# THE ROLE OF IFC FOR SUSTAINABLE BIM DATA MANAGEMENT

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**ABSTRACT**: As the IFC (Industry Foundation Classes) was introduced to exchange data between different BIM (Building Information Modeling) applications, construction professionals speculated how effectively it would solve the interoperability issues between these applications. Although previous investigations have demonstrated some limitations of the IFC in terms of exchanging the geometry of the components in the BIM data, no full understanding of these differences in the IFC code level has been provided yet. This paper presents the preliminary outcome of our investigation on the differences between the IFC codes of the same components created using different BIM applications such as Revit Architecture and ArchiCAD. This preliminary investigation gave us a clear idea as to how we are supposed to use the IFC to sustain the BIM data for the building's lifecycle.

***Keywords**: BIM, IFC, Sustainable Data*

## 1. INTRODUCTION

Collaboration among workers in the construction industry including designers and engineers can be enhanced through sharing the digital models for visualization, analysis, editing, and so on. In other words, it is essential for interoperability to share digital files not only between BIM (Building Information Modeling) applications shown in Table 1 but also other useful tools for designing, construction, managing and maintaining [1]. However, these applications produce outputs including geometric information, appropriate levels of detail, building components and property information based on their own embedded system-specific rules [2]. Thus, in order to exchange correct and exact data more efficiently and effectively, it is required to investigate in detail the data produced by each BIM tool.

Industry Foundation Classes (IFC) [3] represents BIM for sharing construction and facility management data across various applications used in the Architecture, Engineering, Construction and Facility Management (AEC-FM) sector [4]. Additionally, IFC provides a neutral data format which is a ISO global standard and enabling interoperability between systems [3]. So, data files produced by every BIM applications can be compared and checked according to one criterion: IFC file format.

Thus, IFC might be currently the best medium to transfer the building information between existing commercial applications. Furthermore, it could be the best way to compare various data files in the near future. Therefore, the IFC file format appears to be sustainable based on industry software trends.

However, despite plenty of active research on information technology, there are few studies that have been completed regarding data exchange rules, and quality assurance and code level analyzing [6]. In this paper, a computer simulation test will be conducted. IFC files are created from two BIM applications and the data exchange capabilities of building model data are checked. Additionally, the data is compared in code level based on the neutral data file format of the IFC. This study will determine whether data exported from a BIM tool can be modified or edited with ease in another BIM tool. Finally, the results of this study will identify how IFC can be more fully exploited to develop effective collaborative workflows. This is necessarily the first step to be taken in order to increase the possibility of sustainable data.

It is assumed that this preliminary study for data exchange attributes to suggest a standardized and application-independent format and process specification. This specification enhances the ability of exchanging data among applications and reduces the gap of outputs from each application. Ultimately, it is expected that the redundant cost and time for the whole life cycle of a building or a structure are decreased.

| Software Developer | Software Application | Exchange Requirement | Import / Export |
|---|---|---|---|
| Archimen | Active3D | - | O / X |
| Autodesk | AutoCAD Architecture | Architecture | O / O |
| | AutoCAD MEP | BuildingServices | O / X |
| | Revit Architecture | Architecture | O / O |
| Bentley Systems | Bentley Architecture | Architecture | O / O |
| Data Design System | DDS-CAD MEP | BuildingService | X / O |
| Design Data | SDS/2 | Structural | O / O |
| Gehry Technologies | Digital Project | Architecture | O / O |
| Graphisoft | ArchiCAD | Architecture | O / O |
| NEMETSCHEK Allplan | Allplan | Architecture | O / O |
| NEMETSCHEK North America | Vectorworks | Architecture | O / O |
| NEMETSCHEK SCIA | Scia Engineer | Structural | O / O |
| Plancal | nova | BuildingService | O / O |
| Progman | MagiCad | BuildingService | X / O |
| Solibri | Solibri Model Checker | - | O / X |
| Tekla | Tekla Structures | Structural | O / O |
| VIZELIA | Facility on line | - | O / X |

Table 1. Currently registered BIM software applications for buildingSMART international certification [5].

## 2. CONCEPTUAL MODEL and METHODS

A computer simulation test designed to compare the outputs from each BIM application and check the interoperability between the commercial applications is conducted. In this study, the author did the computer simulation with two BIM applications: Revit Architecture 2011 for student of Autodesk [7], which is predominant in North America area, and ArchiCAD 14 for 30-day trial version of Graphisoft [8], which is one of the most popular application in Europe. With these two applications, a wall is created as a 3 dimensional geographic model. Because wall is the basic and fundamental element of the building members such as beam, column, curtain wall, door, footing, member, pile, plate, railing, ramp, roof, slab, stair, wall, and windows, which IFC determined as the IFCBUILDINGELEMENT [3]. Geographical dimension of the wall which is applied in this study is 1000mm of length, 300mm of width, and 5000mm of height. Concrete is applied as material information and structural wall is applied as property information. All of these same information are applied into both applications. A 3D wall with the same information are created and exported as an IFC file format: #1 from Revit Architecture and #3 from ArchiCAD. In order to check the capability of data exchange of two applications, #1 file is imported into ArchiCAD and #3 file is imported into Revit Architecture. Without any modification and editing, 3D walls are exported as #2 and #4 IFC files, respectively. These four outputs from #1 to #4 are analyzed by NIST IFC analyzer and Solibri IFC Model Checker [9][10]. And then they are compared and checked with each other. Figure 1 shows the conceptual model of this computer simulation method.

Through this study, it will be checked and compared exchange capabilities of building model data between existing BIM tools using IFC neutral data file formats. Additionally, it will be determined whether data exported from a BIM tool can be modified or edited with ease in another BIM tool.

In this study, independent, dependent, mediator, and moderator variables are as follows.

- *Independent Variables*: BIM tools (Revit Architecture 2011 & ArchiCAD 14)
- *Ultimate Dependent Variables*: Total redundant cost and time for project
- *Mediator Variables*: Different IFC data file exported from each BIM application
- *Moderator Variables*: Building member (wall)

The hypothesis of this study is as follows.

*Hypothesis #1*: Application-independent, standardized rule including formatting and processes will decrease the gap and error between each commercial BIM tool.

*Hypothesis #2*: Ultimately, fewer gaps and errors will contribute to a reduction in the overall cost and schedule of the entire life cycle of building.

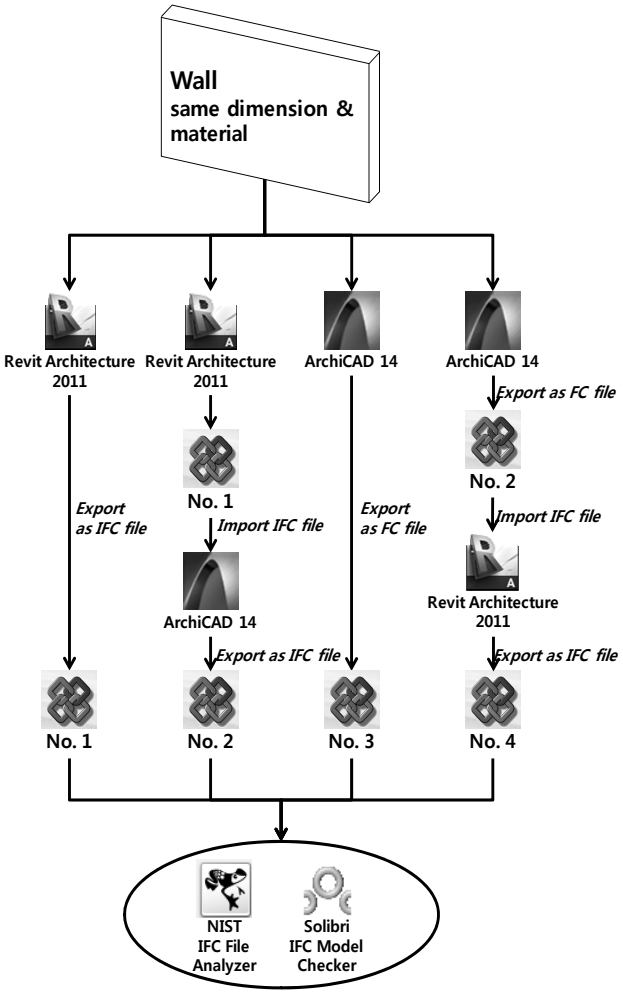


Figure 1 Computer simulation diagram of this study.

## 3. DATA ANALYSIS

Before mentioning the result of analysis, it is shown there is a problem during exchanging data between Revit Architecture and ArchiCAD. When #3 from ArchiCAD is imported into Revit Architecture, an error like a Figure 2 is occurred. Error 20056 is related to temporary 'swapfile'. It is usually generated when a file with geometric information from other applications is imported.

The results of computer simulation, from #1 to #4 files, are analyzed. They have a lot in common, while having definite differences. The basic and the most physically evident difference among them is the entire lines of outputs. #1, #2, #3, and #4 file has 150, 153, 93, 166 lines, respectively. Additionally, through the analytical test by NIST IFC analyzer, the entire number of IFC Entity is 46, 44, 47, and 49, respectively.

First of all, they have the common IFC Entities (about 54%): object entities like IFCPROJECT, IFCPERSON, IFCBUILDING, and IFCSITE, relationship entities like IFCREL-AGGREGATES, and resource entities like IFCMATERIAL and IFCMEASUREWITHUNIT. There are 25 same entities, and they have almost the same attribute which is a kind of detail information of entity.

On the other hand, some of the entities are appeared in the whole outputs, while there are differences of the quantity (24%). And there is no common rule assumed by four results. There are no common rules between #1 and #2 which are exported from Revit Architecture at the first time, and #3 and #4 which are exported from ArchiCAD at the first time, or #1 and #4 which are exported from Revit Architecture at the last time, and #2 and #3 which are exported from ArchiCAD at the last time. For instance, one of the resource entities like IFCAXIS2-PLACEMENT3D is simultaneously appeared in four results with different quantity: 7, 4, 6, and 12 respectively. Also, they have some common point and different point between #1 and #4 which are finally comes from Revit Architecture and #2 and #3 which are finally comes from ArchiCAD. There are three attributes, which is a kind of information in detail, in

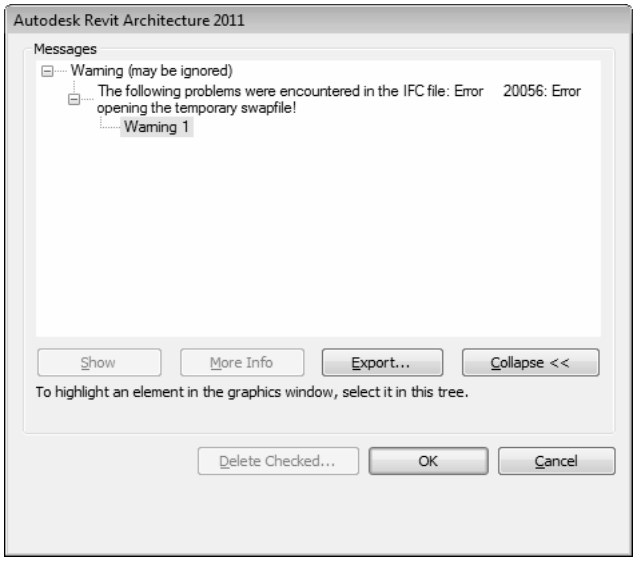


Figure 2. Error message when import #3 file into Autodesk Revit Architecture 2011

| | | #1 Revit Architecture | #2 Revit-ArchiCAD | #3 ArchiCAD | #4 ArchiCAD-Revit |
|---|---|---|---|---|---|
| Total number of Lines | | 150 | 153 | 93 | 166 |
| Total IFC entities | | 40 + 6 | 39 + 5 | 42 + 5 | 43 + 6 |
| Same IFC entities (25) | | IFCAPPLICATION(1), IFCBUILDING(1), IFCCONVERSIONBASEDUNIT(1), IFCDIMENSIONALEXPONENTS(1), IFCEXTRUDEDAREASOLID(1), IFCGEOMETRICREPRESENTATIONCONTEXT(2), IFCGEOMETRICREPRESENTATIONSUBCONTEXT(1), IFCMATERIAL(1), IFCMATERIALLAYER(1), IFCMATERIALLAYERSET(1), IFCMATERIALLAYERSETUSAGE(1), IFCMEASUREWITHUNIT(1), IFCORGANIZATION(2), IFCOWNERHISTORY(1), IFCPERSON(1), IFCPERSONANDORGANIZATION(1), IFCPRESENTATIONLAYERASSIGNMENT(1), IFCPRODUCTDEFINITIONSHAPE(1), IFCPROJECT(1), IFCRELAGGREGATES(3), IFCRELCONTAINEDINSPATIALSTRUCTURE(1), IFCSHAPEREPRESENTATION(2), IFCSITE(1), IFCUNITASSIGNMENT(1), IFCWALLSTANDARDCASE(1) | | | |
| Overlapped IFC entities for entire cases but different number of quantity (13) | IFCAXIS2PLACEMENT3D | 7 | 4 | 6 | 12 |
| | IFCBUILDINGSTOREY | 1 | 1 | 3 | 1 |
| | IFCCARTESIANPOINT | 6 | 8 | 11 | 7 |
| | IFCCOLOURRGB | 1 | 1 | 2 | 3 |
| | IFCDIRECTION | 10 | 5 | 5 | 11 |
| | IFCLOCALPLACEMENT | 4 | 4 | 6 | 4 |
| | IFCPOLYLINE | 1 | 2 | 1 | 1 |
| | IFCPRESENTATIONSTYLEASSIGNMENT | 2 | 1 | 3 | 2 |
| | IFCRELASSOCIATESMATERIAL | 1 | 2 | 2 | 1 |
| | IFCSIUNIT | 5 | 9 | 5 | 5 |
| | IFCSTYLEDITEM | 2 | 1 | 2 | 2 |
| | IFCSURFACESTYLE | 1 | 1 | 1 | 2 |
| | IFCSURFACESTYLERENDERING | 1 | 1 | 1 | 2 |
| Overlapped IFC entities for some cases with some different number of quantity | IFCAXIS2PLACEMENT2D | 1 | - | - | 1 |
| | IFCMATERIALDEFINITIONREPRESENTATION | 1 | - | - | 1 |
| | IFCPOSTALADDRESS | 1 | - | - | 1 |
| | IFCARBITRARYCLOSEDPROFILEDEF | - | 1 | 1 | - |
| | IFCCURVESTYLE | - | - | 2 | 1 |
| | IFCDRAUGHTINGPREDEFINEDCURVEFONT | - | - | 1 | 1 |
| | IFCFILLAREASTYLE | - | - | 1 | 1 |
| | IFCFILLAREASTYLEHATCHING | - | - | 1 | 1 |
| | IFCMATERIALDEFINITIONREPRESENTATION | - | - | 1 | - |
| | IFCPROPERTYSET | 16 | 16 | - | 15 |
| | IFCPROPERTYSINGLEVALUE | 48 | 48 | - | 44 |
| | IFCRECTANGLEPROFILEDEF | 1 | - | - | 1 |
| | IFCRELDEFINESBYPROPERTIES | 16 | 16 | - | 15 |
| | IFCRELDEFINESBYTYPE | - | 1 | 1 | - |
| | IFCSTYLEDREPRESENTATION | 1 | - | 1 | 1 |
| | IFCWALLTYPE | - | 1 | 1 | - |
| | TOTAL | 8 (85) | 6 (83) | 9 (10) | 12 (83) |

Table 2. The result of analysis for 4 IFC files exported from Revit Architecture and ArchiCAD.

IFCAXIS2PLACEMENT3D: AXIS (The exact direction of the local Z Axis), RefDirection (The direction used to determine the direction of the local X Axis), P (The normalized directions of the placement X Axis (P(1)) and the placement Y Axis (P(2)) and the placement Z Axis (P(3))) [3]. For the common point, there is only AXIS information in #1 and #4, while there are all of the attribute information in #2 and #3. For the different point, there are 7 entities in #1 and all of them have only AXIS information, while there are 12 entities in #4. Furthermore, 11 of 12 entities have only AXIS attribute and the other has all of three attribute like the output of ArchiCAD. The reason why it has a difference is assumed that importing #3 that comes from ArchiCAD, an error has occurred and it has to be re-generated by Revit Architecture. Thus, #4 has a feature of Revit Architecture which adds three attributes.

On the other hand, there are definite differences among the four outputs. Some entities are appeared in only one output: IFCMATERIALDEFINITIONREPRESENTATION in #3. Some entities are shown in two outputs: IFCAXIS2-PLACEMENT2D in #1 and #4, and the others are appeared in three outputs. IFCPROPERTYSET in #1, #2, and #4. Any common or differences specifications between these results is not found. For example, Revit Architecture provides 2 dimensional information, even though creating only 3 dimensional model. Hence, the end-outputs of Revit Architecture include 2D information. While #2 and #3 does not possess any 2D information, #1 and #4 embrace it including RefDirection (The direction used to determine the direction of the local X Axis), P (P(1): The normalized direction of the placement X Axis. P(2): The normalized direction of the placement Y Axis) [3]. These results of analysis are shown in Table 2.

## 4. CONCLUSION

Compatibility between the IFC codes of building components produced by different BIM applications is currently investigated by comparing the IFC codes line by line. This paper presents the preliminary findings of our investigation on a simple wall component produced either by Revit or ArchiCAD. The two IFC codes of a simple wall component of a typical building produced by these two BIM applications were compared line by line. The outcome of the investigation gave us some understanding of the similarities and differences between the IFC codes: they have almost 78% of the same entities like IFCPROJECT, even though some of them have different numbers of entities like IFCDIRECTION. However, there is a definite difference among the outputs. Some entities are only shown in some outputs and the attribute which is a kind of detail information is clearly different like IFCAXIS2-PLACEMENT2D. This investigation will be continued to understand the differences between the IFC codes produced by difference BIM applications, which is expected to give us some idea as to how we need to sustain the BIM data at least for the lifecycle of the built facilities.

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