractors are using Revit for building their models. We also specify in the contract about the acceptable file formats for model sign off.

Interviewer: Have you faced any problems while using IFC file format for data exchange?

Interviewee: We have tried IFC for few projects but it did not worked well for us. Somehow, the file size of IFC is huge. I do not know the reason by its like 5-10 times larger than the usual formats. Second, IFC import is not reliable. It changes the geometry of the shape somehow. Did that answer your question?

Interviewer: Yes

GC Code: GC04

Interviewer: Do you exchange Building Information modeling data with other project stakeholders during the construction phases?

Interviewee: Ya, so for one the Hospital project, a large scale project. It involves lots of complex MEP systems and we are using BIM to plan our construction process. So for that we keep on exchanging the both digital and hard copy information quite frequent, CAD files, BIM files etc. All of these are kept on the central server so that they could refer it to whenever they want.

Interviewer: How frequently the exchange of BIM data happens with project participants?

Interviewee: Well it is on weekly basis, but that's not a rule. Sometimes, it could be more frequent and sometimes it could be less. The building services are very complex and almost every day we end up with some clashes which has to be resolved so that others could make progress.

Interviewer: So, what is your current workflow for coordination? What software packages do you use?

Interviewee: We use BIM 360 for overview and creating mark ups, and for clash detection we use Navisworks. This is where we append all the models together and see through the conflicts in a weekly meeting. Once we find the clashes, we group them according to who has to move and then the author of the model will then modify their respective scope.

Interviewer: So, do you use Industry Foundation Classes file format which is dot IFC file extension?

Interviewee: Ya, basically, people who use Tekla for example the steel industry where Tekla is the most common software. So to import their model, the only way is the IFC files. Navisworks cannot import the Tekla files. So we ask for IFC files. Other than that, we have not used IFC for any of the trades.

Interviewer: Why you do not ask for a DWG file exported from Tekla?

Interviewee: We are asking our steel subcontractors to send both IFC as well as DWG file format. The reason for asking both the file format is, because DWG file format is good for performing all kind of clash detection because it is light and smooth, but unfortunately, in DWG, it does not export the all the information related to a particular object. In this case IFC is a good substitute.

Interviewer: Then, how do you deal with interoperability problems if you face any?

Interviewee: As I said, we face this problem only in case of steel models. In that case, we use IFC. Rest of the models could be easily importable into ours. MEP people are using Autodesk tools and importing anything from there into our Navisworks file is easy.

Interviewer: Have you faced any problems while using IFC file format for data exchange?

Interviewee: I have never faced any problem with IFC. The output is as good, as the other file formats.

Interviewer: Yes, Would you like to add anything which I have not asked?

Interviewee: Well, currently IFC is just part of our sign off process. Even, if you want to look through the model, 3D PDF does a better job than IFC. 3D PDFs are easy to visualize and walk through.

GC Code: GC05

Interviewer: Do you exchange Building Information modeling data with other project stakeholders during the construction phases?

Interviewee: Yes, we do. In fact, this is a necessity now. We want a fully coordinated models before we go to the site.

Interviewer: How frequently the exchange of BIM data happens with project participants?

Interviewee: Well it depends on what phase of construction we are in. Sometimes, we have to exchange the files almost every day or sometime it happens only if we have some kind of clashes or error and we have to send the updated model to our sub-contractors as soon as possible. On an average, we have weekly coordination review meeting for almost all the projects and the sub-contractors send their models if there are any updates.

Interviewer: Do you use Industry Foundation Classes file format which is dot IFC file extension?

Interviewee: We were using IFC for data exchange with the steel contractors because they were using some other third party software which was not interoperable to our program. So, we just converted their file format so that we could import them into our program. But, that was for a single project three years ago when we did not had any options to bring the steel structural model into our application.

Interviewer: Was this only for steel contractors? What about the other subcontractors? How do you exchange the BIM data from them?

Interviewee: MEP contractors were using Revit and AutoCAD MEP. So typically, it was not required by them to export the file as IFC because our programs could easily import the Autodesk compatible file formats. Sometimes, it is up to owners. If they want IFC documents to be handed over, then we deliver the IFC document to the owner. Other than that, from general contractor point of view, there is no value to IFC.

Interviewer: Why does owner asks for IFC? Can't they take other file formats such as the ones by Autodesk?

Interviewee: That's because IFC might be useful for their further processes. I do not know what owners do with that file. But for the purpose of general building construction software such as Revit, Navisworks etc., IFC document is not useful.

Interviewer: So what owner is doing with that IFC document?

Interviewee: It is totally up to them. Some owners does use IFC but some are not using it at all. Once, we submit our models to the owners.....umm... I do not what they are using it (IFC) for.

Interviewer: So is it like, IFC submission, sometimes, are just part of your sign off process?

Interviewee: Yes, most of the time it is part of the sign off process where we export the models in IFC and submit it to owners.

Interviewer: You mentioned that you used IFC before but you are not using now. What challenges you face while you use IFC for data exchange?

Interviewee: The main obstacle while using IFC is that, IFC is very hard to coordinate with VDC applications. So, actually, when we import the IFC file format into our

programs such as AutoCAD, Navisworks and others, their coordinate points are not aligned with our coordinate system, because IFC file format does not save the shared coordinate system and it is hard to find the actual coordinate points.

Interviewer: Is there any other reason apart from what you mentioned just now?

Interviewee: We do not use it anymore, so I do not know other problems. But, there are many problems and IFC has no value for us.

Interviewer: So, how do you import now the models from your steel contractors?

Interviewee: Currently, all of them are exporting into NWC or DWG file format because almost every software now has an export option to those formats. So, once they export, we are able to easily import that information into our Navisworks platform and BIM 360 Glue platform. After we moved to the cloud platform i.e. BIM 360 Glue, we provide access to the files to owners too. Owners can see the progress in real time. So, no more sending the BIM data to owners every time. Also, sub-contractors can upload their model into the cloud and BIM 360 Glue does everything for us.

Interviewer: Do you like to add anything which I have not asked?

Interviewee: Well, IFC has no value for us. We are doing almost everything without using IFC. In terms of building coordination, I am not facing any problem. With the Autodesk dominated market and the cloud BIM services, the interoperability problem is not there anymore for us.

GC Code: GC06

Interviewer: Do you exchange Building Information modeling data with other project stakeholders during the construction phases?

Interviewee: Yes we do.

Interviewer: Can you please elaborate why you exchange and what is the frequency of exchange?

Interviewee: Well, in our business, we have several subcontractors who joins together to accomplish several tasks. If a project is BIM enabled, all the partners have to send the model and then we sit together in a coordination meeting which is organized on weekly basis and after discussion, if there are any clashes, then, they have to come up with the revised model which resolves the clashes which has been discussed in the earlier coordination meeting. So, I must say that, data exchange happens at least once in a week.

Interviewer: Do you use Industry Foundation Classes file format which is dot IFC file extension?

Interviewee: We have used IFC a couple of times for exchange of structural fabricator files.

Interviewer: Was this only for steel contractors? What about the other subcontractors? How do you exchange the BIM data from them?

Interviewee: Only for the structural files. Rest of them send us either the RVT or Navisworks file. I meant MEP sub-contractors use RVT or Navisworks file formats. We use Navisworks for coordination so, other sub-contractors file formats are not a problem for us.

Interviewer: What challenges you face while you use IFC for data exchange?

Interviewee: The most important one is the file size. The subcontractors are embedding lots of constructible information into their Building Information Model and hence, the file sizes are getting bigger and bigger day by day. Exporting their models into IFC is further increasing the file size and hence making the entire process slow. Therefore, file size of IFC format is a concern for us. We cannot afford to lose the time wasted in slow performance of our models.

Interviewer: Apart from file size, have you faced any other problems?

Interviewee: Well, we find that sometimes, when we import the IFC file into our BIM authoring tool, some part of the model does not show up in the IFC export.

Interviewer: Then what do you do to fix these problems?

Interviewee: Well, we do several trial and errors until we get a good result.

GC Code: GC07

Interviewer: Do you exchange Building Information modeling data with other project stakeholders during the construction phases?

Interviewee: We ask our sub-contractors to send their models, because we run the coordination meeting. So yes, we do exchange BIM model with each other.

Interviewer: Can you please elaborate why you exchange and what is the frequency of exchange?

Interviewee: So, in a project, where we are using BIM, we chose the sub-contractors who are capable of working in BIM. Because, we do not build the model, it's the sub-contractor who makes the model and send it to us. We just provide the coordination support to our partners. So, for this coordination, the subcontractors send us the model so that we can append those models into the Navisworks and do whatever we want to do.

Interviewer: And, what is the frequency of model exchange?

Interviewee: Frequency is totally up to them and also how the project goes off. If they feel that, there are some significant update in the model then they can send it as many times they want. But ideally, we do run a coordination meeting every week to resolve the clashes and the partners at least updates their models once in a week to take care of the comments or markups which we provide to them.

Interviewer: Do you use Industry Foundation Classes file format which is dot IFC file extension?

Interviewee: Very limited. IFC is only for the structural files which are exported from Tekla.

Interviewer: So IFC is only for the exchange of structural file? What about the other subcontractors? How do you exchange the BIM data from them?

Interviewee: Yes, because Tekla is the main authoring tool for our structural guys. And, we do not have a system in Navisworks to import the Tekla file directly. So, we export the IFC file from Tekla and import it into our system. About the other sub-contractors, all of them are using Autodesk BIM tools to build their models, mostly on Revit. So importing anything from there is easy.

Interviewer: What challenges you face while you use IFC for data exchange?

Interviewee: challenges in exporting IFC?

Interviewer: I meant any problem you face when you import or export the IFC file of the structural model?

Interviewee: Well, I never faced a problem with the IFC. I have used for a couple of projects and it worked just fine. But, we prefer not to use them.

Interviewer: Is there any reason for your reluctance to use IFC?

Interviewee: IFC file sizes are usually larger than the other files which makes our compiled model heavier and it responds a little bit slow.

GC Code: GC08

Interviewer: Do you exchange Building Information modeling data with other project stakeholders during the construction phases?

Interviewee: Well, we do not build any model. It is the subcontractors who make the models of their scope of work. So, yes they do send us the model for review and coordination purpose.

Interviewer: So typically, how frequently they send the models to you?

Interviewee: That is totally up to the coordination progress. When we just start with, the progress is slow but once we have all the models, we sit in the coordination meeting to discuss if there are any potential conflicts. So exchange of the files are totally up to how many clashes are there, what are the deadlines, who are affected by the coordination and how much time it will take to update the model. But before every coordination meeting, all the subs (sub-contractors) publish their models into either the cloud or send us the models through FTP.

Interviewer: Do you use Industry Foundation Classes file format which is dot IFC file extension?

Interviewee: Well yes or no. We use it only for exchanging steel structure files. Because, Tekla is mostly used by our steel partners and it does not have an option to export the NWC file from there. So the workaround is, we import the IFC from Tekla then import the IFC into Revit and then export the NWC from Revit. We usually try to avoid the IFC file into our Navisworks because it slows down the model performance.

Interviewer: Was this only for steel contractors? What about the other subcontractors?
How do you exchange the BIM data from them?

Interviewee: Other model exchanges are not at all a problem. Our subs (sub-contractors) are using Revit MEP for producing their models and it integrates easily with our BIM tool which is Navisworks.

Interviewer: What challenges you face while you use IFC for data exchange?

Interviewee: Well we have tried importing the IFC file directly into our BIM system, but the size of the IFC file is larger than the NWC. Because of the huge file size of IFC, as I mentioned, the performance of our federated model is affected. Also, some time importing the IFC file creates total mess because some elements do not show up in the imported model. We also face problems while editing IFC because there are no parametric definitions of the objects.

APPENDIX E: VITA

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