BIM4EEB

BIM based fast toolkit for
Efficient rEnovation in Buildings

D2.3 List of construction companies' needs and requirements for BIM-based renovation processes

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EXECUTIVE SUMMARY

The construction sector (AEC) has been facing several changes related to technology and innovation in order to improve the building process. It is known that the AEC is one of the sectors with the lowest digitalization index and that its productivity can grow if the sector become more digitalized. However, this process is not easy since it requires investments in digital technology, in new machinery, in training of the professionals, and it needs also a modification in the traditional methods of information exchange used by the construction companies.

Some enterprises are already moving towards digitalization achieving good results. However, the barriers for adopting a different approach during the building process are many. Companies have been testing new methods and learning with their daily practices, but there is still a considerable amount of issues to solve. Most of the criticalities of these companies are related to the lack of a proper information management. The repetition of procedures to input data is constant and it consumes valuable time that could be invested in other areas. In some cases, a software for enterprise planning is used, but then, there is a problem linked to the lack of expertise to manage the tool.

The goal of the research presented in this deliverable is to identify construction companies' needs to promote the development of an efficient and effective way to exchange information. In order to achieve this goal, an online questionnaire was created and sent to companies in Europe (to develop the questionnaire an Italian construction companies association was directly involved). From the initial part of the questionnaire, some opportunities of BIM implementation were identified within the information exchange practices. It has been proven that the exchange of information can be improved by using different management tools and by having collaboration between all the actors. It is possible to say that the companies' main needs are the improvement of the exchange of information, by using better or more specific software of data management, as well as, by updating the drawings as soon as possible to avoid change during or after the construction phase. The results presented are valid not only for new buildings, but also for renovation practices. Renovations can be very complex from the point of view of data collection and information exchange, however there are technologies and team work collaboration methods already applied in new buildings projects that would improve the process and increase the quality of the deliverable if applied also to renovation projects.

PUBLISHING SUMMARY

The construction sector (AEC) has been facing several changes related to technology and innovation in order to improve the building process. Some enterprises are already making moves towards digitalization and are achieving good results, but some barriers exist when trying to adopt a new approach. The goal of the research presented in this deliverable is to identify construction companies' needs to promote the development of an efficient and effective way to exchange information. An online questionnaire was sent to construction companies in Europe in order to figure out the best way to help the companies to satisfy their needs. The respondents profile shows that they are responsible for different roles in the construction process and that they work with different types of projects. It has been proven that the exchange of information can be improved by using different management tools and by practicing collaboration between all the actors. It is possible to say that the companies' main needs are the improvement of the exchange of information, by using better or more specific software of data management, as well as, by updating the drawings as soon as possible to avoid change during or after the construction phase. The results presented are valid not only for new buildings, but also for renovation practices. Renovations can be very complex from the point of view of data collection and information exchange, however there are technologies and team work collaboration methods already applied in new buildings project, that would improve the process and increase the quality of the deliverable if applied also to renovation projects.

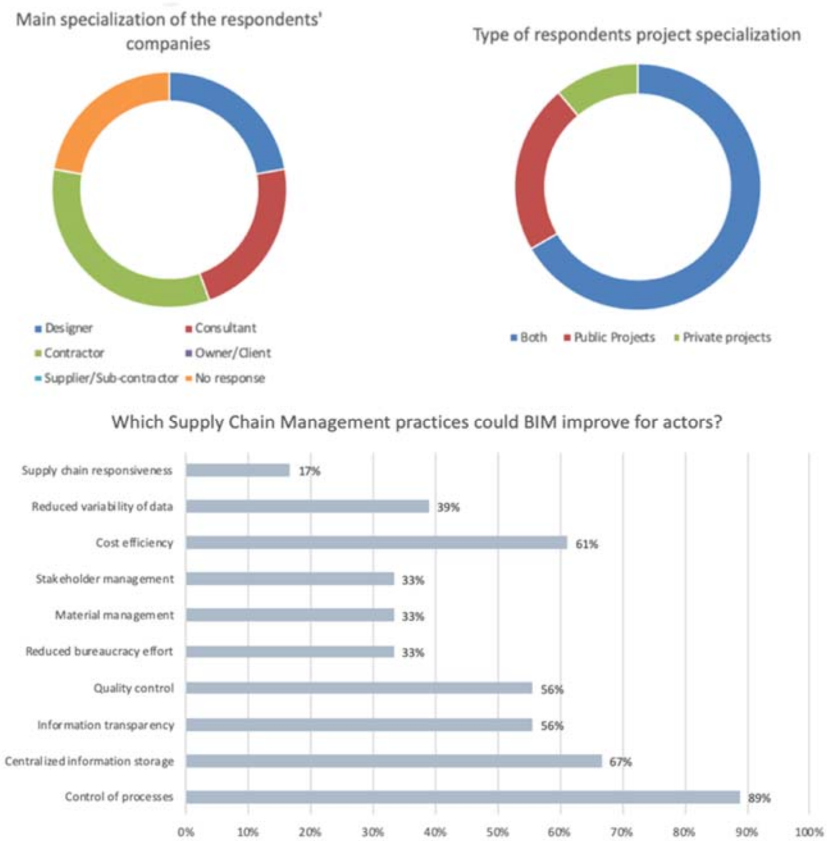


Figure 1 - Respondent profile / BIM improvements for Supply Chain Managemet (SCM)

TABLE OF CONTENTS

1 Introduction 8
2 Information exchange issues 11
  2.1 From the client to the company 11
  2.2 From the company to the supplier 11
  2.3 From the supplier to the company 12
3 Investigation 14
  3.1 Attributes 14
    3.1.1 List of attributes 15
4 Questionnaire 17
  4.1 General questions 17
    4.1.1 Company Information 17
    4.1.2 BIM for Supply Chain Management 17
    4.1.3 Checklist 20
    4.1.4 Documents 20
    4.1.5 Scheme 21
    4.1.6 As-built drawings 22
    4.1.7 Management of the data 22
  4.2 Specific questions 22
5 Data analysis and results 49
  5.1 Requirements from general questions analysis 50
    5.1.1 Introduction 50
    5.1.2 BIM for Supply Chain Management 50
    5.1.3 Documents management 54
  5.2 Requirements from specific questions analysis 55
    5.2.1 Attribute questions 56
    5.2.2 Different types of maintenance 61
6 Conclusions 62
7 Bibliography 63

LIST OF FIGURES

Figure 1 - Respondent profile / BIM improvements for Supply Chain Managemet (SCM) 5
Figure 2 - Traditional (left) and BIM (right) methods- based on Franchini, 2018 10
Figure 3 - Information model -based on Franchini, 2018 10
Figure 4 - Client to company information exchange - based on Franchini, 2018 11
Figure 5 - Company to supplier information exchange- based on Franchini, 2018 12
Figure 6 - Supplier to company information exchange- based on Franchini, 2018 12
Figure 7 - Not digitized supplier- based on Franchini, 2018 13
Figure 8 - Profile of respondents company 50
Figure 9 - project phase benefits 51
Figure 10 - SCM practice improvements 52
Figure 11 – Feasibility contractors 52
Figure 12 - Feasibility supplier/sub-contractors 53
Figure 13 - Possible problems 54
Figure 14 - Future 54

LIST OF TABLES

Table 1 - Analysed article about BIM in SMEs 9
Table 2 - List of attributes based on NBS, 2015 15
Table 3 – Structural element 24
Table 4 – External vertical closure 30
Table 5 – Frames (i.e. window) 37
Table 6 – Hot water and sanitary water system 43
Table 7 – Information exchange - main requirements 62
Table 8 – "Structural element"- main requirements 62

1 Introduction

BIM has received significant attention by the academic and industrial world because of its characteristic to produce benefits in the architecture, engineering, construction (AEC) sector (Lee and Yu, 2016). BIM seems to be one of the most promising developments in the building and construction industry (Eastman et al., 2011) and it is closely aligned with innovation adoption process (Hosseini et al., 2016). Nowadays the construction industry is applying Building Information Modelling in its projects with the goal to become extremely productive and environmentally sustainable (Lau et al., 2018). Furthermore, in the coming years EU member states, due to the Directive 2014/24/EU, may require the use of specific electronic tool as BIM for public procurement in the civil construction sector.

BIM process first appeared in the industrial sector in the 1980s (Tranchant et al., 2017). Moreover, the first documented use of the term "building information model" in an international referred journal appeared in Automation in Construction in the article "Modelling multiple views on buildings" by G.A. Van Nederveen and F. Tolman in the December 1992. The peculiarities of BIM concern the information management across all the construction process (design, construction, operations and maintenance, decommissioning/deconstruction).

The overall benefits of BIM can be expressed in an improved efficiency in all the phases, reducing cost and time (especially when modifications and change orders appears) with enhanced documentation and information flow, better coordination among the stakeholders, better safety of the workers. The possibility to visualise and simulate the project evolution in a 3D way during the different project phases permits to identify promptly the errors, reducing the consequent rework. The peculiarity of BIM to create a model where the current information can be automatically updated in real time is very profitable. In fact, managing the data from the project phase to the O&M phase by a unique information model is extremely useful to simplify the management of the information flow that otherwise is recorded in multiple database, causing possible conflicts not only among the data but also among people and departments that manage that data.

The overall barriers can be clustered in two main groups: the technological issue and the cultural issue. The technological issue relates to the need to improve the existing technology: software interoperability, laser scanning and points cloud handling. In the next future, computer technologies will have to face many efforts to overcome these barriers. The cultural issue relates to the well-known aspect that in the construction industry exists a rigid approach to use new technologies and to collaborate with stakeholders. It is necessary that all relevant stakeholders and team members engage and support the use of new technologies. Appropriate staff training would facilitate the transition to BIM workflows.

In the last years some studies have been developed regarding the application of BIM in the construction enterprises, but research on BIM adoption in small and medium-sized enterprises (SMEs) have remained an under-represented area (Hosseini et al., 2016; Li et al., 2019). The research on SMEs it is of fundamental importance because SMEs have greatly contributed to the economic development of regions or countries (Li et al., 2019) and, currently, guidance to assist SMEs to make an informed decision about BIM adoption are lacking (Lam et al. 2017). It is necessary to understand the main challenges delaying the adoption of BIM in SMEs and to consider corresponding strategies that can be applied in order to obtain further understanding of BIM in SMEs (Li et al., 2019).

Focusing on the small and medium enterprises, the main barriers derived from the risks associated with an uncertain return on investment (ROI) for BIM implementation (Hosseini et al., 2016). The findings of Hosseini et al. (2016) show that currently around 42% of Australian SMEs use BIM in Level 1 and Level 2 with only around 5% that have tried Level 3[1]. According to (Lam et al., 2017) there is evidence to suggest that small and medium sized enterprises are currently losing out in winning publicly funded projects. Hosseini et al. (2016) affirm that the findings of their study show that around 42% of SMEs have been engaged in BIM, instead of the 25% provided by the study by Gerrard et al. (2010). This gap indicates how fast-moving BIM is within the Australian construction industry, but the findings also indicate that the

[1] BIM levels are defined in BSI PAS 1192-2:2013

immaturity of BIM implementation is still a problem within Australian market because only the 5% of SMEs had used Level 3 and 8% had utilised Level 2 BIM on their projects. According to Li et al., (2019), based on previous studies and interviews, in SMEs six challenges exist: (1) SMEs are short on resources, (2) collaboration challenges, (3) lack of BIM awareness, (4) legal disputes and uncertainties in policies, (5) difficulties in meeting SMEs' needs, and (6) concerns about data and information. Bosch-Sijtsema et al. (2017) assert that the results from their study on SMEs indicated that more than half of medium-sized contractors in the sample used BIM in some projects and the main obstacles for BIM implementation is related to the lack of normative pressure. Tranchant et al. (2017) carried out an immersive 3D projection for the simulation of the Ajaccio hospital in France. According to Thranchant et al. (2017), the heart of the economy of France is that of SMEs, which represents 96% of companies. As a result, the innovation of the BIM is becoming a necessity for SMEs, even if they do not practice public contracts. Malacarne et al. (2018) affirm that the BIM Pitch concept that they developed in their research is unsuitability for SMEs since it is highly time consuming to develop as additional model, as consequence further study are required.
The framework on the recent studies on SMEs underlines that they are limited to few countries (see Table 1). As consequence, additional research is needed to understand the needs of the industry and existing barriers in digitalization and BIM use in AECOO sector.

Table 1 - Analysed article about BIM in SMEs

Journal Article	Country
Bosch et al., 2017	Sweden
Tranchant et al., 2017	France
Malacarne et al., 2018	Italy
Li et al., 2019	China
Lam et al. 2017	UK
Hosseini et al., 2016	Australia

The exchange of information between the three main parties of a project is a common problem in construction sector.

1. Communication and information exchange between the client and the contractor (under the word "client" are also considered the design teams)
2. Information exchange from the contractor to the supplier (under the word "supplier" is also considered the subcontractor)
3. Information exchange from the supplier to the contractor

The three problems mentioned above are better explained in this document in order to clarify the importance of having an efficient informative flow.

The traditional information exchange is done by paper or digital format, using graphics, pictures, documents and static media documents. This type of exchange of information has several limitations that can be improved utilizing a more digitization method such as BIM.

The BIM method includes the use of information models to replace documents that can be digitalized, and it optimizes the transmission of data, promoting interoperability between the parties involved in the project.

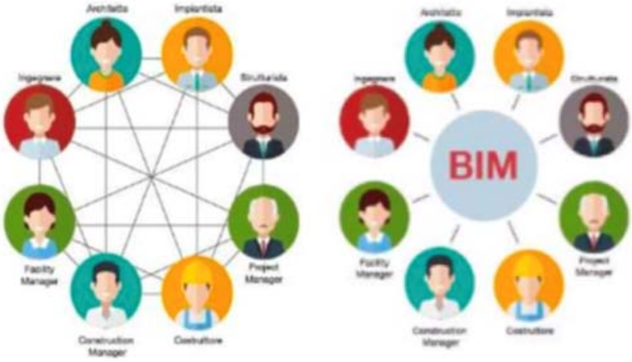


Figure 2 - Traditional (left) and BIM (right) methods- based on Franchini, 2018

An information model is a virtual representation of a building or infrastructure, simulating reality contents, which contains a series of information. The model of a building is proposed in the first instance as a three-dimensional representation of the project idea or reality. It can be single or the result of an aggregation of models produced within the various design disciplines (architectural, engineering, structural, etc.).

However, the geometric representation is not the only purpose of a BIM model; in fact, this type of approach is used with the addition of data and information characterizing the model itself. From the informative model, it is possible to extrapolate, in addition to the geometric visualization, also data of an informative nature and the latter can be contained in documents linked to the model, such as quantities estimation, specifications or reports, or within the objects constituting the model itself.

Figure 3 - Information model -based on Franchini, 2018

Most of the existing issues related to the information exchange in the construction sector have been explored in the research field. However, due to the differences between cultures, practices and market composition there is the need to develop deeper and broader studies to clearly identify the needs of the industry and consequently understand how to limit and/or remove existing issues.

A questionnaire was developed in order to obtain the necessary data to identify the needs and challenges of the companies, and further, to discover the essential types of information and data that should be exchanged and communicated between the contractor and other parties involved in the construction project.

2 Information exchange issues

Commonly, information exchange issues are related to three main parties involved in a project, namely client, contractors and supply chain as following explained based on Franchini, 2018.

2.1 From the client to the company

At the base of the process, there is the need of the client to have the work carried out. The client, therefore, represents the main figure of every transaction. To this end, the company should clearly understand what the client's objectives are.

Figure 4 - Client to company information exchange - based on Franchini, 2018

To clarify these intentions, the client trusts the elaboration of the project to a team that draws up part of the documents that must be supplied to the companies.

In a frequent scenario, once they have received the material, they must analyze the information and data received from the design team and verify the completeness. If the papers are inadequate, the responsibility of filling these gaps will nevertheless remain with the company, in order to draw up a complete construction project.

Often, for example, the executive project is incomplete, leading to a loss of time and resources for the company.

At the end of the process, the company has to deliver to the client the complete As-Built, including all the information useful for the maintenance of the work. Currently many companies have an ERP system (such as SAP), where part of the As-Built information is collected. However, many documents remain stored in other location in the company there is the need to transfer all this inputs to the client and the end of the project.

2.2 From the company to the supplier

This exchange of information happens in order to present an offer.

The traditional exchange of information between the company and the supplier happens by paper or digital support, exploiting the use of graphic, documentary and static multimedia documents. This type of information exchange is usually successful but has several limitations, including:

- The documents or files exchanged are not self-explanatory. Therefore, the meaning of the message may be subject to personal interpretation;
- The exchange of information through this type of support forces the subjects involved to operate in a non-optimal way;
- This way often leads to the loss of time and valuable information, and the waste of a large amount of paper.

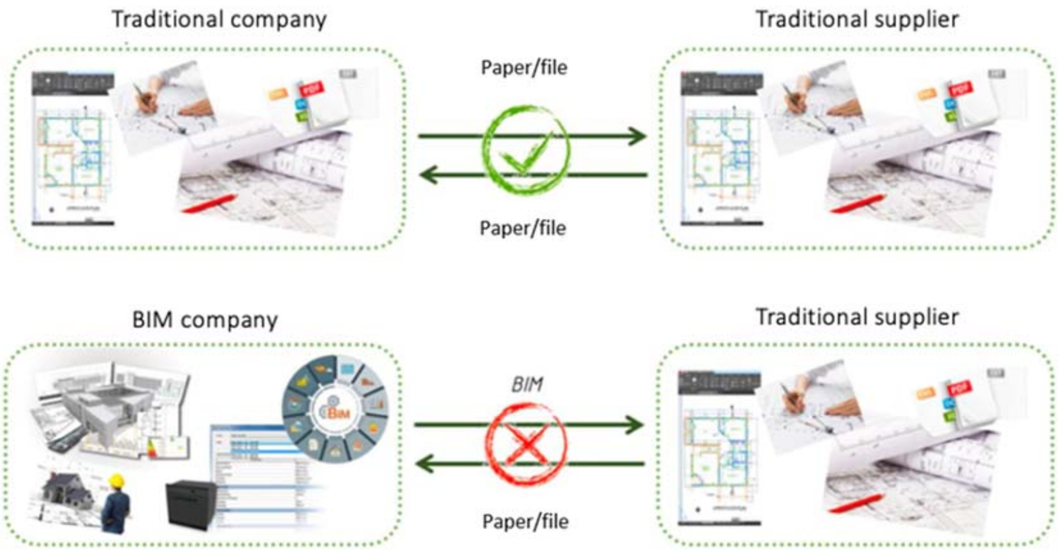


Figure 5 - Company to supplier information exchange- based on Franchini, 2018

Even the world of construction companies is getting closer to a more complete digitization; an act that regards information exchange very closely. However, it is important to emphasize that this step forward by companies lies not only in the digitization of their process, but in the use of information models to replace the documents which can be either digital or not. All this makes it possible to optimize the transmission of data, promoting interoperability between subjects, limited by having to know how to use the tool.

If the company was digitized, in the BIM sense, the transfer of information to suppliers would be difficult, if not impossible. The supplier would not be able to open and exploit the information models received, because he is used to using antiquated methods (paper) and/or non-standardised practices. In fact a supplier may deliver products to hundreds of companies and each of them may have different practices.

2.3 From the supplier to the company

This exchange of information happens in order to allow the company to present an offer; to realize the as-built, and the maintenance documentation.

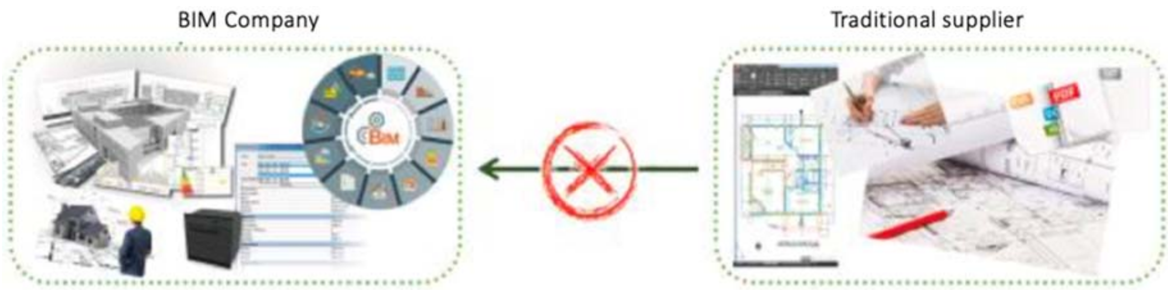


Figure 6 - Supplier to company information exchange- based on Franchini, 2018

This passage of information is significant at different stages of the process starting from the pure design phase, in which the company must take care to carry out the constructive translation of the client's requests, up to the preparation of the maintenance plan that will be used by the final users.

The necessary inputs can be multiple, such as:

- The date of installation of a material or the date of installation of a product;
- Information in relation to the acceptance of the material;
- The possibility of replacing a product;

The supplier not digitized in the BIM sense, in the same way as in the previous case, will not be able to respond to the needs and requests of the company due to the lack of knowledge of the information method adopted.

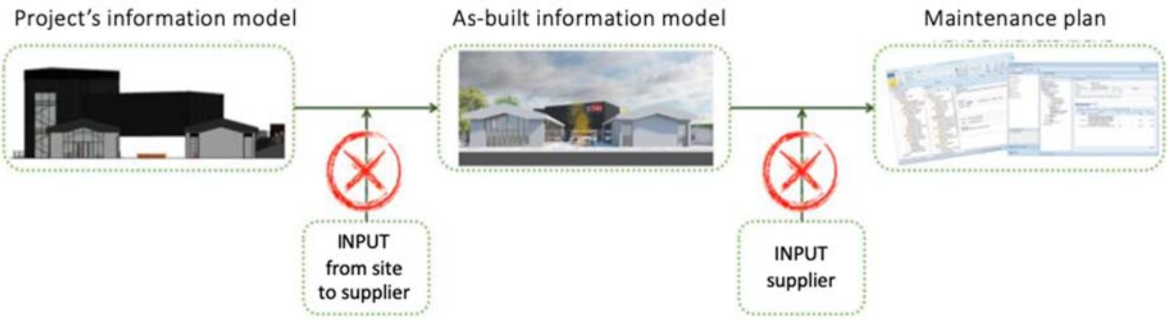


Figure 7 - Not digitized supplier- based on Franchini, 2018

There are two possibilities to solve this issue:

1. Translate the informative models back into elaborates so that the supplier can analyze the documentation and work on this to respond to the business needs;
2. Develop an intelligent method so that the supplier, despite not knowing the BIM platforms and software, is able to exploit these intuitive and practical methods to meet the needs of the company, together with those of the client.

The first point is feasible but would lead to a waste of time and resources that could instead be addressed elsewhere.

To try to constitute the practical method, instead of at the second point, it will be necessary to carry out an accurate investigation to try to better understand the needs of the companies, in such a way as to be able to obtain results that are practically exploitable and standardized.

3 Investigation

To explore solutions related to the above mentioned information exchange issues, it is necessary to know some information regarding the companies, such as:

- What information does the supplier need to provide for the preparation of an offer?
- Which documents are useful for the preparation of an offer besides the specifications and the calculation?
- What are the necessary inputs to the model for the preparation of an As-Built or a maintenance plan?
- Which of this information is essential to be digitized in order to optimize the process?
- Which of this information should be given exclusively by the supplier or site manager?
- What are the attributes that are needed to characterize an object?

3.1 Attributes

To find out what are the attributes, in particular, three types of objects are considered, representing the category to which they belong, such as:

- A construction work characterized by geometry without the use of industrial products.
- An industrial product without geometry in BIM (e.g. brick) with geometry defined by the construction work (e.g. wall).
- An industrial product geometry both in BIM and in the real world (e.g. air handler).

The first step is to create a basic list of attributes, useful for the company to characterize the object.

It is important that this list can be implemented to be able to add both specific needs and attributes, expressly requested by the client or designer, and new attributes considered essential by the supplier.

- Is each proposed attribute necessary?
- Is it essential to identify others, and if so, which ones?
- Which of these are needed in the offer phase, such as for the preparation of an As-Built, and what for a maintenance plan?
- Which of these attributes is essential to be digitized in order to optimize the process?
- Which of these attributes should be given exclusively by the supplier or by the site manager?

3.1.1 List of attributes

Table 2 - List of attributes based on NBS, 2015

#	ATTRIBUTE	DESCRIPTION
1	Accessibility	Accessibility performance (ability to solve problems in this sense)
2	Type	Flexibility of the object
3	Category	Coding indicating their classification (e.g. Uniclass2015)
4	Code performance	Category requirements
5	Color	Primary color or characterizing the product
6	Component	Optional components (parts, characteristics, and finishes)
7	Description	Description of the object that clarifies the design intent
8	Useful life	Life expectancy of the object (typically indicated in years)
9	Use	Typical service use
10	Characteristics	Other essential features related to product specifications
11	Finish	Main finish
12	Category	Standard category
13	Manufacturer	Useful manufacturer's contact
14	Material	Main material
15	Serial Number	The code assigned to the object by the manufacturer
16	Name of the model	Name of the object used in the model
17	Name	Alphanumeric code that uniquely identifies the object (the code must first report the type of product)
18	Nominal height	Size typically measured vertically
19	Nominal length	Size typically measured horizontally
20	Nominal weight	Object weight
21	Cost of replacement	Indicative cost for replacement
22	Form	Main or characteristic form
23	Dimension	Main or characteristic dimension
24	Sustainability	Description of sustainability requirements
25	Warranty	Warranty description and possible exclusions
26	Duration of warranty (installation)	An indication of the duration of warranty of the installation
27	Duration of warranty (components)	An indication of the duration of warranty of the components

28	Duration of warranty (object)	Duration of warranty of the object (normally in years)
29	Guarantor warranty	Contact details of the guarantor for the installation
30	Guarantor of the guarantee (component)	Contact details of the guarantee guarantor for the components
31	Specific identification	Identification of a specific activity to distinguish it from the others
32	Bar code	Bar code or RFID for unique identification of the object
33	Date of installation	Date the object was installed
34	Serial number	An indication of the serial number
35	Tag	Tag indication
36	Warranty start date	Date the warranty begins

4 Questionnaire

The questionnaire was developed in close collaboration with the association of Italian construction companies in Milan and it consists of two parts: general questions (4.1) and specific questions (4.2).

4.1 General questions

Questions related to company information and questions related to the construction trade and supply chain management (SCM). To start answering the questionnaire, the participant has to accept the terms and conditions.

4.1.1 Company Information

1. What is the main role of your company?
   a. Owner
   b. Contractor
   c. Designer
   d. Consultant
   e. Supplier
   f. No response
   g. Other __________

2. What country and city is your company located?

____

3. What type of projects is the company specialized in?
   a. Public projects
   b. Private projects
   c. Both

4. What is the size of the company related to the number of employees?
   a. 1 to 9 employees
   b. 10 to 50 employees
   c. More than 50 employees
   d. More than 100 employees

5. What is your annual turnover?

   a. Up to EUR 2 million
   b. EUR 3 million to 10 million
   c. EUR 11 million to 50 million
   d. More than EUR 50 million
   e. No response

4.1.2 BIM for Supply Chain Management

Overview of current Supply Chain Management (SCM) trends is crucial to provide possible guidelines for improvement with the support of BIM as a technological enabler for collaboration among the stakeholders. The perception is that potential of BIM has still not been exploited for SCM.

6. How does your company select sub-contractors and material suppliers?
   [ ] Quality
   [ ] Timeliness
   [ ] Price
   [ ] Trust
   [ ] BIM application
   [ ] other

7. Do you have some strategic partnerships in place with suppliers or sub-contractors?
   a. Yes (if "a", fo to question 30)
   b. No (if "b", go to question 31)

8. [yes] If you have some strategic partnerships, in which Supply Chain activities?
   [ ] Partner sourcing
   [ ] Integration of operations
   [ ] Logistics management
   [ ] Quality management
   [ ] Information and knowledge exchange
   [ ] Cultural alignment
   [ ] Other

9. [no] If you don't have strategic partnerships, what are the barriers for partnership and their strength? (1- low importance/ 5- high importance)
   a. Lack of trust [1-5]
   b. Complexity of integrating processes [1-5]
   c. Short term project orientation [1-5]
   d. Fear of transparency and appropriate risk allocation [1-5]

10. Which Supply Chain Management practices could BIM improve for actors?
    [ ] Control of processes
    [ ] Centralized information storage
    [ ] Information transparency
    [ ] Reduced variability of data
    [ ] Reduced bureaucracy effort
    [ ] Supply Chain responsiveness
    [ ] Cost efficiency
    [ ] Stakeholder management
    [ ] Material management
    [ ] Quality control
    [ ] Don't know
    [ ] Other

11. In which project phases would most benefits arise?
    [ ] Initiative (concept)
    [ ] Initiation
    [ ] Design
    [ ] Procurement
    [ ] Construction
    [ ] Use,

[ ] End of life

12. In which supply chain activities could BIM bring benefits?
    [ ] Sourcing
    [ ] Procurement
    [ ] Production/prefabrication
    [ ] Transportation and logistics
    [ ] On-site assembly

13. In your opinion, how much is BIM-based Supply Chain Management feasible for the Contractors from various perspectives: (1- low feasibility/ 5- high feasibility)
    a. Organizational: Clear roles and responsibilities [1-5]
    b. Technological: Appropriate software infrastructure for collaboration [1-5]
    c. Economical: Sufficient financial resources [1-5]
    d. Social: Openness for information transparency and risk allocation [1-5]

14. In your opinion, how much is BIM-based Supply Chain Management feasible for the Suppliers and Sub-Contractors from various perspectives: (1- low feasibility/ 5- high feasibility)
    a. Organizational: Clear roles and responsibilities [1-5]
    b. Technological: Appropriate software infrastructure for collaboration [1-5]
    c. Economical: Sufficient financial resources [1-5]
    d. Social: Openness for information transparency and risk allocation [1-5]

15. If Suppliers' readiness is not so high, how should Contractor incentivize them to do so?
    [ ] Long-term partnerships
    [ ] Short-term project benefits sharing
    [ ] Trainings, Seminars
    [ ] Seminars
    [ ] No response
    [ ] Other

16. Which benefits can arise when implementing BIM overall?
    [ ] Cost efficiency
    [ ] Time efficiency
    [ ] Higher output quality
    [ ] Information exchange
    [ ] Information storage
    [ ] Data standardization
    [ ] Client satisfaction
    [ ] Supplier satisfaction
    [ ] Sub-contractor satisfaction
    [ ] Stronger competitiveness
    [ ] Don't know
    [ ] Other

17. Which problems can arise when implementing BIM overall?
    [ ] Inadequate skills
    [ ] Inadequate organizational structure
    [ ] Complexity of usage

[ ] Financial
[ ] Interoperability with existing ICT systems
[ ] Interoperability with suppliers/sub-contractors
[ ] Don't know
[ ] Other

18. Overall, how efficient do you perceive information exchange among Supply Chain actors in construction? (1- low efficiency/ 5- high efficiency) [1-5]

19. How do you see the future development of Construction Supply Chain Management with BIM?
[ ] Increased diffusion due to the regulation
[ ] Increased Supply Chain integration
[ ] Control of logistics
[ ] Usage of blockchain
[ ] More frequent prefabrication practices
[ ] Usage of barcodes/QR codes
[ ] Don't know
[ ] Other

4.1.3 Checklist

20. Do you have a Checklist of all documents provided by the client in order to verify the completeness?
    a. Yes [if Yes, go to question 14]
    b. No [if No, go to question 16]

21. Is the Checklist based on a standard?
    a. Yes [if Yes, go to question 16]
    b. No [if No, go to question 15]

22. According to which of the following does the checklist differ?
    a. Public or private procurement
    b. Type of building
    c. Design level
    d. Other ______

4.1.4 Documents

23. What documents does the company send to the supplier in order to receive useful and necessary information regarding the project and scope of the work?
    [ ] Plans
    [ ] Other graphic designs
    [ ] Specifications
    [ ] Technical reports
    [ ] Other ______

24. Does the company send the vendor full documentation, only documents relating to that specific vendor or revised documentation?
    a. Whole documentation [if "a", go to question 19]
    b. Documentation related to that vendor [if "b", go to question 19]

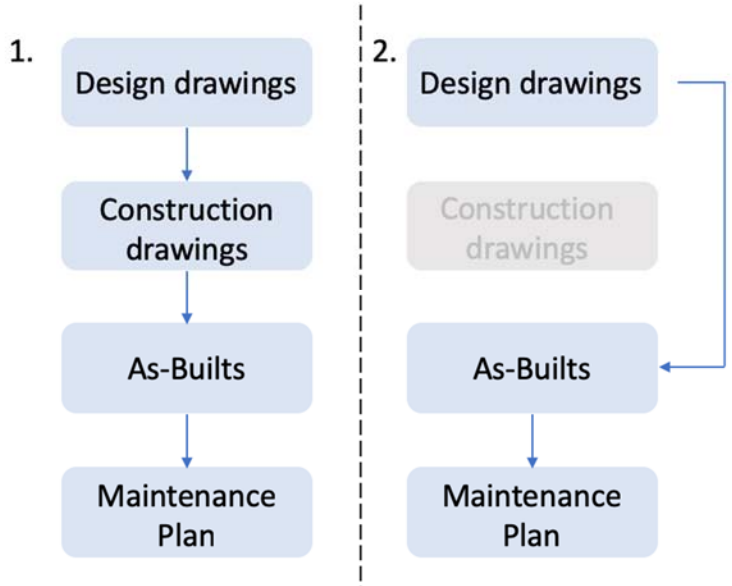
c. Revised documentation [if "c", go to question 18]

25. What was the purpose of the revision/change of the documentation before it was sent to the supplier?
    a. Re-elaboration "ex-Novo"
    b. Adding extra information
    c. Vague or unclear information

26. Which documents does supplier return to the company (contractor)?
    [ ] Shop drawings
    [ ] Project changes orders
    [ ] Construction details
    [ ] Datasheets
    [ ] Maintenance cards
    [ ] A quote
    [ ] Other ______

4.1.5 Scheme

27. Which of the schemes shown below, corresponds to what happens in reality?



a. 1. Are drawn up sequentially: the design drawings, construction drawings, As-Builts, and maintenance plan [if "a", go to question 24]
b. 2. The construction drawings are not produced moving directly to the elaboration of the final as-built [if "b", go to question 25]
c. 1 and 2. Both schemes are used [if "c", continue with the order of the questionnaire]

28. At what point are construction drawings drafted?
    a. Before the start of the construction phase
    b. At a random time during the construction phase

c. During the construction of each phase

29. If there are changes to the design drawings, at which phase are the drawings updated?
    a. During the construction phase
    b. At the end of each construction phase
    c. At the end of the whole project

4.1.6 As-built drawings

30. How does the company draw up the as-built drawings?
    a. By using own resources exclusively [if "a", go to question 28]
    b. By using external resources exclusively [if "b", go to question 27]
    c. By using both, own and external resources [if "c", go to question 27]

31. In case the company uses external resources, does it refer to?
    a. To external consultants
    b. To suppliers that the company collaborated with
    c. To both
    d. Other ______

4.1.7 Management of the data

32. Does the company use a certain type of software to help managing the data? (Some type of enterprise planning software, cloud service, etc.)
    a. Yes [if "a", go to question 33]
    b. No [if "b", go to question 34]
33. Which one? Do you find it useful?

34. Do you think it would be better to have a certain type of software helping to manage the data?

35. In what type of environment does the company normally exchange information between the stakeholders? (email, phone, specific file to fill out the information, etc)

36. What would be the ideal way of sharing this information in your opinion?

4.2 Specific questions

In this part of the questionnaire, based on Franchini (2018), it was decided to introduce a series of categories to the attention of the respondents, among all those the following 4 were chosen:

- Structural element
- External vertical closure
- Window;
- Hot sanitary water system

It is not mandatory to answer to all the sections. The respondent is able to choose the one he is more familiar with.

For each of these, a series of attributes were identified that would characterize them in the most comprehensive way possible.

These attributes are the result of a reworking study of those proposed by the BIM Toolkit as well as elements that are typical of the construction industry.

Empty tables were created in such a way so that the respondents were influenced as little as possible in providing the answers. The survey had several objectives:

- To know in which phase the single attribute was defined or modified;
- Know the person responsible of this definition or modification;
- Identify the documents containing the aforementioned information;
- Identify the amount of information provided
- Below are the indications on how to complete this part of the questionnaire

Following are the phases, numbered 1 to 7:

In this case, it is asked to indicate in the table, in which of these seven phases, the attribute in question is defined for the first time.

1. Initiative (concept)
2. Initiation
3. Design
4. Procurement
5. Construction
6. Use
7. End of life

Then, it is asked to indicate who is responsible for defining the attribute:

CL	Client
D	Designer
CC	Contractor
S	Supplier

Also, it is asked in which document it is possible to find the information. And finally, if there is any different attribute then the ones presented before in case of:

- Ordinary Maintenance
- Extraordinary maintenance
- Restoration
- Renovation

First, a series of attributes that would characterize the structural elements in the most comprehensive way were identified.

Table 3 – Structural element

Structural Element															
ID	Sections	Name	Description	In which phase?							By whom?				
				1	2	3	4	5	6	7	CL	D	CC	S	NO
a.	Product Identification	Family	Name that indicates the classification (e.g. Uniclass2015). Ex. Closure - partition - etc.												
		Serial Number (Specifications)	Identification of the concrete and identification of steel bars.												
		Description	Description of the product that clarifies the design intent.												
b.	Useful Information	Function	Typical usage												
		Location	Geographical location, with identification of the position and the position of the elements.												
		Features	Other important features related to product specifications.												
		Components	Optional components (parts, features and finishes).												
c.	Materials and Finishes	Materials	Main materials												
		Other materials	Other materials present in the element												
		Color	Primary color that characterizes the material												
		Finish	Final finish												

d.	Dimensions and sizes	Nominal height	Vertical dimensions												
		Nominal length	Horizontal dimensions												
		Normal width	Dimension typically measured horizontally.												
		Nominal volume	Volume of the material												
		Nominal weight	Weight of the material												
		Unit of measurement	Main dimension or characteristic used in the computation of the element.												
		Form	Principle form or characteristics												
e.	Schedule, times, & Durations	Program	The program of the key dates of the project including the dates of installation, completion, supply delivery, renovation (if applicable), etc.												
		Date of Delivery	Indication of the timing of material delivery												
		Layout schedule	Estimated layout time												
		Maintenance schedule	Maintenance or replacement schedule												
		Date of installation	Date of installation												
		Testing	Testing schedule for the elements												
		Useful life	Life expectancy of the material, building, elements, etc. (years)												

f.	Manufacturer	Manufacturer	Manufacturer contact information												
g.	Costs	Design cost	Design cost related to the product being analyzed.												
		Cost of management	Cost of information management												
		Product cost	Cost of materials or finished product												
		Installation cost	Cost of installation & layout												
g.	Costs	Testing costs	Cost of testing of the element.												
		Replacement cost	Estimated cost of replacement or maintenance												
		Disposal cost	Cost of waste disposal and / or demolition.												
h.	Environmental Sustainability	Sustainability	Description of sustainability requirements												
		Environmental assessment	The basis for assessing the environmental impact of the product, for example BREEM, LEED.												
		Environmental assessment index	Summary of the evaluation obtained for the product.												
		Environmental impact	Specific criteria for recycling, use of recycled materials in the product												
i.	Guarantees & Warrantee	Warranty	Description of the warranty and any exclusions												
		Warranty start date	Date on which the warranty starts												

		Warranty duration(layout)	Indication of the duration of the warranty for layout.												
		Warranty duration (components)	Indication of the duration of the warranty for product components												
		Warranty duration for the product	Duration of the guarantee for the product (typically indicated in years).												
		Guarantor of the warranty (laying)	Contact information for the guarantor of the warranty												
		Guarantor of the warranty (components)	Contact details for the guarantor for the components.												
j.	Management of the information flow	Information management	Information management system and decision-making system including file format.												
		Information format	Are the digital information related to the modeled object in a format compatible with BIM programs?												
		Datasheet	Manufacturer's technical sheets for the product												
		Other existing information	Existing documentation and information can be used to characterize design solutions.												
		Proposed information	The information generated to communicate the design solution.												
		Purchasing Information	Purchase details including the date of purchase and												

			the order reference.												
		Health and safety information	Information on the conditions and security of the product												
k.	Worksite	Delivery	Delivery details including time and date.												
		Logistics	Logistical details including storage and placement on site												
		Execution	Installation sequence including start and end date and duration.												
		Risk management	Detailed risk management plan related to the object.												
		Construction Design & Management	Safety instructions related to the implementation and use of the object.												
		Constructability	Index that identifies the simplicity of the process of supply and installation of the object.												
l.	Maintenance	Maintenance and operation	Operational requirements for the object.												
		Maintenance and cleaning	Maintenance and cleaning of the object.												
m.	Requirements	All requirements	e.g. fire resistance, insulation, tightness, etc.												
n.	Structural Elements	Substructures other than foundations	Substructures other than foundations, for example bases, stands												

		Foundations	Foundations necessary for the structure.												
		Main frame of support	The primary supporting structure.												
		Attic	Supporting structures that support defined floor loads over defined spans.												
		Roofs	Structures that bear climatic loads must provide a certain level of waterproofing.												
		Bearing walls	Planar vertical bearing elements different from columns that support the vertical load. It may also necessary to have soundproofing.												
		Stairs	Stairs or ramps to allow internal movement inside the structure.												
		Elevator Shafts	Vertical structures to accommodate lifts and which can provide the basic stability for the superstructure.												
		Masonry	Masonry products required for the building.												

Then, the same procedure was done for the external vertical closure.

Table 4 – External vertical closure

External vertical closure																
ID	Section	Name	Description	Stages							By whom?					
				1	2	3	4	5	6	7	CL	D	CC	S	NO
a.	Product Identification	Family	Name that indicates the classification (e.g. Uniclass2015). Ex. Closure - partition - etc.												
		Serial Number (Specifications)	Identification of the batch of the materials in the stratigraphy.												
		Model's name	Name of the Used model (from manufacturer)												
		Description	Description of the object that clarifies the design intent.												
b.	Useful Information	Function	Typical usage												
		Location	Geographic location, with dimension identification and item position.												
		Features	Other important features related to product specifications.												
		Components	Optional components (parts, features and finishes).												
		Exterior Finish	Description of the exterior finish.												
		Carrier Layer	Description of the bearing layer.												
		Secondary Layer	Description of the secondary layer (e.g. if there is a cavity, or a second masonry wall).												
		Thermal Insulation	Description of thermal insulation.												
		Vapor Barrier	Description of the vapor barrier.												

		Acoustic Insulation	Description of sound insulation												
		Interior Finish	Description of the interior finish.												
		Waterproofing	Description of waterproofing system.												
		Regularization	Description of the regularization layer.												
		Lintel	Description of the lintel type.												
		Spreads	Description of the type of shoulder pads.												
		Joints	Description of joints												
c.	Materials	Material	Main material												
		Other materials	Other materials present in the element												
		Color	Primary color characterizing the product												
		Finish	Main finish												
d.	Dimensional characteristics	Normal height	Size typically measured vertically.												
		Normal length	Dimension typically measured horizontally.												
		Normal width	Dimension typically measured horizontally												
		Nominal area	Nominal Area of the object.												
		Nominal volume	Nominal Volume of the object.												
		Nominal weight	Weight of the object												
		Units of measure	The main or characteristic dimension used in the item calculation.												
		Masonry Unit-Inner layer	Descriptions of the masonry elements specified for the inner layers.												

		Masonry Unit-Intermediate layer	Descriptions of the masonry elements specified for the intermediate layers.												
		Unit-Outer layer	Descriptions of the masonry elements specified for the outer layers.												
		Form	Main or characteristic form.												
		Height-Exterior	Overall height of the wall above DPC.												
		Height-Inside	Height of the wall between associated elements of the structure e.g. for example the upper part of the ground floor slab with the lower part of the first-floor slab												
		Length-Exterior	External length of the wall without interruption, for example between returns.												
		Length-Interior	Internal length of the wall without interruption, for example between returns.												
		Outside Area	Area (length x height) excluding openings.												
		Inside Area	Area (length x height) excluding openings.												
		Thickness	Total wall thickness, excluding internal and external finishes, e.g. Render, plaster												

e.	Schedule, times, & Durations	Program	The program of the key dates of the project including the dates of installation, completion, supply, restructuring, etc.												
		Delivery time	Indication of the timing of the material supply.												
		Layout Schedule	Estimated layout time												
		Maintenance schedule	Maintenance or replacement schedule												
		Installation date	The date on which the object was installed												
		Testing	Testing schedule for the item												
		Useful life	Life expectancy of the object (typically indicated in years).												
f.	Manufacturer	Manufacturer	Manufacturer's contact information												
g.	Costs	Design cost	The design cost of the item being analyzed.												
		Cost of management	Cost of information management												
		Product cost	Cost of the materials or the finished product.												
		Installation cost	Cost of installation including everything you need to have the work to the finished.												
		Testing cost	Cost of testing the item												
		Replacement cost	Estimated cost of replacement or maintenance												
		Cost of disposal	Cost of waste disposal and / or demolition.												

h.	Environmental sustainability	Sustainability	Description of fulfilled sustainability requirements.												
		Environmental assessment	The basis for assessing the environmental impact of the object e.g. Bream, LEED												
		Environmental Assessment Index	Summary of the evaluation obtained for the object.												
		Environmental impact	Specific criteria for recycling, use of recycled materials in the object.												
i.	Guarantees & warrantees	Warranty	Description of the warranty and any exclusions												
		Warranty start date	Date on which the warranty starts												
		Warranty duration(layout)	Indication of the duration of the warranty for layout.												
		Warranty duration (components)	Indication of the duration of the warranty for product components												
		Warranty duration for the product	Duration of the guarantee for the product (typically indicated in years).												
		Guarantor of the warranty (laying)	Contact information for the guarantor of the warranty												
		Guarantor of the warranty (components)	Contact details for the guarantor for the components.												
j.	Management of the information flow	Information management	Information management system and decision-making system including file format.												

		Information format	Are the digital information related to the modeled object in a format compatible with BIM programs?												
		Datasheet	Manufacturer's technical sheets for the product												
		Other existing information	Existing documentation and information can be used to characterize design solutions.												
		Proposed information	The information generated to communicate the design solution.												
		Purchasing Information	Purchase details including the date of purchase and the order reference.												
		Health and safety information	Information on the conditions and security of the product												
k.	Worksites	Delivery	Delivery details including time and date.												
		Logistics	Logistical details including storage and placement on site												
		Execution	Installation sequence including start and end date and duration.												
		Risk management	Detailed risk management plan related to the object.												
		Construction Design & Management	Safety instructions related to the implementation and use of the object.												

		Constructability	Index that identifies the simplicity of the process of supply and installation of the object.												
l.	Maintenance	Maintenance and operation	Operational requirements for the object.												
		Maintenance and cleaning	Maintenance and cleaning of the object.												
m.	Requirements	All types of requirements	E.g. Fire resistance, insulation, sealing, etc.												
n.	Details	Windowsills	Description of the windowsills												
		Sill Entrapment Mortar	Sill mortar												
		Wall Plates	Description of the plates covered on the inner and intermediate layers.												
		Containment Straps	Description of lateral connection straps.												
		Expansion Joints	Description of expansion joints in internal, intermediate and external layers.												
		Drains	Description of the exhaust components in the masonry.												
		Pierced Bricks	Description of the perforated bricks present in the inner, intermediate and external layers												
		Transfer Grids	Description of transfer grids in internal, intermediate and external layers.												
		Ventilation ducts	Description of ventilation ducts in internal, intermediate and external layers.												

		Punctures	Description of the holes in the outer layers.													

The next categorie to analize was Frames (i.e. window)

Table 5 – Frames (i.e. window)

Frames (i.e. window)																
ID	Sections	Name	Description	Stages							By whom?					
				1	2	3	4	5	6	7	CL	D	CC	S	NO	
a.	Product Identification	Family	Name indicating the classification (e.g. UNICLASS2015). Es. Closure-partition-etc.													
		QR Code	Object's Identification code throughout its life.													
		Serial Number (Specifications)	Identification of windows and doors.													
		Object ID	The name of the model object used. Es. P01-CV04-etc.													
		Description	Description of the object that clarifies the design intent.													
b.	Useful Information	Function	Typical usage													
		Location	Geographic location, with dimension identification and item position.													
		Features	Other important features related to product specifications.													
		Components	Optional components (parts, features and finishes).													
		Opening operations	Manual or Electric power													

		False frame	Description of the false frame.												
		Frame	Description of the frame with reference also to the thermal cut.												
		Glazing	Type of glass and double glazing.												
		Sealants	Description of the sealants used.												
		Seals or inserts	Static or dynamic seals.												
		Frame fixing elements	Description of the frame fastening systems.												
		Windowsills	Description of Windowsills, internal and external.												
		Lintels	Description of Lintels.												
		Darkening Systems	Descriptions of the darkening systems.												
c.	Materials	Material	Main material												
		Other materials	Other materials present in the element												
		Color	Primary color characterizing the product												
		Finishes	Main finish												
d.	Dimensional characteristics	Normal height	Size typically measured vertically.												
		Normal length	Dimension typically measured horizontally												
		Normal width	Dimension typically measured horizontally.												
		Normal weight	weight of the object												
		Units of measure	The main or characteristic dimension used in												

			the item calculation.												
		Form	Main form or characteristics												
		Exterior height	Overall height of the wall above DPC.												
		Sill height	Height of the sill.												
		Relationship between Glass and frame	A relationship that will be the contribution of natural light and the external view.												
e.	Schedule, times, & Durations	Program	The program of the key dates of the project including the dates of installation, completion, supply, restructuring, etc.												
		Delivery time	Indication of the timing of the material supply.												
		Layout Schedule	Estimated layout time												
		Maintenance schedule	Maintenance or replacement schedule												
		Installation date	The date on which the object was installed												
		Testing	Testing schedule for the item												
		Useful life	Life expectancy of the object (typically indicated in years).												
f.	Manufacturer	Manufacturer	Manufacturer's contact information												
g.	Costs	Design cost	The design cost of the item being analyzed.												

		Cost of management	Cost of information management												
		Product cost	Cost of the materials or the finished product.												
		Installation cost	Cost of installation including everything you need to have the work to the finished.												
		Testing cost	Cost of testing the item												
		Replacement cost	Estimated cost of replacement or maintenance												
		Cost of disposal	Cost of waste disposal and / or demolition.												
h.	Environmental sustainability	Sustainability	Description of fulfilled sustainability requirements.												
		Environmental assessment	The basis for assessing the environmental impact of the object e.g. Bream, LEED												
		Environmental Assessment Index	Summary of the evaluation obtained for the object.												
		Environmental impact	Specific criteria for recycling, use of recycled materials in the object.												
i.	Guarantees & warrantees	Warranty	Description of the warranty and any exclusions												
		Warranty start date	Date on which the warranty starts												
		Warranty duration(layout)	Indication of the duration of the warranty for layout.												

		Warranty duration (components)	Indication of the duration of the warranty for product components												
		Warranty duration for the product	Duration of the guarantee for the product (typically indicated in years).												
		Guarantor of the warranty (laying)	Contact information for the guarantor of the warranty												
		Guarantor of the warranty (components)	Contact details for the guarantor for the components.												
j.	Management of the information flow	Information management	Information management system and decision-making system including file format.												
		Information format	Are the digital information related to the modeled object in a format compatible with BIM programs?												
		Datasheet	Manufacturer's technical sheets for the product												
		Other existing information	Existing documentation and information can be used to characterize design solutions.												
		Proposed information	The information generated to communicate the design solution.												
		Purchasing Information	Purchase details including the date of purchase and the order reference.												

		Health and safety information	Information on the conditions and security of the product												
k.	Worksites	Delivery	Delivery details including time and date.												
		Logistics	Logistical details including storage and placement on site												
		Execution	Installation sequence including start and end date and duration.												
		Risk management	Detailed risk management plan related to the object.												
		Construction Design & Management	Safety instructions related to the implementation and use of the object.												
		Constructability	Index that identifies the simplicity of the process of supply and installation of the object.												
l.	Maintenance	Maintenance and operation	Operational requirements for the object.												
		Maintenance and cleaning	Maintenance and cleaning of the object.												
m.	Requirements	All types of requirements	E.g. Fire resistance, insulation, sealing, etc.												

Finally, the hot water and sanitary water systems category was analized.

Table 6 – Hot water and sanitary water system

HOT WATER AND SANITARY WATER SYSTEM																
ID	Sections	Name	Description	In which phase?							By whom?					
				1	2	3	4	5	6	7	CL	D	CC	S	NO
a.	Product Identification	Family	Name that indicates the classification (e.g. Uniclass2015). Ex. Closure - partition - etc.												
		QR Code	Object's Identification code throughout its life.												
		Serial Number (Specifications)	Identification of elements present in the ACS system												
		Object ID	Name of the used object and the model. Ex. P01 - CV04 - etc.												
		Description	Description of the product that clarifies the design intent.												
b.	Useful Information	Function	Typical usage												
		Location	Geographical location, with identification of the position and the position of the elements.												
		Features	Other important features related to product specifications												
		Components	Optional components (parts, features and finishes).												
c.	Plant characteristics	Connection size	Types of connections and dimensions												
		Pipe	Type of tubing												
		Terminals	Type of terminals												
		Jets	Types of jects for allowing water to escape												
		Excess water	Excess water management												

		Drains	Types of drains												
		Support Frame	Types of framing to support the terminal												
		Integral accessories	Prefabricated accessories supplied by the manufacturers												
c.	Plant characteristics	Accumulation	Types of storage tanks												
		Generator	Type of generator												
		Other components	Components such as valve, flanges, softeners, filters, expansion vessels, indicators.												
		Insulation	Characteristics and types of insulations for pipes												
d.	Dimensional characteristics	Maximum capacity	Maximum water capacity that can contain the tubing												
		Normal flow	Delivery of tubing												
		Flow power	Maximum power flow												
		Water temperature supplied	Maximum water supply temperature (hot tap)												
		Maximum length	Maximum tubing length at the most deprived terminal												
		Maximum height	Maximum tubing height at the most deprived terminal												
		Pressure	Pressure required upstream and downstream of the circuit												
		Utilities	Number of users												
		Peak period	Length of the peak period												
		Accumulation capacity	Maximum capacity of the storage tank												

		Size	Internal and external diameter of the piping												
e.	Schedule, times, & Durations	Program	The program of the key dates of the project including the dates of installation, completion, supply, restructuring, etc.												
		Date of delivery	Indication of the timing of material delivery												
e.	Schedule, times, & Durations	Layout schedule	Estimated layout time												
		Maintenance schedule	Maintenance or replacement schedule												
		Sanitary procedures	Disinfection timing e.g. change filters, or anti-grass cycles												
		Installation date	The date on which the object was installed.												
		Testing	Testing schedule for the elements												
		Useful life	Life expectancy of the object (typically indicated in years).												
f.	Manufacturer	Manufacturer	Manufacturer contact information												
g.	Costs	Design cost	Design cost related to the product being analyzed.												
		Management cost	Cost of management of information												
		Product cost	Cost of materials or finished product												
		Installation cost	Cost of installation & layout												
		Testing costs	Cost of testing the item.												
		Replacement cost	Indicative cost for replacement or maintenance.												
		Cost of disposal	Cost of waste disposal and / or demolition zone.												
h.	Environmental sustainability	Sustainability	Description of fulfilled sustainability requirements.												

		Environmental assessment	The basis for assessing the environmental impact of the object e.g. Breem, LEED												
		Environmental Assessment Index	Summary of the evaluation obtained for the object.												
h.	Environmental sustainability	Environmental impact	Specific criteria for recycling, use of recycled materials in the object.												
		Renewable sources	Use of renewable sources for the production of ACS.												
i.	Guarantees & warrantees	Warranty	Description of the warranty and any exclusions												
		Warranty start date	Date on which the warranty starts												
		Warranty duration(layout)	Indication of the duration of the warranty for layout.												
		Warranty duration (components)	Indication of the duration of the warranty for product components												
		Warranty duration for the product	Duration of the guarantee for the product (typically indicated in years).												
		Guarantor of the warranty (laying)	Contact information for the guarantor of the warranty												
		Guarantor of the warranty (components)	Contact details for the guarantor for the components.												
j.	Management of the information flow	Information management	Information management system and decision-making system including file format.												
		Information Format	Are digital information about the modeled object in a format compatible with BIM programs?												
		Datasheets	Manufacturer's technical sheets for the product												

		Other existing information	Existing documentation and information can be used to characterize design solutions.												
		Proposed information	The information generated to communicate the design solution.												
j.	Information Flow Management	Purchasing Information	Purchase details including the purchase date and the order reference.												
		Health and safety information	Information about the condition and safety of the object.												
k.	Worksites	Delivery	Delivery details including time and date.												
		Logistics	Logistical details including storage and placement on site												
		Execution	Installation sequence including start and end date and duration.												
		Risk management	Detailed risk management plan related to the object.												
		Construction Design & Management	Safety instructions related to the implementation and use of the object.												
		Constructability	Index that identifies the simplicity of the process of supply and installation of the object.												
l.	Maintenance	Maintenance and operation	Operational requirements for the object.												
		Maintenance and cleaning	Maintenance and cleaning of the object.												
m.	Requirements	Fire resistance	Fire resistance requirements both in BS EN 13501 and in BS 476.												
		Reaction to fire	Fire reaction requirements (fire propagation) in both BS EN 13501 and BS 476												

		Combustibility	Fire propagation requirements in both BS EN 13501 and BS 476												
		Surface condensation	Aptitude to avoid the formation of water of conductivity inside the elements.												
		Acoustic Performance	Acoustic attenuation requirements.												
m.	Requirements	Other types of requirements	E.g. Fire resistance, insulation, sealing, etc.												

5 Data analysis and results

In this chapter are reported the analysis and the results obtained through the questionnaire. According to the structure of the questionnaire, the results are related to both the needs and requirments of construction companies in the information exchange phases and in the information management during the project phases.

The questionnaire has been trasmitted to the following european institutions:

1. Bam
2. BSI
3. Bsint
4. Cece Aisbl
5. Cpe
6. Cstb
7. Cstc (BBRI)
8. CU/BRE
9. Ebc
10. Ectp
11. Efca
12. Fiec
13. Indra
14. LIST
15. Ljubljana University
16. NTNU
17. Tecnalia
18. TNO

As seen above, the questionnaire has been conducted on the European level, where the target respondents are multiple actors within the AEC industry: Owners/Clients, Contractors, Designers, Consultants, Suppliers/Subcontractors. These respondents have been chosen in order to get a multi-disciplinary perspective of information and document management practices, due to highly complex project supply chain.
Aim of the initial part of the survey is to understand the feasibility, potential and barriers of BIM-based Supply Chain Management for Contractors and Suppliers/Sub-contractors, from the perspective of multiple project actors. By doing so, distinction of their needs and benefits which they could obtain can be seen during different project phases, especially trying to understand if they are somewhat more significant during the Use phase of the project lifecycle.
In addition to that, the goal of the documents management part plus the specific questions was to understand how the actors involved in the project collaborate between each other, how they exchange information and who is responsible for defining and attribute during the building process, from the point of view of the actors. In the end, the aim is to underline companies' needs and requirements for BIM-based renovation processes.

5.1 Requirements from general questions analysis

5.1.1 Introduction

5.1.1.1 Profiling the respondents company

As can be seen in the figure below, respondents are quite diversified regarding their annual turnover and number of employees, while majority of them are Contractors, specialized in both public and private projects.

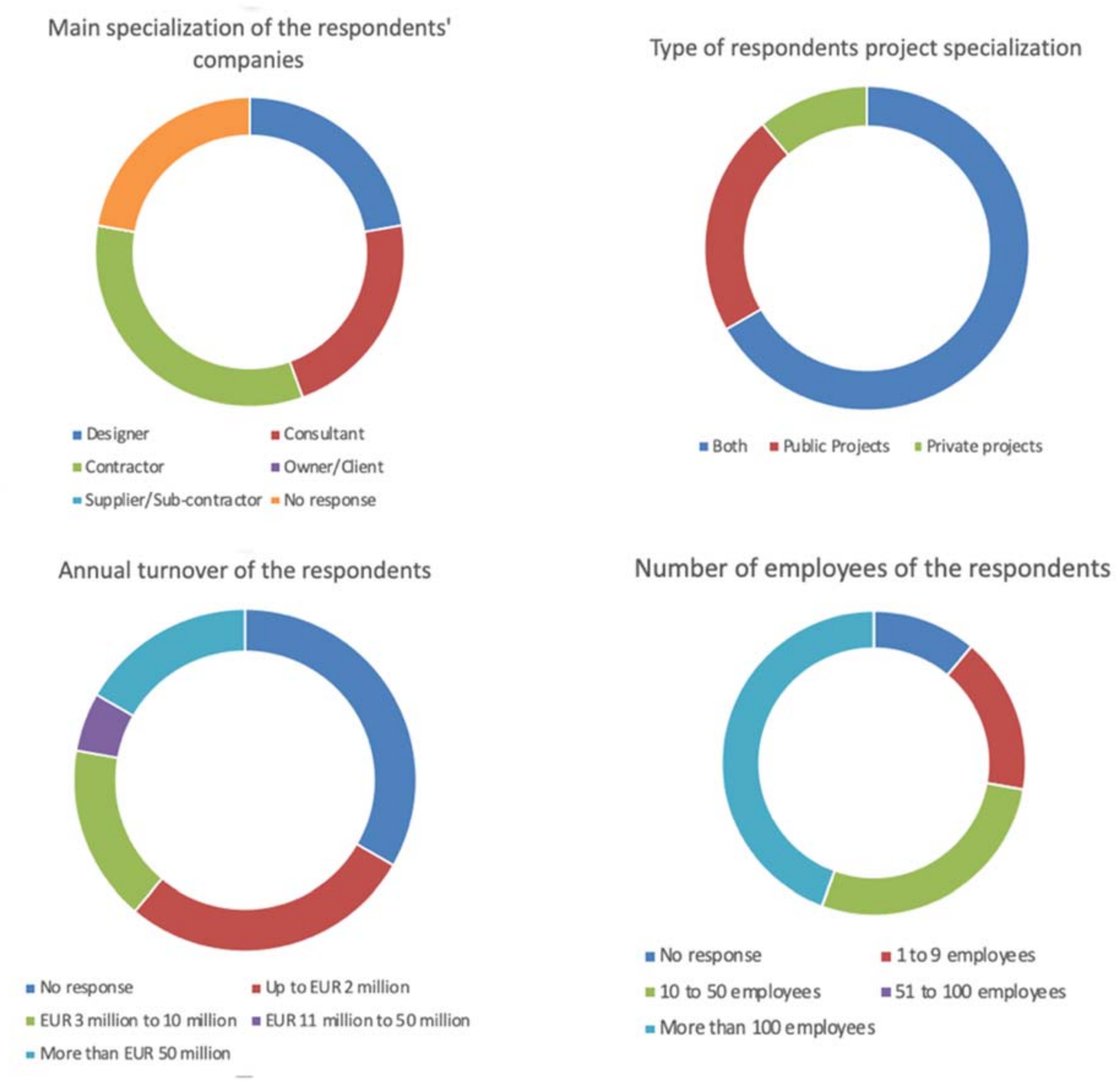


Figure 8 - Profile of respondents company

5.1.2 BIM for Supply Chain Management

Following part of the analysis concerns the overall Construction Supply Chain practices and potential of BIM for its application, by looking at the opportunities, barriers and feasibility for different project chain actors.

5.1.2.1 Relationships among actors within the Supply Chain

Selection of suppliers in the project chain is mainly done by giving most weight to price, quality and trust, while BIM application and competences are not considered so relevant.
If strategic partnerships with suppliers or sub-contractors are present, it is mostly for the purpose of partner sourcing of information and knowledge exchange, while few of the respondents are using it for integration of operations, as well as logistics and quality management. For those not pursing partnering practices, strongest barriers perceived are the complexity of integrating processes with the actors outside their organization, especially due to their short-term project orientation. Lack of trust along with the fear of transparency and appropriate risk allocation are somewhat weaker obstacles for collaboration.

5.1.2.2 Information exchange efficiency perception

Overall, perception of information exchange efficiency is low-medium or medium, which does show an opportunity for the improvement within the supply chain practices. This observation will be strengthened with further data analysis below.

5.1.2.3 Potential of BIM-based Supply Chain along project phases and Supply Chain practices

Design, Procurement and Construction are considered as project phases which could benefit the most from the application of BIM for Supply Chain Management (figure below), followed by the use and initiative (concept) phases. Regarding the supply chain processes, main contribution of BIM is expected within on-site assembly, followed by procurement and production/prefabrication, which is quite coherent with the project phases identified above. Interestingly, no high potential is seen in transportation and logistics management improvement.

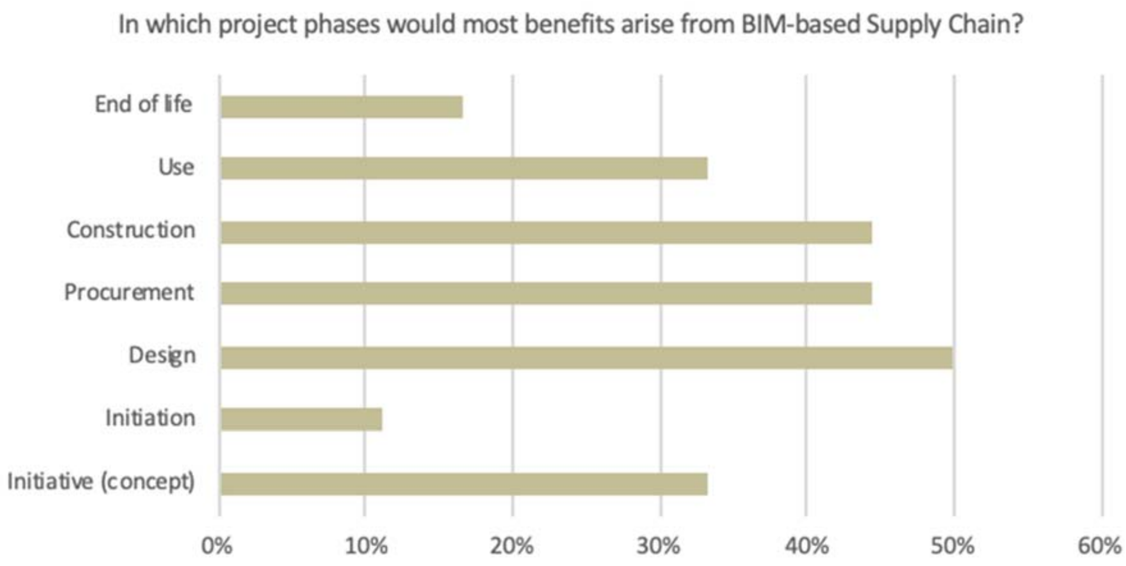


Figure 9 - project phase benefits

Going more into depth regarding Supply Chain practices (figure 10), Control of processes along the Supply Chain has been identified as key area of benefiting from BIM application. Furthermore, big importance has been given to the practices of Centralized information storage and Information transparency, especially for the highly fragmented Construction Supply Chain, thus providing actors with the improvement in information flows. Cost efficiency and quality control arise as subsequent benefits, while the potential in material and stakeholder management is not considered as crucial.

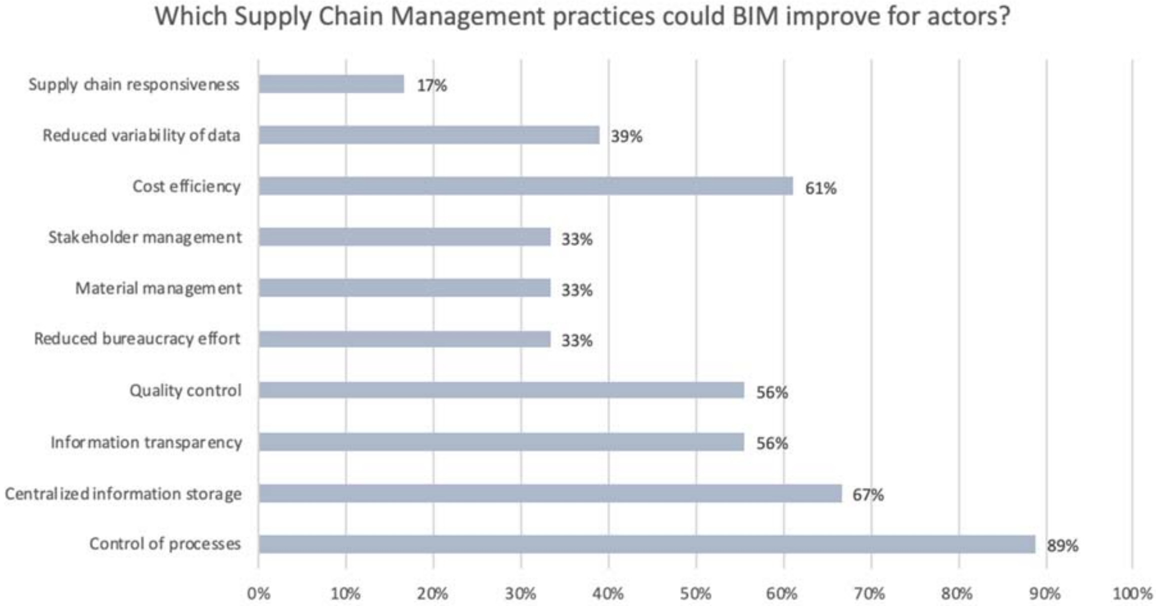


Figure 10 - SCM practice improvements

5.1.2.4 Feasibility of BIM-based Supply Chain for Contractors and Suppliers/Sub-contractors

Feasibility of BIM-based Supply Chain has been analysed from four different perspectives: Organizational, Technological, Economic and Social, both for the Contractors and Supplier/Sub-contractors. Respondents had to give the weight to each of these categories from 1 (low feasibility) to 5 (high feasibility). As seen in the chart below, majority of the respondents perceive that contractors somewhat have sufficient financial resources for BIM implementation (medium feasibility), while feasibility from technological and organizational perspective is perceived as a bit higher.

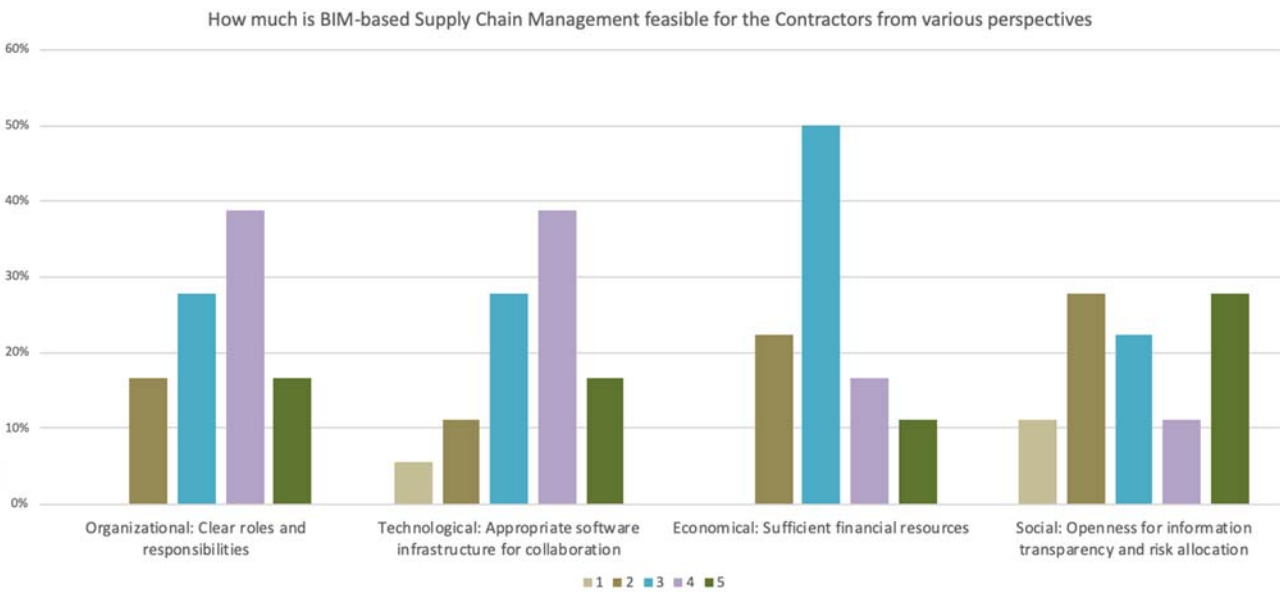


Figure 11 – Feasibility contractors

Using the same approach when looking at the feasibility for Suppliers/Sub-contractors, results are a bit different. Organizational and social feasibility seem as the highest ones, while technological and economical somewhat lower overall. By saying so, they may be eager for implementing BIM into their supply chain practices, but they do not have adequate financial and technological capacity to do so.

Figure 12 - Feasibility supplier/sub-contractors

Finally, when asked about ways for incentivizing the suppliers for implementing BIM, respondents considered trainings and long-term partnerships as crucial, while short-term project benefits sharing has not obtained such significance.

5.1.2.5 BIM implementation: benefits and obstacles

Overall, when looking at the benefits arising from BIM implementation (regardless of the supply chain), majority of the companies agree on obtaining time efficiency on their projects, as well as improved information exchange practices, coupled with data standardization which BIM provides. Higher output quality and client satisfaction are seen as somewhat advantageous, while supplier/sub-contractor satisfaction during the BIM implementation as least advantageous.

But there are some obstacles for BIM implementation as well. Seems that inadequate skills and interoperability with existing ICT systems within organization can pose the strongest difficulties for actors, as well as systems' interoperability with project actors outside the organization (suppliers/sub-contractors).

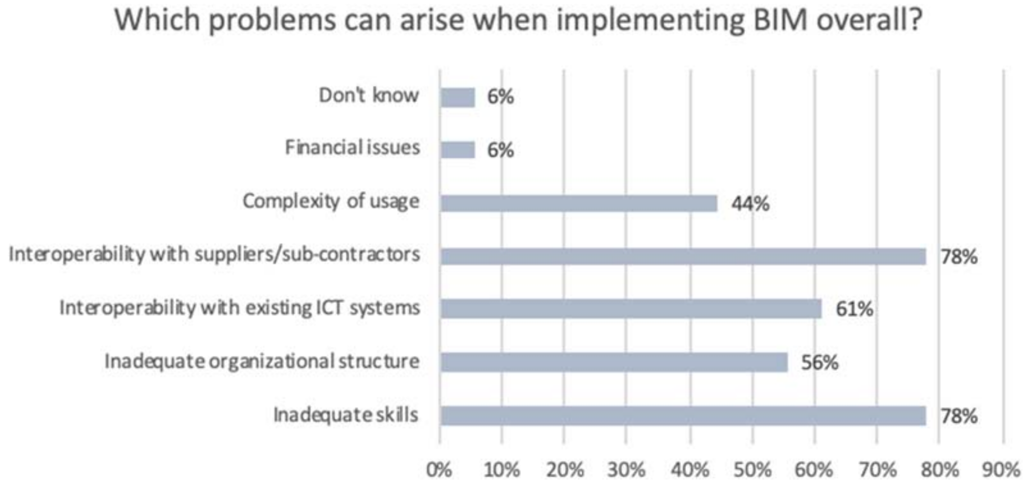


Figure 13 - Possible problems

5.1.2.6 Future development of BIM-based Construction Supply Chain

Stronger integration force along the supply chain, usage of barcodes/QR codes for material management and more frequent prefabricated practices are seen as most promising future developments. On the other hand, potential perceived for logistics control is very low, as well as usage of blockchain. It would be interesting to deep dive into these two opportunities and discover why do the actors think they cannot be exploited? Due to unawareness of their potential or technological barriers?

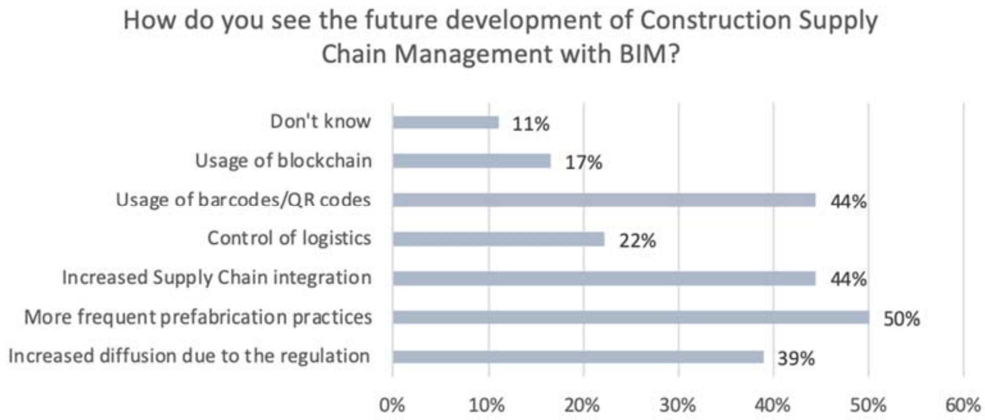


Figure 14 - Future

5.1.3 Documents management

5.1.3.1 Documents checklist

It is evident that most companies have a checklist to verify that the documents are complete, however, some still do not have, which can generate some problems of lack of information. The results are as expected, considering that this is a basic strategy in the documents management.
Another important aspect to consider is that according to the results, still the checklists are made not following a standard, less than half of the companies that have a checklist follows a standard, which can generate operability and requirements problems with other companies. Specially if the companies do not

have the same specific market, because the checklist according to the companies change mostly according to the type of project and sector.

5.1.3.2 Documentation shared with the supplier

The documents that the companies exchange with the suppliers are only the ones specifically related with the supplier, so the plans, specifications, technical reports, etc., are shared in a controlled way, in some cases the companies modify the documents to avoid share all the information to the supplier. Another aspect that can be seen frequently is that for the companies it is essential that the supplier delivers constructive details, as well as the technical sheets, so these are the documents that they required the most from the suppliers.

5.1.3.3 Drawings process

In this topic the companies show a great variety of processes. Some carry out the design drawings and only at the end of the project modify these drawings in the as-built drawings, while others modify the design drawings at the time of starting the construction or in each phase of the same, to finally have the drawings updated and finally finish with the as-built drawings. In both cases the maintenance specifications are given at the end of the project.
It is clear that the construction drawings are made before starting each phase, however if changes occur is because the decision making changed. In some cases it is tried to modify the drawings before starting the construction, in another during the construction process and at the end of the construction stage taking into account the changes made on site.

5.1.3.4 As-built drawings

Something important to emphasize in this aspect is that most companies carry out the as-built drawings with their own and external resources, so the collaboration in this stage with the different actors of the project is fundamental. It is interesting to see how it is necessary in most projects and for most companies, to make the final drawings with the other actors of the project, which can become an inconvenience if the information between them does not match perfectly.

5.1.3.5 Documentation management software

According to the results obtained, most of the companies do not use a specific software for the handling of the information and documents. This shows an unfocused handling of the information. However, most of them consider important to use software that allows managing the project information and interactions with other stakeholders in a better way.
Currently, most companies use emails, instant messaging applications or online platforms that do not have an organized management of the information, or tools that allow efficient management of it. Bearing this in mind, there is a lack of knowledge about the different tools to manage the information and the project documents within the same company and with the other stakeholders.

5.2 Requirements from specific questions analysis

The data analysis for the specific questions is done for the structural element part only, since it is the one that has been selected the most by the respondents, around 55,5%.

5.2.1 Attribute questions

The analysis starts with the section "product identification" and it follows the order presented on the questionnaire.

It is important to mention that some respondents preferred to answer "no" for this part, meaning that they were not sure about what answer to give, or they did not want to contribute.

The respondents were asked to say in which phase a specific attribute was indicated for the first time in the project, and also who was the person responsible for it.

a. Product identification

In which stage?

Family: initiation, design, and construction were the three different stages selected by the respondents, but the most selected was design.

Serial number: different answers were given, from defining the specification during the initiative phase, to the use of the building.

Description: most of the respondents affirm that the description of the element is defined in the design phase, however, some of them said that it is defined only in the construction or use phase of the building.

By whom?

Family: this attribute has been defined most of the times by the designers. It is almost a unanimous choice, but the option "contractor" was also selected in few cases.

Serial number and description: the serial number and the description of the structural element follow the same logic for the respondents, and in this case, they have been defined by the contractor and by the supplier most of the times, however, it is possible to be defined also by the designer.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in manuals and technical documents such as drawings, data sheets, and certifications.

b. Useful information

In which stage?

Function: initiation, design, and construction were the three different stages selected by the respondents. However, in the majority of the cases the definition of this attribute is done during the initiation and design phase of the project.

Location: design phase was the most selected choice, but not only. It is important to mention that stage 4 was selected, meaning that the location of a structural element was defined during the construction stage.

Features: different answers were given, from initiative phase, until construction, all of them were selected.

Components: the definition of the components was done during the design phase for most of the people. However, for others, this attribute was defined during the construction stage (important to mention that this is for those who affirmed that the location attribute was also defined during the construction phase).

By whom?

Function, location, features and components: for all these cases, the definition of the attributes was done by a collaboration between the designer, contractor and client. Some people mentioned that was also defined together with the supplier.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in planning documents and feasibility studies.

c. Materials and finishing

In which stage?

Materials: different answers were given, from initiative phase, until the construction phase, but the design stage was the one with the higher amount of selections.

Other materials: three different stages were selected, initiative, procurement and construction.

Colors: this attribute was defined during the procurement phase for most of the respondents.

Finishing: the type of finishing, according to the answers, is defined basically during the construction phase.

By whom?

Again, for all these cases, the definition of the attributes was done by a collaboration between the designer, contractor and client. Some people mentioned that was also defined together with the supplier.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in technical specifications about the structure and also in interior design projects.

d. Dimensions and sizes

In which stage?

These are all the attributes presented in this section: Nominal height, nominal length, nominal width, nominal volume, nominal weight, form. The different attributes got the same answers, since they are defined at the same stage according to the respondents. The difference is between the answers of each respondent. There were three types of answers. As an example: for respondent type A, all the attributes above were defined in the design stage. While for respondent type B, it was during the procurement stage, and for respondent type C, during the construction stage.

By whom?

Again, for all these cases, the definition of the attributes was done by a collaboration between the designer, contractor and client. Some people mentioned that was also defined together with the supplier.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in technical drawings and calculation reports.

e. Schedule, times and durations

In which stage?

These are all the attributes presented in this section: Program, date of delivery, maintenance schedule, date of installation, testing, useful life.

Program: This attribute is mostly defined during the construction stage, followed by procurement, design and initiative phase.

Date of delivery and Layout schedule: Both attributes got the exact same answers. For most of the respondents, they are defined during the construction phase.

Maintenance schedule: This attribute has been defined during the use of the building. Only a very small number of respondents said that it is defined during the initiative or design phase.

Date of installation and testing: Defined during the construction stage.

Useful life: The useful life is defined, according to the respondents, during initiative, construction and use stage.

By whom?

For all these cases, the definition of the attributes was done by a collaboration between the contractor and the client. Some people mentioned that was also defined together with the supplier.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in maintenance manuals, building program and as built drawings.

f. Manufacturer

In which stage?

Manufacturer: Different answers were given, from initiative, until construction stage. The most selected was the construction stage.

By whom?

The definition of the attribute was done by a collaboration between the designer and supplier.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in workshop drawings.

g. Costs

In which stage?

Design cost, cost of management and product cost: These attributes obtained basically the same answers, the stage in which these attributes were defined is the procurement, followed by the initiative, design and construction stages.

Installation and inspection cost: these attributes obtained basically the same answers, the stage in which these attributes were defined is the construction, followed by the initiative, initiation and procurement.

Maintenance cost: in most of the cases, this attribute was first defined in the use stage. There were also other answers saying that this attribute was defined in the initiative, initiation and procurement stage.

Disposal cost: first defined in end of life stage according to most of the respondents. A few of them said that is defined during the construction stage.

By whom?

The definition of the attributes was done by a collaboration between the client and contractor, with a small participation of the designer and supplier sometimes. Only in the attribute disposal cost, they all agreed that it is defined by the client.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in management documents of the project manager.

h. Environmental sustainability

In which stage?

Sustainability: defined for the first time during the initiation or design stage.

Environmental assessment, environmental assessment index: Defined for the first time during the design and procurement stage.

Environmental impact: defined for the first time during the design stage.

By whom?

The definition of the attributes was done by a collaboration between the client and the designer.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in documents related to QA, Energy and Environment impact assessment.

i. Guarantee and warranty

In which stage?

These are all the attributes presented in this section: Warranty, warranty start date, warranty duration of components and product, guarantor of the warranty (laying), guarantor of the warranty components. They are basically defined for the first time in the construction stage according the answers of the questionnaire.

By whom?

The definition of the attributes was done by the contractor together with the supplier.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in technical documents.

j. Management of the information flow

In which stage?

These are all the attributes presented in this section: Information management, information format, datasheet, other existing information, proposed information, purchasing information, health and safety information. They are basically defined for the first time in the same stage, during the design stage, followed by the construction phase.

By whom?

The definition of the attributes was done by a collaboration between the client, designer and contractor, with a small participation of supplier sometimes.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in management documents of the project manager.

k. Worksite

In which stage?

These are all the attributes presented in this section: delivery, logistics, execution, risk management, construction design and management, constructability. They are basically defined for the first time in the same stage. All the attributes besides the last one (constructability) are defined for the first time, according to the respondents, in the construction stage. The last one is defined in the design stage.

By whom?

The definition of the attributes was done by a collaboration between the client, designer and contractor, with a small participation of supplier sometimes.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in management documents of the project manager.

l. Maintenance

In which stage?

These are the two attributes presented in this section: maintenance and operation, maintenance and cleaning. They are basically defined for the first time in the same stage, according to the respondents, in the construction stage.

By whom?

The definition of the attributes was done by a collaboration between the client and contractor.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in facility management documents, as built drawings, technical documents.

m. Requirements

In which stage?

All requirements (e.g. fire resistance): defined for the first time in the design phase.

By whom?

The definition of the attributes was done by a collaboration between the designer, client and contractor.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in calculation reports.

n. Details

In which stage?

These are all the attributes presented in this section: substructure other than foundations, foundations, main frame of support, slab/attic, roofs, bearing walls, stairs, elevator shafts, masonry. They are basically defined for the first time in the design stage.

By whom?

The definition of the attributes was done by a collaboration between the designer, contractor and in some cases together with the supplier.

In what documents the above attributes were indicated?

When the respondents were asked this question, they affirmed that it is possible to find this information in calculation reports and technical documents.

5.2.2 Different types of maintenance

This part analyzes the answers about the additional attributes needed in case of not a new building, but for ordinary maintenance, extraordinary maintenance, restoration and renovation.

This was an open and not mandatory part of the questionnaire and around 20% of the respondents replied to this part.

It is possible to separate the answers in two types, the ones related to ordinary and extraordinary maintenance, and the ones related to restoration and renovation. For the first ones, the respondents highlighted the importance of having different actors such as the facility manager and auditor for environmental assessment during a maintenance phase, as well as having inspections by the authorities. For the part related to restoration and renovation, they mentioned the importance of having technical documents and as built drawings that show the reality they will find on site.

6 Conclusions

From the initial part of the questionnaire main opportunities of BIM implementation have been identified within the information exchange practices. By enabling data standardization and interoperability of the information exchanged among the actors, BIM does give to the actors more control of their supply chain processes and flows exchanged. This observation is very relevant due to the complexity of the project chain related to its fragmentation and multidisciplinarity, and especially due to the perception of medium-low information exchange efficiency. Opportunities identified are considered as relevant during design, procurement and construction project phases. Interestingly, respondents have given less relevance to the information storage benefits during the phase of Use, where their needs in terms of available data for maintenance operations can be very complex.
According to what it is seen from the analysis of the data, it is possible to say that the companies' needs are the improvement of the exchange of information, by using better or more specifique software of data management, as well as, by updating the drawings as soon as possible to avoid change during or after the construction phase.This is true not only for new buildings projects, but also for renovations in buildings. The design process of a renovation should be very well detailed and informed to all the actors in order to achieve a high quality process and to maintain the schedule, without any drawbacks. Renovations and restorations can be more complex from the point of view of data collection and information exchange than a new building, however there are technologies and team work collaboration methods already applied in new buildings project, that would improve the process and increase the quality of the deliverable if applied also to renovation projects.
For the aim of an overall view, in Tables 7 and 8 are presented the principal companies requirements for the building element "structural element", and the principal companies requirements for the information exchange between the contractors and the stakeholders.

Table 7 – Information exchange - main requirements

Principal companies requirements
Improved interoperability with the stakeholders information systems
Improved interoperability with existing ICT systems used within the organization
Improved ICT skills
Accurate As-Built drawings for projects of restoration and renovation

Table 8 – "Structural element"- main requirements

Principal companies requirements
Greater clarity on the source where the information are located (which documents)
More clarity about the phase where the attributes would be defined
More clarity about who is the responsible for the definitions of the attributes

7 Bibliography

[Bosch, 2017] Bosch-Sijtsema, P. et al. (2017) 'Barriers and facilitators for BIM use among Swedish medium-sized contractors - "We wait until someone tells us to use it"', Visualization in Engineering. Visualization in Engineering, 5(1).

[Eastman et al., 2011] Eastman Chuck; Teicholz Paul; Sacks Rafael; Liston Kathleen, BIM Handbook — a guide to building information modeling for owners, managers, designers, engineers and contractors, Aufl, 2, Wiley, Hoboken, 2011.

[Franchini, 2018] Franchini, Chiara. *Scambio informativo nei processi edilizi: ottimizzazione della comunicazione tra imprese e fornitori - definizione dello strumento di analisi*. (master thesis, supervisor Alberto Pavan). Politecnico di Milano, Italy.

[Gerrard et al., 2010] Gerrard, A., Zuo, J., Zillante, G. and Skitmore, M., 2010. Building Information Modeling in the Australian Architecture Engineering and Construction Industry. In: U. Jason and I. Umit eds. Handbook of Research on Building Information Modeling and Construction Informatics: Concepts and Technologies. Hershey, PA, USA: IGI Global. pp.521-45.

[Hosseini et al., 2016] Hosseini, M. R., Banihashemi, S., Chileshe, N., Namzadi, M. O., Udeaja, C. E., Rameezdeen, R., & McCuen, T. (2016). BIM adoption within Australian Small and Medium-sized Enterprises (SMEs): an innovation diffusion model. Construction Economics and Building, 16(3), 71-86.

[Lam et al., 2017] Lam, T. T., Mahdjoubi, L., & Mason, J. (2017). A framework to assist in the analysis of risks and rewards of adopting BIM for SMEs in the UK. Journal of Civil Engineering and Management, 23(6), 740-752.

[Lau et al., 2018] Lau, S. E. N., Zakaria, R., Aminudin, E., Saar, C. C., Yusof, A., & Wahid, C. M. F. H. C. (2018, April). A Review of Application Building Information Modeling (BIM) During Pre-Construction Stage: Retrospective and Future Directions. In IOP Conference Series: Earth and Environmental Science (Vol. 143, No. 1, p. 012050). IOP Publishing.

[Lee and Yu, 2016] Lee, S. and Yu, J. (2016) 'Comparative Study of BIM Acceptance between Korea and the United States', Journal of Construction Engineering and Management, 142(3), p. 05015016.

[Li et al., 2019] Li, P., Zheng, S., Si, H., & Xu, K. (2019). Critical Challenges for BIM Adoption in Small and Medium-Sized Enterprises: Evidence from China. Advances in Civil Engineering, 2019.

[Malacarne, 2018] MALACARNE, G., TOLLER, G., MARCHER, C., RIEDL, M., & MATT, D. T. (2018). Investigating benefits and criticisms of bim for construction scheduling in SMEs: An Italian case study. International Journal of Sustainable Development and Planning, 13(1), 139-150.

[NBS, 2015] NBS BIM Toolkit: Classification (Uniclass 2015). Retrieved Febrary 14, 2018, from https://toolkit.thenbs.com

[Tranchant, 2017] TRANCHANT, A., BELADJINE, D., & BEDDIAR, K. (2017). BIM IN FRENCH SMES: FROM INNOVATION TO NECESSITY. WIT Transactions on The Built Environment, 169, 135-142.