Collaboration challenges for detailed design and optimisation via building performance simulation

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Abstract

At the present time, Building Information Modelling (BIM) has become a standard practice in the AEC industry. However, with this wide embrace from the industry, new problems and challenges are appearing. The largest of these issues is the interoperability, which hinders the BIM adoption through the whole lifecycle of building projects. The interoperability had been more developed in areas such design coordination, in detriment of other areas such as Building Performance Simulation (BPS). This lack of interoperability in BPS had discouraged the early collaboration in design, and then simulations are carried out as late as possible to minimize the number of information exchanged.

Considering the existing conditions, this research aims to solve the collaboration issue at early design by providing information exchange guidance between various BIM tools used by designers. The methods to achieve the aim include: literature review focused on describing the project communication; challenges to achieve an integrated approach (interoperability issues and the state of the art for BIM servers); development of a business process model for early design by Information Delivery Manual (IDM).

These research findings will encourage early collaboration for performance analysis by enabling information exchange between stakeholders. Besides, the development of a guideline can be used by the BIM vendors to improve their BIM tools for successful interoperability. The outputs will reflect on the design process, with increased flexibility such as development and review different design alternatives and addressing the building performance challenges at early design successfully.

Keywords

Building Information Modelling, interoperability, collaboration, Information Delivery Manual

1. Introduction

Building Performance Simulation (BPS) allows simulating the thermal performance for a design, making possible to determine how a change in it affects the energy consumption through the project life cycle. However BPS is a newest discipline into the AEC industry and needs facing some challenges in order to facilitate a wide adoption in the design. The largest of these problems is the absence of collaborative work as a result of a lack of interoperability or ability to share data created by different software. This lack in sharing data push to designers to spend time re-entry manually missed data. As a consequence, the collaboration is reduced or carried out as late as possible to minimize the time used in the re-entry data process.

Even though the BPS tools are not widely used in the industry, there some hints to think that the current outlook will improve in the coming years. The reasons to expect a higher demand than the current engagement are based on: the disruptive emergence of Building Information Modelling (BIM) in the AEC industry is boosting the interest for simulation tools; government policies to reduce the carbon footprint; awareness about the environment and better use for resources.

This research seeks go on ahead for an increasing demand of energy tools that facilitate the collaboration through a better interoperability. Once this issue is solved, will be possible an early collaboration between different actors to optimize the designs ensuring a low energy consumption through the project lifecycle.

2. Literature review

The interoperability is the ability of a BIM tool to exchange data with other applications (Eastman et al, 2011), stimulating collaborative relationships among team members and enabling an integrated project execution (McGraw Hill 2007; Smith & Tardiff, 2009).

Despite the importance of the interoperability, many authors (Attia, 2010; Krygiel & Nies, 2008; Hemsath, 2014; Levy, 2012) have reported an underdevelopment in the interoperability into BPS. As a consequence of a lack of interoperability, running a performance analysis will be slow because some data will need to be re-entry manually then collaboration will be affected (Sanguinetti et al, 2014). Even though most of the tools are able to translate from their native formats into a common format readable for other tools (Kymmell, 2008), the data created by these software is not completely mature and then fundamental data for the analysis is missed (Eastman et al, 2011).

2.1. Data management and project communication

It is possible to manage the data developed in a project through two approaches such as standard practice and integrated workflow, each of these approaches have a different way to set the communication between actors. Depending how the communication is carried out it could require interoperability between tools.

In the standard practice (fig 1, on the left side) every consultant is responsible to manage their own data, when an update is required, it is passed through different consultants to ask for their check and approval. This approach uses the same platform to create the data, and then does not exist any interoperability issue, however it is unlikely that all consultants will use the same platform in a project. Besides there is no tool able to create the entire data for the life cycle project (CRC, 2009a), then creating the data for the whole life cycle will require using different tools through each stage and as a result interoperability issues will appear between the different project stages.

On the other hand, in the integrated workflow (fig 1, on the right side) each actor will make their own information available to others specialists uploading it in a server. This approach is more realistic than standard practice because of different tools are used by each consultant. Nonetheless the success of this approach will require a good information exchange between the different tools and project members (CRC, 2009a; Kymmell, 2008), otherwise the each actor could share their own information but other contractor should not able to read it or some data could be missed.

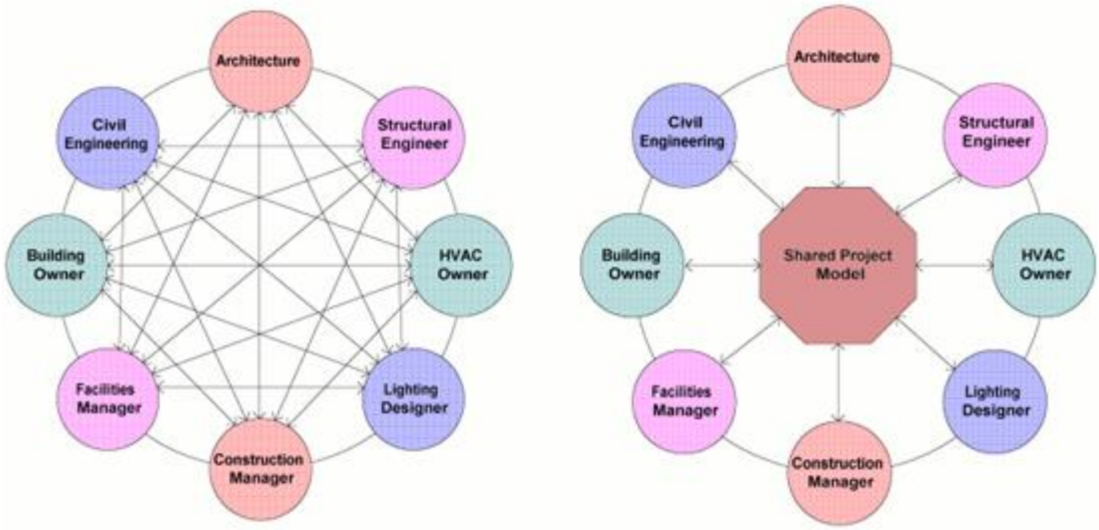

Fig. 1. Data management view (Lister, 2012)

2.2. Challenges for integration

As previously have been explained, the most likely data management approach to be used in a project is the integrated workflow, but it needs to face the interoperability issue in order to achieve a successful implementation. The information exchange problem may be divided in two parts (CRC, 2009a; Kymmell, 2008): interoperability between tools; information exchange between actors.

a) Interoperability issues

Currently the interoperability issues are addressed via two formats: Industry Foundation Class (IFC) and Green Building XML (gbXML). The IFC schema has been widely accepted by the AEC industry (Smith & Tardiff, 2009), nevertheless many researches have remarked different problems with this schema. The IFC format is able to provide geometric information, non-geometric properties (material properties) and relationship between the components, nonetheless the IFC data exchanged by commercial tools is general and it includes generic data and then most of the specific information will be missed in the exchange process (Juan & Zheng, 2014). The gbXML schema allows exchanging some HVAC information that is missed in the IFC schema, but nevertheless this format is not mature enough and it is limited to simple designs given that the exportation process is not able to read complex geometries (Bahar et al, 2013).

The interoperability issue between authoring and BPS tools is shown in the figure 2, here are introduced the results for a comparative study between ten simulation tools (Attia, 2010). From the figure 2 is possible to state that most of these software have a low interoperability what is focused mainly in CAD files. IES and Vasari have a better information exchange via gbXML and RVT files respectively. However the workflow in both software is unidirectional (authoring-simulation tool way), then there is no way to send back the changes from the simulation to the authoring tool.

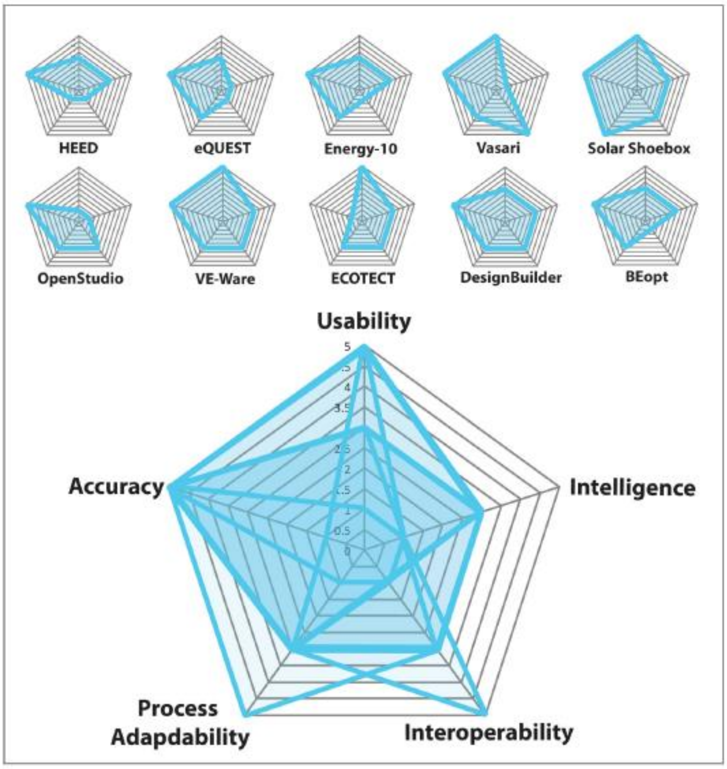

Fig. 2. Benchmarking for energy tools (Attia, 2010)

b) BIM servers

The second challenge to obtain an integrated workflow is creating a server. This is a database system used to facilitate the collaboration allowing query, transfer, updating and data management created by different applications (Eastman et al, 2011; Jørgensen et al., 2008).

The early servers in the AEC industry have been focused on document management, however the interest of the industry for using digital models have pushed to adopt this technology from other well-established industries such as manufacturing, electronics and aerospace (Beetz et al., 2010; Eastman et al, 2011). Nonetheless, the technology is not mature enough and needs to be adapted to BIM requirements yet (Shafiq, Matthews & Lockley, 2013). Currently the BIM servers available in the market are centred on the building planning, design and construction stages (Wong et al, 2014).

To create a server will be necessary to define some requirements to ensure a proper management of data (CRC, 2009b; Eastman et al, 2011; Jørgensen et al, 2008; Smith & Tardiff, 2009). Shafiq, Matthews & Lockley (2013) identified some key features to considerate in a BIM server, these elements may be grouped in four categories:

- Model content management: requirements related with storage, operation and maintenance of the data into the BIM model.

- Model content creation: requirements related with creation of data into the building model.

- Design review: requirements related with design review activities, including visualization, mark-up and consultation of information, navigation functions, team communication and interaction.

- Data security: requirements related with system, users and data management, to define activities as access control, data backup, security etc.

The above requirements will be useful to compare the different servers available in the market and understand how those servers could be suitable to the interoperability requirements.

Choosing the right software to be analysed is hard because of the changing scenario where there is not a clear dominant tool (Beetz et al., 2010). Based on the literature it is possible to identify some tools that are constantly mentioned (Eastman et al, 2011; Shafiq, Matthews & Lockley, 2013; CRC, 2009a; Singh, Gu and Wang, 2011): Express Data Manager, ArchiCAD BIM Cloud, ProjectWise Navigator, BIMserver, Onuma Planning System and Autodesk BIM 360 Field.

Table 1: Model content management (Shafiq, Matthews & Lockley, 2013)

	EDM	*Archicad BIMcloud*	*Bentley projectWise*	*BIMserver*	*Onuma Planning System*	*Autodesk A360*
Model upload/download	*x*	*x*	*x*	*x*	*x*	*x*
Multiple data model format	*x*			*x*	*x*	*x*
Partial model exchange	*x*	*x*		*x*	*x*	
Versioning	*x*	*x*	*x*	*x*	*x*	*x*
Model merging	*x*	*x*	*x*	*x*	*x*	*x*
Data locking	*x*	*x*	*x*	*x*		
Clash detection	*x*	*x*	*x*	*x*	*x*	*x*
Conflict resolution	*x*	*x*	*x*	*x*	*x*	*x*
Audit trail	*x*	*x*	*x*	*x*	*x*	*x*
Data publishing	*x*	*x*	*x*	*x*	*x*	*x*
Workflow management	*x*	*x*	*x*			*x*

The table 1 shows interoperability issues for Archicad BIMcloud and Bentley projectwise, these software are not able to manage IFC files, then these software will not able to read BIM models created for other authoring tools.

Besides is worrying that Onuma and Autodesk A360 cannot locking their files, it means that these servers are not able to set access privileges then any user has access to the information to modify it.

Table 2: Model content creation (Shafiq, Matthews & Lockley, 2013)

	EDM	*Archicad BIMcloud*	*Bentley projectWise*	*BIMserver*	*Onuma Planning System*	*Autodesk A360*
Model modifications	*x*	*x*	*x*	*x*	*x*	*x*
2D data modelling	*x*	*x*	*x*		*x*	*x*
Data querying	*x*	*x*	*x*	*x*	*x*	*x*
Reference data linking	*x*	*x*	*x*	*x*	*x*	*x*
Product libraries support	*x*	*x*	*x*	*x*		
Model checking	*x*	*x*		*x*		
Rule-based modelling	*x*			*x*		
Model comparison	*x*	*x*	*x*	*x*	*x*	
Change management	*x*	*x*	*x*	*x*	*x*	*x*

The table 2 shows some problems in model checking, then it will not possible to validate and verify data using pre-defined rules. Neither it is possible to compare two models to identify changes in those models, this fail could be worrying during the design stage where is need to identify the frequent changes made to the project.

Table 3: Design review (Shafiq, Matthews & Lockley, 2013)

	EDM	*Archicad BIMcloud*	*Bentley projectWise*	*BIMserver*	*Onuma Planning System*	*Autodesk A360*
Remote model viewing			*x*		*x*	*x*
3D navigation	*x*	*x*	*x*	*x*	*x*	*x*
Mark-up	*x*	*x*	*x*		*x*	*x*
Collaborative communication	*x*	*x*	*x*	*x*	*x*	*x*
Report generation	*x*	*x*	*x*	*x*	*x*	
FM data support	*x*	*x*	*x*	*x*	*x*	*x*
Colour customization	*x*	*x*	*x*	*x*	*x*	*x*
Workflow reporting	*x*	*x*	*x*	*x*	*x*	*x*
Mobile computing support		*x*	*x*		*x*	*x*

The problems identified in the table 3 are of little relevance, being the most important the inability of BIMserver to communicate design problems to other team members via mark ups.

Table 4: Data security (Shafiq, Matthews & Lockley, 2013)

	EDM	*Archicad BIMcloud*	*Bentley projectWise*	*BIMserver*	*Onuma Planning System*	*Autodesk A360*
User profiling	x	x	x	x	x	x
Access control	x	x	x	x		x
Data handling	x	x	x		x	x
Interface customization				x	x	x
Security	x	x	x		x	x
Disaster protection	x	x	x		x	x
Data archiving	x	x			x	

The table 4 shows that BIMserver has serious security problems to manage their files, these problems are related with the impossibility to create data backups and to check the system security, then for BIMserver exist a likely to miss data easily.

3. Methodology

Bazjanac (2008) says that an automatic exportation from authoring software to simulation tool will not possible without improving the interoperability for IFC files created by HVAC software. In this sense, Juan and Zheng (2014) point out that Information Delivery Manual (IDM) will become the foundation for improving the interoperability breaking down a complex workflow to make explicit the functional parts to be exchanged. This methodology is very simple to use then any user can develop an IDM following a series of basic steps such as process modelling, use case, information exchange and functional part (buildingSMART, 2010) to break down the IFC schema and adding the data required in the information exchange.

3.1. Process modelling

The first activity to carry out is identifying the needs of information; this data can be made visible mapping the business process through methods such as Business Process Modelling Notation (BPMN), it describes the flow of activities for a particular topic, roles played by each actor involved and the information used or created by each of them (Eastman et al, 2011; BS ISO, 2010).

The figure 3 shows the main components of a process model developed with BPMN, this method uses rows and columns called swim lanes to categorize activities with different functional capabilities. The rows identified the actors involved in the exchange while the columns show project phases. Into the cells created by the swim lanes, it is possible to represent activities as white rectangles and data to be exchanged shown as corner folded blocks (Eastman et al, 2011).

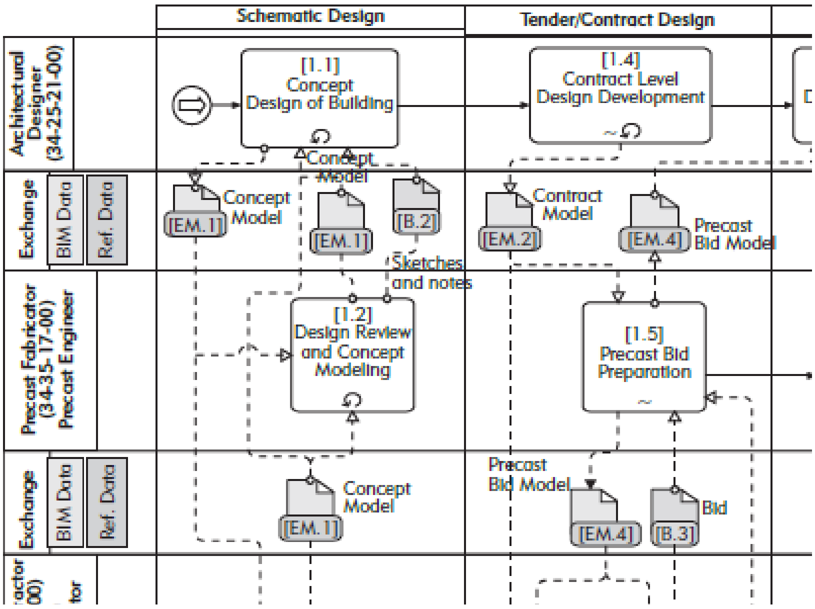

Fig. 3. Process map (Smith & Tardiff, 2009)

3.2. Use case modelling

Use case describes the information exchange between any two actors within a particular stage of project lifecycle. The use case diagram deals with functional requirements for a system, it means that just describe how the information exchange must works. Other requirements such as order in which the activities are performed and high detail about the information exchanged, must be described separately (Microsoft, 2013).

The data shown by the use case is lower than process modelling, however it describes a requirement on the system so a correct system design allows each use case to be carried out (Aouad & Arayici, 2010), and then the use case will be useful as a checking tool to avoid missing exchange information data.

The use case model in the figure 4 shows the information exchange requirements between energy expert and client to carry out a feasibility study. The use case starts with the energy expert running feasibility studies and generating results for it, then this data is shared with the client who will analyse the information to set the design performance values.

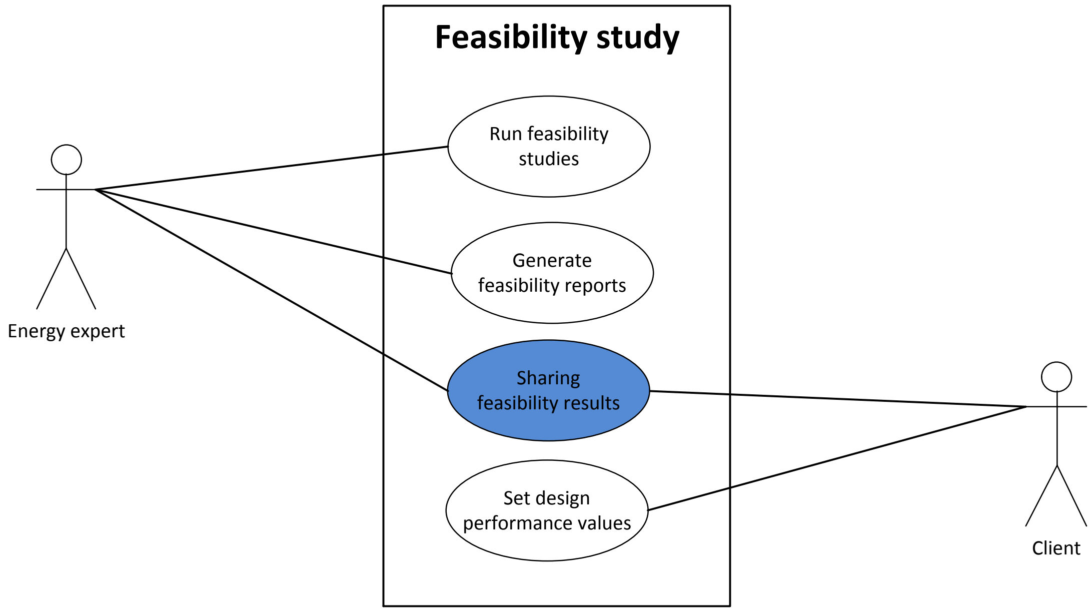

Fig. 4. Use case model

3.3. Information exchange requirements

Based on the outcomes from the modelling process, a set of information exchange requirements are defined. Next step, will be to specify the information exchange and its content.

An exchange requirement represents the link between process and data. It contains the relevant data to ensure the correct exchange of data between two business processes at any stage of the project (buildingSMART, 2010).

Below in the figure 5 is shown an example for an exchange template:

• Header section: it contains name of the exchange requirement; project stage during the exchange will be carry out; disciplines involved in the exchange.

• Overview section: it states the aims and content of the exchange requirement explained in terms that are familiar to the user.

• Information section: it provides the breakdown of technical information required by the exchange requirement. It is the exchanged data, but explained in technical terms.

• Footer section: it describes the exchange models between which are located the information exchange described.

Project Stage	31-10 41 44: Feasibility stage
Exchange Disciplines	34-20 11 21 – 34-10 11 00 : Energy expert - Client
Description	• Purpose: to share the feasibility results with the client who will use them to determine the best option according their requirements • Content of the exchange: feasibility results • Detailed exchange data:: ○ LCC (Euro/m2) ○ ROI (years) ○ Low energy demand ○ Renewable Energy Source (%) ○ Self Sufficiency rate (%) ○ Primary energy need for electricity, heat, cooling (kWh/m2) ○ Energy Supply Reliability, including the reliability of local grid (%) ○ Environmental Impact • Possible tools: GIS Simulation tool • Possible format for data exchange: GML, cityGML, XML • One way exchange
Related Exchange Models	

Fig. 5. Information exchange example

3.4. Functional parts

Each functional part provides a detailed technical specification of the information that should be exchanged. Since that action may occur within many exchange requirements, a functional part can be linked to one or many exchange requirements. Therefore, maintaining the balance in the level of granularity for exchange is critical to ensure that they are not context specific, otherwise it would be difficult to use them in multiple applications in various exchange models related to different context (buildingSMART, 2010).

Below in the figure 6 is shown a detail for a functional part, it contains the technical information specified in the information exchange template. To carry out with the feasibility results data is required to exchange lifecycle cost, return of investment, low energy demand, renewable energy sources, self-efficiency rate, primary energy needs, energy supply reliability and environmental impact.

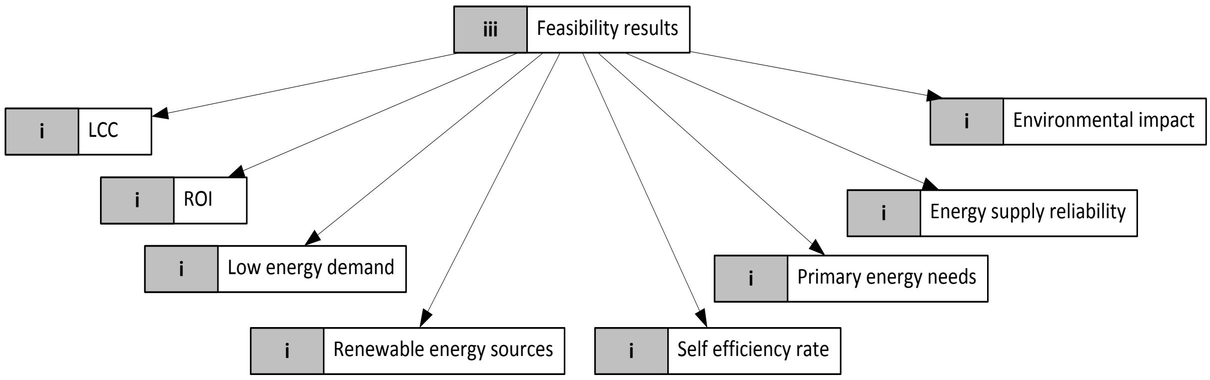

Fig. 6. Functional Parts example

4. Conclusions

This research has pointed out the collaboration problems in BPS field as consequence of a low interoperability, having a clear urgency to improve it in order to obtain the early collaboration benefits claimed by BIM.

The standard information exchange approach does not work in a real situation given that in most of projects each consultant uses their own tools. Additionally, no tool is able to create the entire data required for a project through the life cycle. Then to generate the whole data in a project will be need to use an integrated information exchange approach that will allow using any tools. Nonetheless the formats used to manage the interoperability are not good enough and some data is missed in the process.

Overcome the interoperability issue requires using Information Delivery Manual methodology to improve the information exchange within an IFC file. IDM is a procedure simple enough to allow the communication between technical and non-technical users via plain language. However for further stages it will be need to validate the IDM with the IFC structure, in doing so, the programmer will understand which data is required by the user.

While the servers analysed are able to read the IFC format, the analyse shown that most of these servers are not reliable enough to manage data, being likely to miss data or that external actors could access to the information, then creating a server with security standards will be a must in order to keep safe the data.

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