PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
ESCUELA DE INGENIERIA

TOWARDS SOCIAL BIG BIM IN HOSPITAL PROJECTS

FABIÁN ANDRÉS RIQUELME FERNÁNDEZ

Thesis submitted to the Office of Research and Graduate Studies in partial fulfillment of the requirements for the Degree of Master of Science in Engineering

Advisor:
CLAUDIO MOURGUES ÁLVAREZ

Santiago de Chile, (December, 2015)

PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
ESCUELA DE INGENIERIA

TOWARDS SOCIAL BIG BIM IN HOSPITAL PROJECTS

FABIÁN ANDRÉS RIQUELME FERNÁNDEZ

Members of the Committee:

CLAUDIO MOURGUES ALVAREZ

PAZ ARROYO RIQUELME.

EDUARDO LYON RIERA

GUILLERMO THENOUX ZEBALLO

Thesis submitted to the Office of Research and Graduate Studies in partial fulfillment of the requirements for the Degree of Master of Science in Engineering

Santiago de Chile, (December, 2015)

To my mother, Margarita. She allowed this work to exist.

ACKNOWLEDGEMENTS

This work was supported by the Ministry of Public Infraestructure (MOP), Ministry of Health (MINSAL), CONCESIONARIA SIGLO XXI, SIRVE, and CANVAS which are the main participants in Antofagasta Hospital Project and allowed me to obtain the information to fullfill this thesis.

I would like to thank my advisor Dr. Claudio Mourgues for support and guidance over this time, which has lead me to get interested in research and the study of new topics. His knowledge and research experience has helped me to develop journal papers and this thesis, also my colleagues and professors of the Department of Construction Engineering and Management for their collaboration and friendship.

My special thanks to Zañartu Ingenieros Consultores Spa, the advisor of the Fiscal Inspection in Antofagasta Hospital Project, and his General Manager, Sergio Clavería, for their support in the development of this thesis and for hire me during the project duration, which allowed me to be part of other projects as Hospital Felix Bulnes, Maipo Bridge and Santiago Subways, which full me with excellent labour experience. I am also very grateful to my work friends that received and allowed me, be part of the team and to share a lot of good moments.

I want to thank all my friends which help in some part of this thesis: Sandra Burgos, who helped with my presentation, Paula Arevalo for advisory in the grammar of this thesis and Tania Conca for the beginning of this work. Finally, I would like to thank my family and friends for their patience and support for my academic pursuits.

TABLE OF CONTENTS

Pág.

LIST OF FIGURES

Pág.

LIST OF TABLES

Pág.

ABSTRACT

BIM is the methodology of generating and managing building data during its life, affecting the relationship between actors and the project process in order to improve quality and productivity. Due to the complexity of healthcare projects, the use of BIM has become essential, and in the case of public healthcare policies, the implementation of BIM's methodology has been successful but, at the same time, there have been some failures. Therefore, various organizations have developed different documents to support their BIM implementations, avoiding interpretation, responsibility, competency and scope problems, among others. In the case of Chile, public hospital projects have been slowly including BIM in their requirements, but its implementation is not achieving expected benefits. Therefore, there is a need for a better understanding of BIM implementation on hospital projects, how to support it process and clarity to project stakeholders, obtaining the full benefits of the methodology. This thesis establishes the challenges to implement BIM within hospital projects, also reviews publicly available BIM documents, describes their content and purpose and discusses the relation between them. Finally, presents a case study that explores the use of BIM in a project about the construction of a public hospital, describes the main challenges, the outcomes, and the learned lessons.

The findings indicate that the main challenges are: A lack of appropriate specifications in the BIM requirements, a lack of punishment for noncompliance, inefficient BIM procedures, poor objectives alignment among the stakeholders, and a lack of proper BIM knowledge. Based on these findings and the literature, a set of strategies are proposed: Include a formal evaluation of BIM deliverables, develop public national standards with the public agencies objectives, require the development of a BIM project execution plan for every new project and generate BIM guides as well as an agency in charge of maintaining a long-term BIM vision.

Keywords: BIM, Support documents, Standards, Guides, Project Execution Plan, Public Projects, Hospital , Case study.

RESUMEN

Building Information Modeling es una metodología de generación y manejo de información del proyecto, afectando la relación entre los actores y el proceso del proyecto con el fin de mejorar la calidad y la productividad. Debido a la complejidad de los proyectos de salud, el uso de BIM se ha convertido una necesidad. En el caso de salud pública, la implementación de la metodología de BIM ha tenido éxito y fracasos. En consecuencia, varias organizaciones han desarrollado diferentes documentos para apoyar sus implementaciones, evitando problemas de interpretación, de responsabilidad, competencias y ámbito de aplicación, entre otros. En Chile, los proyectos de hospitales públicos están incluyendo BIM en sus requerimientos, pero su aplicación no está logrando los beneficios esperados. Por lo tanto, hay una necesidad de una mejor comprensión de la implementación BIM en proyectos hospitalarios, para así, obtener todos los beneficios que la metodología promete. Esta tesis establece los desafíos para implementar BIM dentro de los proyectos del hospital, revisa los documentos de apoyo de a la implementación BIM, describe su contenido y propósito, y analiza la relación entre ellos. Por último, presenta un estudio de caso que explora el uso de BIM en un hospital público, se describen los principales desafíos, los resultados y las lecciones aprendidas. Los hallazgos indican que los principales problemas son: La falta de especificaciones apropiadas en los requisitos de BIM, la falta de castigo por incumplimiento, procedimientos BIM ineficientes, objetivos no alineados entre participantes, y falta de conocimientos adecuados. Las principales estrategias son: Incluir una evaluación formal de los entregables BIM, desarrollar estándares nacionales públicas con los objetivos de los organismos públicos, requiere el desarrollo de un plan de ejecución de proyectos BIM para cada nuevo proyecto y generar BIM guía, así como una agencia a cargo de mantener una visión BIM a largo plazo .

Palabras Clave: BIM, Documentos de apoyo, Estándares, Guías, Plan de Ejecución de Proyecto, Proyectos Públicos, Hospitales, Caso de Estudio.

1. INTRODUCTION

The construction is known as a project-based and complex industry (Nawary, 2012) where productivity, cost and project duration are always a concern, but it has some characteristics that difficults it, for example: the increasing amount of competences and technical and quality requirements (Serpell, 2012a), the amount of participants, lack of deep analysis in decisions and the slowness to adopt new technologies (Saldías Silva, 2010). To address these challenges, one of the most accepted strategies is that construction implements and promotes, technology and methodology innovations, to facilitate project management (Serpell, 2012b);(Ghio Ca & Bascuñan Walker, 2012). Some examples of these innovations are: Building Information Modeling (BIM) methodology work in building large-scale hospitals (Khanzode, Fischer, & Reed, 2008), Lean Construction and Last Planner in mining infrastructure projects (Ballard & Howell, 1994), among others.

Governments are responsible for developing a big amount of projects in their countries and they are very interested in increasing the quality, and reducing the cost and the execution time of their projects (Wong, Wong, & Nadeem, 2009). In consequence, they are requiring in their projects, technology and methodology innovations, aiming to improve project productivity and satisfy public agencies interests. Therefore, important countries such as USA, Singapore, Australia, New Zealand and UK are working to implement BIM as a standard methodology for their public projects, requiring it in project contracts and also preparing some implementation strategies and developing support documents.

Healthcare projects are one of the most important projects that public agencies are in charge, as they focus on the health of a big amount of people in the country. Their complexity and the amount of designers that have to be coordinated, among other reasons, are making the use of BIM, a requisite to this type of project, because of all the benefits it brings. BIM, in private healthcare projects, has shown good results, increasing the coordination of details and design information amongst the multiple parties involved and also, improving the facility design (Chidambaram et al., 2011; Khosrowshahi & Arayici, 2012).

In Chile, some efforts to implement BIM in the AEC industry are being made. Some public projects (Hospitals, airports and highways) are requiring the use of BIM, mandated by public agencies. In specific, Healthcare projects are requiring BIM, but the project results have shown that the expected benefits are not yet achieved. As BIM is starting to be required and will be maintained for future hospital projects, these challenges could be studied in order to improve the BIM implementation results, determining how to approach BIM challenges, in order to remove implementation barriers found in current projects and, in consecuence, achieve expected BIM benefits.

Nowadays, BIM requirements are moving from a lonely little BIM (particular use made by a single actor) to a social BIG BIM (Multi-use and Collaborative BIM) (Jared, 2013), where most of the benefits of using this methodology are (Grilo, Zutshi, Jardim-Goncalves, & Steiger-Garcao, 2012). This increased and more complex use, generates many challenges such as the misalignment of objectives within the industry – where each stakeholder seeks its own benefits hindering cooperation and integration (Hartmann, Van Meerveld, Vossebeld, & Adriaanse, 2012) – and the lack of organized and standardized information that support the social BIG BIM processes (Howard & Bjork, 2008). Therefore, a correct BIM implementation is more difficult to achieve.

This thesis is divided into five main chapters. This chapter summarizes the main points of research: objectives, hypothesis, research questions, research methodology, and expected results. The second is about the literature review of this thesis. The third and fourth chapters are scientific articles. The first article is about BIM support documents that can be found and can help the BIM process in any project. The second is a case of study in a Hospital Project “Hospital de Antofagasta”. Finally there is a last chapter of the general conclusions.

Due to the structure of this thesis, there is a degree of redundancy in the contents of the chapters. The Research is summarized in the horseshoe research methodology diagram in Figure 1-1

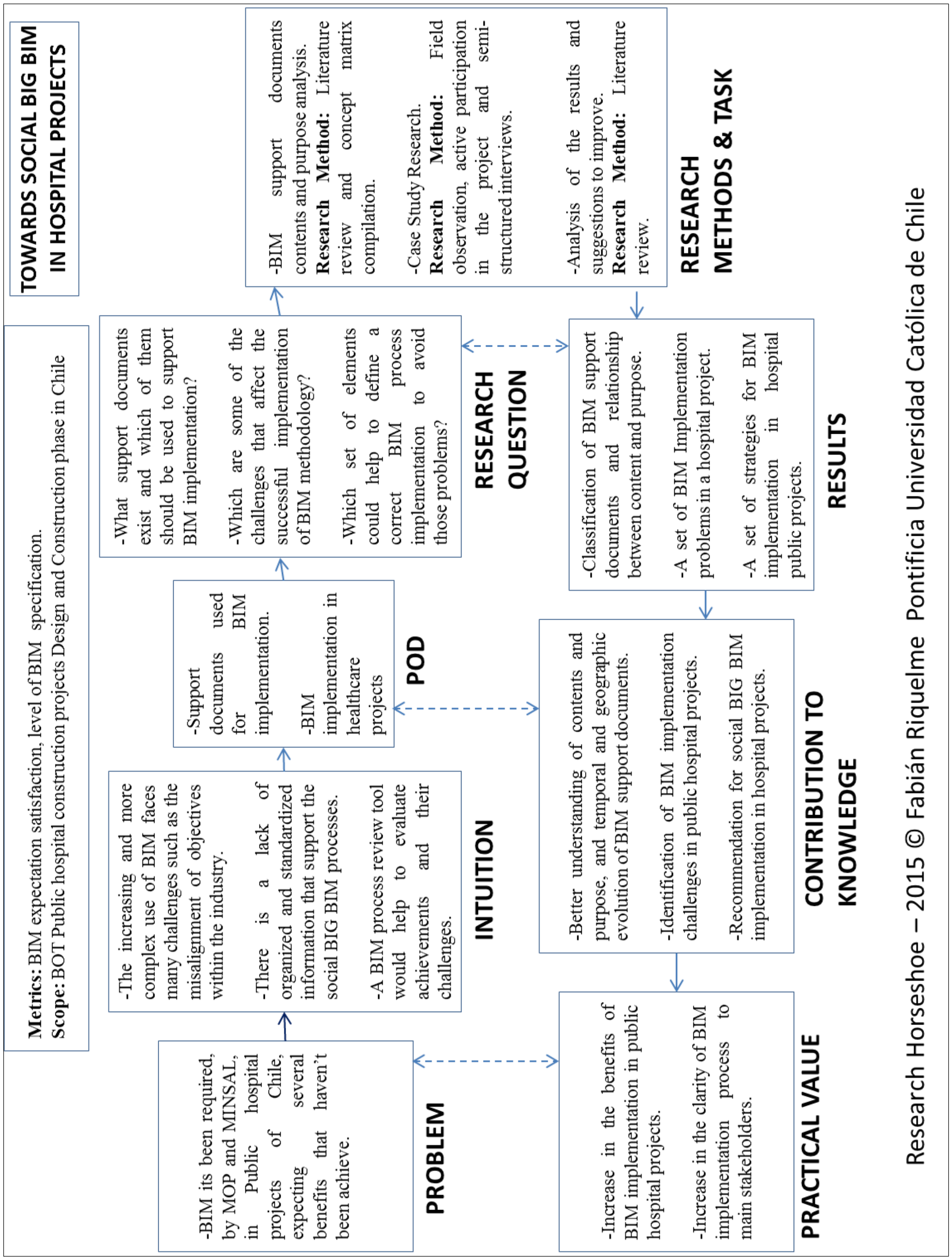

Figure 1-1 Research methodology diagram (Horsehoe Diagram)

1.1.Problem definition

Public agencies, such as MOP and MINSAL, are expecting that BIM work methodology increases the general productivity of the projects, reducing their cost and duration, but **these expected benefits haven't been achieved**. Some BIM deliverables are not achieved and others are outside the scheduled time.

Moreover, there is a lack of organized and standardized information that supports the social BIG BIM (Collaborative and multiple uses) processes and in specific in public healthcare projects which its project delivery characteristics have led to failures in the use of BIM methodology. Increasing the implementation cost and causing an innovative barrier to AIC companies.

Interviews with participants of projects where BIM was required exemplifies the problem identified: The process of coordination is usually late causing troubles with deadlines, its process is ineficcient developing 3D models of every change in the 2D drawings, with no process definition, BIM is outside the project process and the BIM actors do not interact with other participants limiting the collaboration and finally and more important, the BIM coordination is developed at the same time of tradicional coordination.

1.2. Intuition

The increasing and more complex use of BIM faces many challenges such as the misalignment of objectives within the industry, this plus the fact that there is a lack of planning of the BIM methodology in the earlier stages of the project, are the main problems of BIM implementation in healthcare projects. Providing tools and methodologies for planning the BIM process will reduce implementation problems and increase the chance of achieving the expected benefits in the project.

1.3.Objectives

Consistent with the intuition proposed, the objective of this research is to help removing barriers and difficulties of using BIM methodology in Chilean hospital infrastructure projects and thus increase the number of projects that use Social BIG BIM in an efficient way, improving the quality, cost and duration of the project. For this, some specific objectives should be defined to structure the research.

Specifics Objectives:

- Improve the understanding of contents and purpose, and temporal and geographic evolution of BIM support documents.

- Identify BIM implementation challenges in public hospital projects.

- Generate recommendations for social BIG BIM implementation in hospital projects.

1.4.Research Questions

The specific objectives described above can also be expressed as the following research questions:

- What support documents exist and which of them should be used to support BIM implementation?
- Which are some of the challenges that affect the successful implementation of BIM methodology?
- Which set of elements could help to define a correct BIM process implementation to avoid those problems?

1.5.Research methodology

The general work methodology, which can be seen in Figure 1-2, includes three main tasks: (1) BIM support documents contents and purpose analysis, (2) a case study analysis, and (3) the analysis of the results that led to suggestions for implementation improvements. The methodology considers the study, classification and analysis of important documents to support BIM implementation in projects, in order to be a reference from where organizations can learn. The methodology also considers an active participation of the researcher in the Antofagasta Hospital project, the application of deliverable control and assessment instruments, and interviews to the main participants in the BIM process.

The participation in a project allowed the researcher to directly observe project deliverables and allowed to participate in coordination project meetings with stakeholders (representatives of the project designers, BIM modelers and BIM coordinators). Also, the observations, interviews with staff and the review of support documents, provided the material to generate suggestions for improving the results of BIM implementation in public healthcare projects.

The case of study is a public hospital project, requested by the Ministry of public Infrastructure and Ministry of health in Antofagasta, Chile. It is a highly complex project

(114,000 m2, 671 Beds), with modern design requirements and advanced in medical technology equipments.

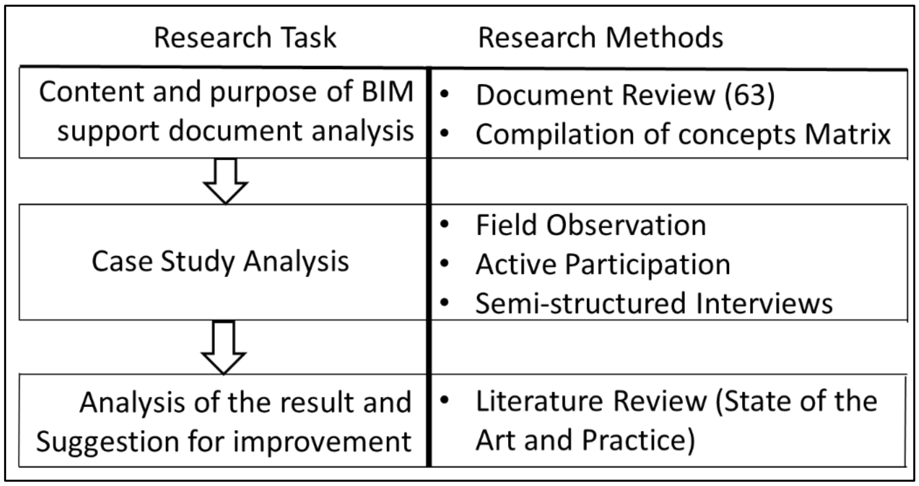

Figure 1-2 General Work Methodology

1.5.1. BIM Support Documents and contents analysis

Initially, the researcher looked through all available means (by internet search and scientific papers) the various documents that support the use of BIM methodology in projects. Being a search throughout the world, there was a lack of standardization: Each country or organization had a different naming for their documents, different contents and different scopes. Therefore, it was clear that a classification methodology was needed to extract relevant information. The researcher found 3 classifications that would be the basis for classifying BIM documents (Staub-French, Fourgues, et al., 2011) and (Sattineni & Mead, 2013), and a product, organization and process ontology to represent major aspects of the design that can be controlled and delivered by managers (Garcia, Kunz, Ekstrom, & Kiviniemi, 2004).

The classification was used, by a Concept Matrix Method (Webster & Watson, 2002), to obtain the contents of the different BIM support documents and therefore, categorize them in different types. Finally, the relationship of the various types of documents, was determined. Figure 1-3 shows the activities for BIM support documents and content analysis.

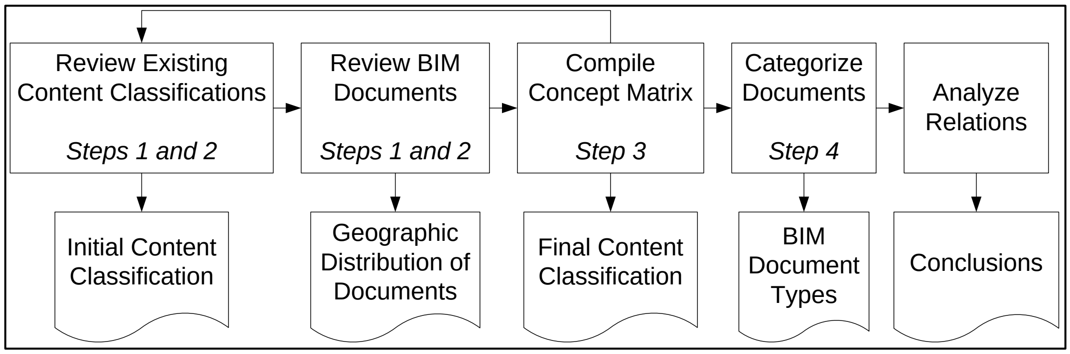

Figure 1-3 BIM Support Document Research Activities

1.5.2. BIM Case Study Review

The classification of documents and content review allowed the researcher to acquire tools, processes and information needed to analyze a BIM implementation. The first part of the investigation led to a scientific basis for the proposals that were made in this second stage, and allowed a critical analysis of the current situation, and also comparing it with what exists in other parts of the world, to generate recommendations in the BIM process in Chile.

The first activity was to study the project requirements and deliverables, through the study of contracts and conversation sessions with project participants. Knowing the deliverables, the researcher performed a review process based on checklists that allowed the control and assessment of the BIM deliverables and the gathering of information to identify challenges of the implementation.

As a process of quality assurance, the review process is an iterative activity that helps to improve the project's and company's BIM process. Figure 1-4 shows the activities for the case study research.

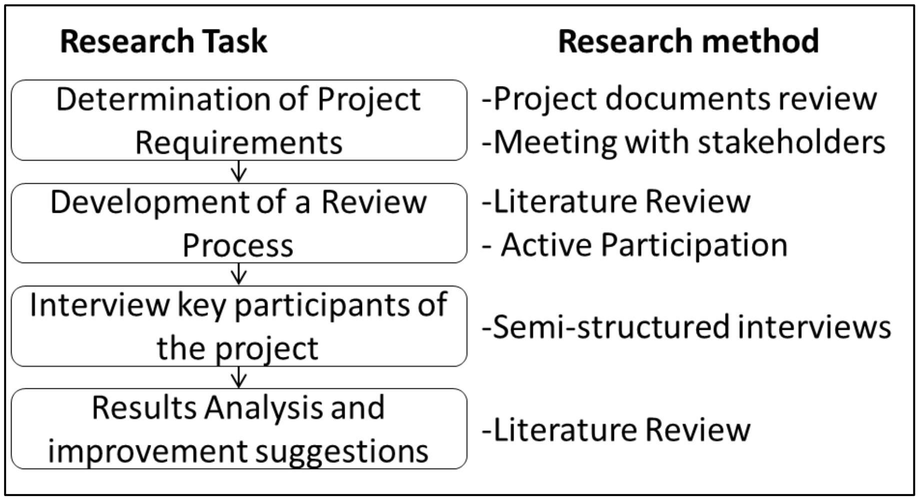

Figure 1-4 Antofagasta Hospital -Case Study Research Methodology

1.6.Expected Results

The expected results of this thesis is to generate a supported recommendation in order to remove barriers and difficulties of using BIM methodology in Chilean hospital infrastructure projects and thus to improve quality, cost and duration of the project.

To achieve this, we specificaly expect to improve the understanding about the content and purposes, and the temporal and geographical evolution of BIM supporting documents; identify BIM implementation challenges in public hospital projects; and obtain recommendations for the implementation of collaborative BIM in hospital projects.

2. LITERATURE REVIEW

This chapter examines in depth the thematics that are relevant to the development of this thesis.

As a starting point a number of issues related to BIM methodology general information are explained, in order to understand the central thematic of this thesis, then some industry limitations were reviewed, also collaboration thematic of BIM and in specific the Social BIG BIM. Finally, we identify and discuss ways of literature content classification of BIM support documents and then review existing case study of BIM in healthcare and public projects

2.1.BIM General Information

Building information modeling (BIM) it’s one of the new methodologies that is revolutionizing the way things are done in construction.

BIM provides a concept for describing and displaying information required in the design, construction and operation of constructed facilities. It can bring together the diverse sets of information used in construction into a common information environment reducing, and often eliminating, the need for the many types of paper documentation currently in use (ISO, 2010). It’s based on the use of digital 3D representations which includes a set of information and parameters that can represent the project and perform multiple analyzes to support decision-making.

This methodology, used and properly controlled, aims to improve quality, reduce costs and deadlines throughout the lifecycle of a project: Design, Construction and Operation (W. Lu, Peng, Shen, & Li, 2013). Therefore, BIM aims to increase de collaboration between actors of the construction industry. Also, some authors believe that BIM implied big changes in the design and construction process (Azhar, Hein, & Sketo, 2008) for a properly implementation.

In successful projects has been shown to decrease the development time of a project, increasing fluidity at work at the design and construction stage, reducing the changes during construction, reduce the total project costs (N. Lu & Korman, 2010) and improves the overall quality of the project .

There is a complete agreement in the literature that BIM is a successful tool for improving results of a project. Some authors have identified some BIM benefits. A few of these benefits are named below. Manning and Messner (Manning & Messner, 2008) have identified six benefits of using BIM in the earlier conceptual stage, this stage is recognize to be one of the most important in the lifecycle of a project, there are:

- Rapid Visualization.
- Better decision support upstream in the project development process.
- Rapid and accurate updating changes.
- Reduction of man-hours required to establish reliable space programs.
- Increase communication across the total project development team (users, designers, capital allocation decision makers, contracting entities, and contractors).
- Increased confidence in completeness of scope.

In addition to conceptual stage, Azhar et al, recognize 7 more important characteristics that's affect all project lifecycle (Azhar et al., 2008), these are:

- Faster and more effective processes: information is more easily shared, can be value-added and reused
- Better design: building proposals can be rigorously analyzed, simulations can be performed quickly and performance benchmarked, enabling improved and innovative solutions
- Controlled whole-life costs and environmental data: environmental performance is more predictable, lifecycle costs are better understood
- Better production quality: documentation output is flexible and exploits automation.

- Automated assembly; digital product data can be exploited in downstream processes and be used for manufacturing/assembling of structural systems
- Better customer service: proposals are better understood through accurate visualization.
- Lifecycle data: requirements, design, construction and operational information can be used in facilities management.

Finally Saldías (2010), Khanzode (2008), between others authors recognize a positive financial result by using BIM in their projects, great return on investment, less RFI which in consequence reduce time and cost of redoing task, and faster designs that reduce total payment to specialists. (Saldías Silva, 2010) (Khanzode et al., 2008).

BIM in Chile

BIM adoption among Chilean projects is increasing; some public and private projects are requiring BIM in their projects. A questionnaire made by the Architectural School of the University of Chile (Loyola Vergara, 2013) mentioned that 61% of a total of 810 answer of people of the construction industry are classified as regular BIM users, respondents, although they are close to these new technologies and may be a biased assessment, is a clear indicator that BIM is already well recognized. This quantity is distributed in 3 categories: Architecture, engineering and construction users, being the architecture the biggest group between them. Also, in the questionnaire was asked to determine the principal BIM uses, being the visualization and document elaboration the most BIM applications used. The three main types of projects using BIM according to the survey are: (1) Residential Projects, (2) Offices Projects and (3) Healthcare Projects. (Loyola Vergara, 2013)

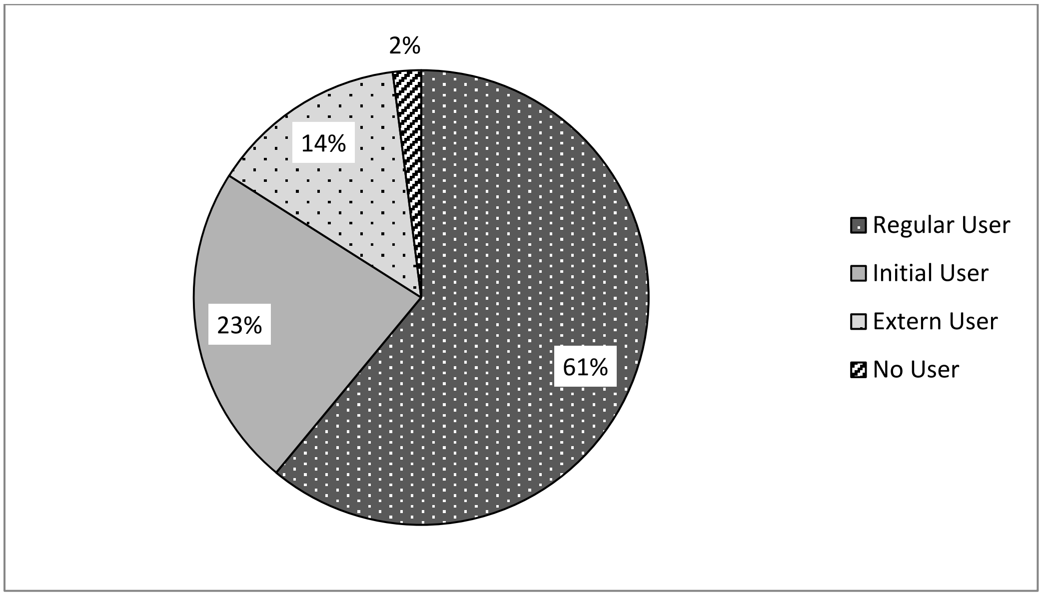

Figure 2-1 Level of BIM Users - Encuesta Nacional BIM (Loyola Vergara, 2013)

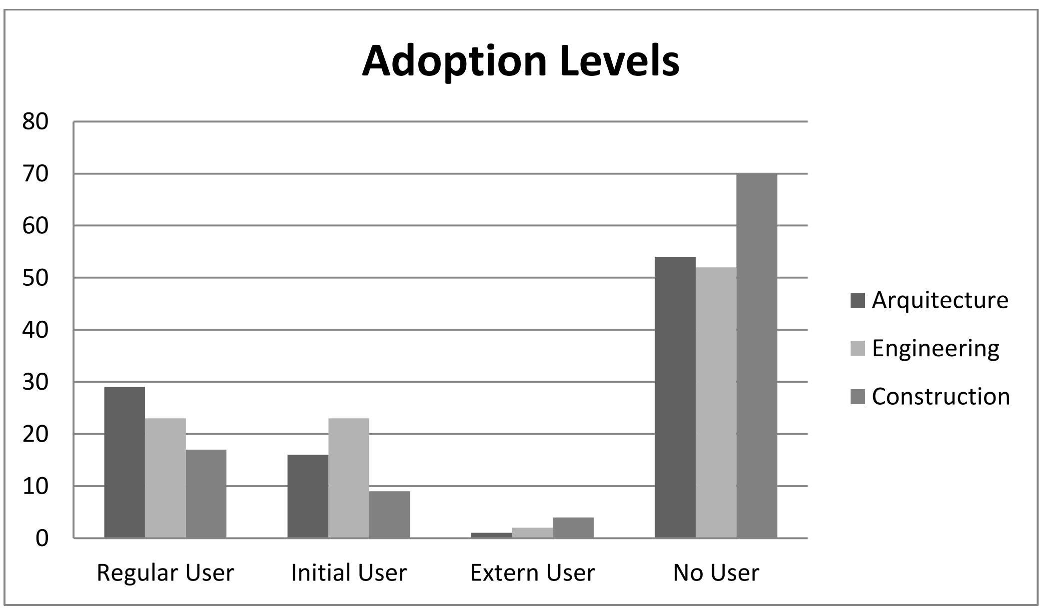

Figure 2-2 Adoption Levels - Encuesta Nacional BIM (Loyola Vergara, 2013)

There have been several attempts in the Chilean industry to implement BIM in hospital projects (EMB, 2013). The Ministry of Public Infrastructure (Ministerio de Obras Públicas) and Ministry of Health (Ministerio de Salud), visionary, has introduced some innovative requirements regarding the use of BIM methodology for some of its projects, specifically in the healthcare projects area. The recent biddings for "Concessions Health Facilities" (adopted in 2011) include requirements for use of BIM for the coordination of designs, control and review progress on their projects. Also, it’s expected that the requirements will be increased in the future, aiming to use BIM in a full collaborative way.

2.2.Industry Limitations

There exist some reasons that make the BIM implementation be difficult on a project. These are caused, among other reasons, because of some of the construction industry characteristics.

Since construction projects are often large and complex, the plan, design, build and operate requires many specialized persons. In general, most industries are characterized by producing high quality, reasonable cost and delivery service in a timely manner, while the construction industry is characterized by the opposite. This is due primarily to three factors:

The nature of the projects: They involve many participants with different capacities and interests, and often in conflict. They are assigned to risks and uncertainties. Many decisions are based only on experience (Saldías Silva, 2010). Also, each time a project is terminated and a new one is started up, a new coalition of actors with new experience will shape roles and relationships in the network.(Linderoth, 2010), Figure 2-3 exemplifies this statement.

The industry characteristics: Highly fragmented with many specialties involved. Low investment in research and technology. Slow to adopt new technologies. (Saldías Silva, 2010). The disruptive nature of the networks that constitute building and construction it's a real challenge.

The challenges facing: Restricted budgets, more restricted times and higher quality demands. Lack of skilled resources (Saldías Silva, 2010). Also, the knowledge and benefits of projects have to be transfer to organizations and to other projects in order to get more benefits for the investment.

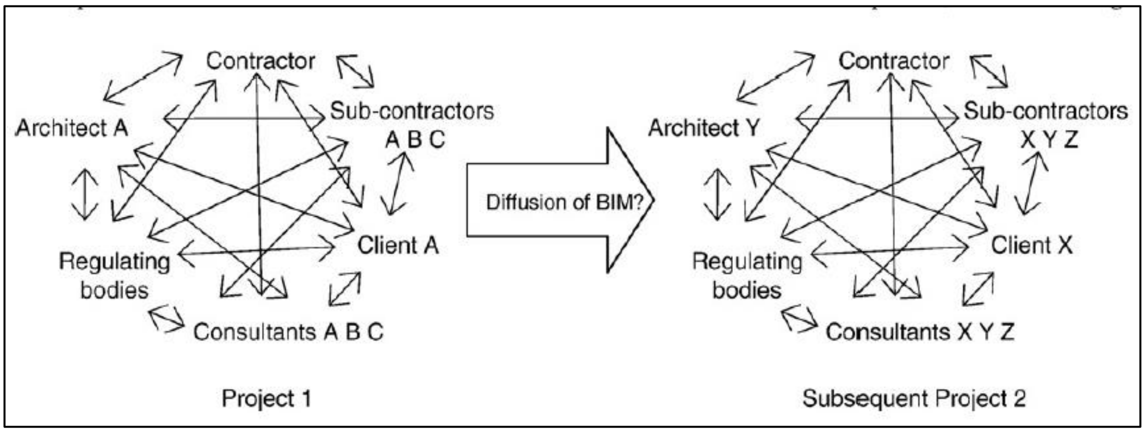

Figure 2-3 The challenge of adoption and use of BIM in a project based context.

These factors cause that the collaboration of any construction project is difficult. Also any innovation implemented in this industry should take this into consideration. Unfortunately some methodologies as BIM not focuses on planning, and their social dimension causing implementation barriers (Suwal, Javaja, & Porkka, 2013).

As collaboration is a concern to a correctly use of BIM methodology, collaboration levels are discusses by some authors to standardize the concepts, these issues are reviewed in the next section.

2.3.BIM Collaboration Classification

The BIM methodology has different ways that can be used depending on the objective (Coordination, Planning, Cost Evaluation, among others) and collaboration required (Used by one actor or fully collaborative). In order to describe different levels of these, in the literature could be found two BIM classifications.

The first one is a classification by levels, from level 0 to level 3 (less to more collaborative), it was written by Mark Bew and Mervyn Richards in a document called PAS 1192 “Specification for information management for the capital/delivery phase of construction projects using building information modeling” (Bew & Richards, 2013) in Britain. It can be seen schematically in Figure 2-4. This classification is highly accepted by the industry.

Level 0 is the no use of BIM and using only 2D CAD documents for the project. Level 1 is the use of 2D CAD documents and 3D but not necessary BIM models (3D representation without elements information). Level 2 use BIM models. In this level there exists some level of interaction between companies (Called actors in a process nomenclature). The level 3 is a complete interoperable level where there are interoperable standards defined in the project like IFC (Industry Foundation Class), IFD (International Framework Dictionary), IDM (Information Delivery Manual) , also these kind of collaborative approaches to working are often termed as “Social BIM”, “Collaborative BIM” and “integrated BIM” (Suwal et al., 2013).

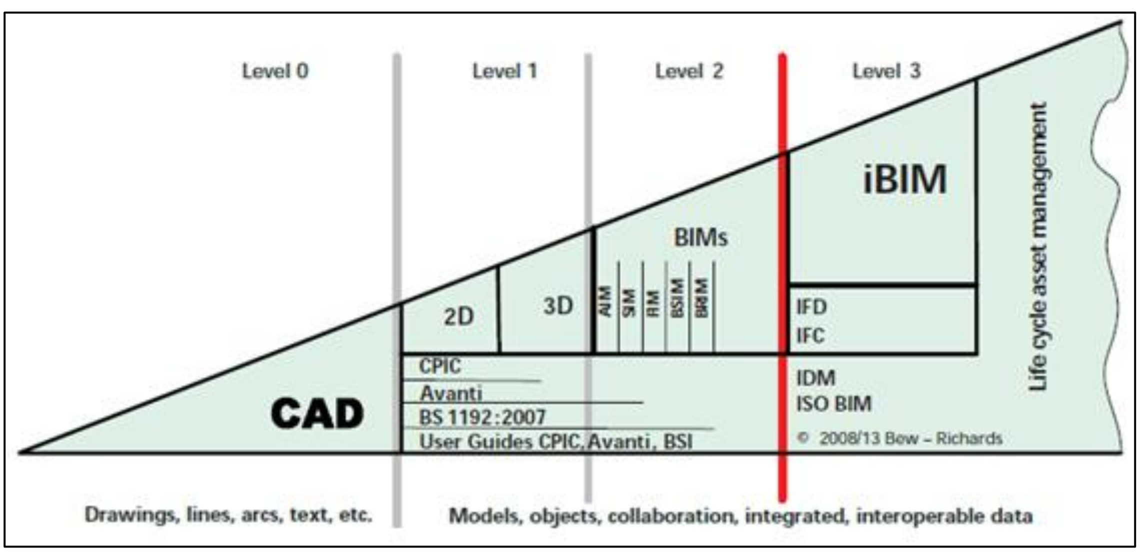

Figure 2-4 BIM Maturity Diagram (Bew & Richards, 2013)

Another interesting perspective to BIM collaborative levels, founded in literature include lonely BIM and social BIM, named BIM Flavours (Jared, 2013). In Figure 2-5 Jared Explains the different transition from CAD to different BIM levels. The transition from traditional CAD based workflow to the full utilization of BIM is represented by shift from quadrant I to IV and the possible approaches currently underlying in the industry are represented by the arrows.

I. lonely little BIM: BIM is primarily used for enhancing the workflow in individual organization, because of its primary benefits like reducing errors and time through coordinated documentation, quick 3D visualization of the project. The BIM created largely aims for the production benefits within the organization and is not shared with other disciplines(Suwal et al., 2013).

I-II-IV social little BIM: In addition to lonely BIM, social little BIM approach shares BIM data with other collaborators and between different BIM authoring tools through little or one-time 3D data exchange primarily within design and merely for construction phase. Various aspects of collaborative BIM features are not taken into consideration (Suwal et al., 2013).

I-III- IV lonely BIG BIM: Lonely BIG BIM goes beyond visual utilization however the BIM data is shared with basic 2D traditional formats. Its major advantage is to build efficiency and effectiveness in the design process. Comparative alternative solutions are produced and analyzed through the use of BIM for informed design decisions. (Jared, 2013).

I-II-III-IV social BIG BIM: This approach is considered as the real BIM with the integrated collaborative approach between all the stakeholders and various disciplines of authoring tools. Full benefits and advantages of BIM deployment in almost all the phases in an integrated manner throughout the project lifecycle is actively considered and used. It also involves models that are shared between collaborators and clients for different types of analyses like detailed energy analysis. (Suwal et al., 2013).

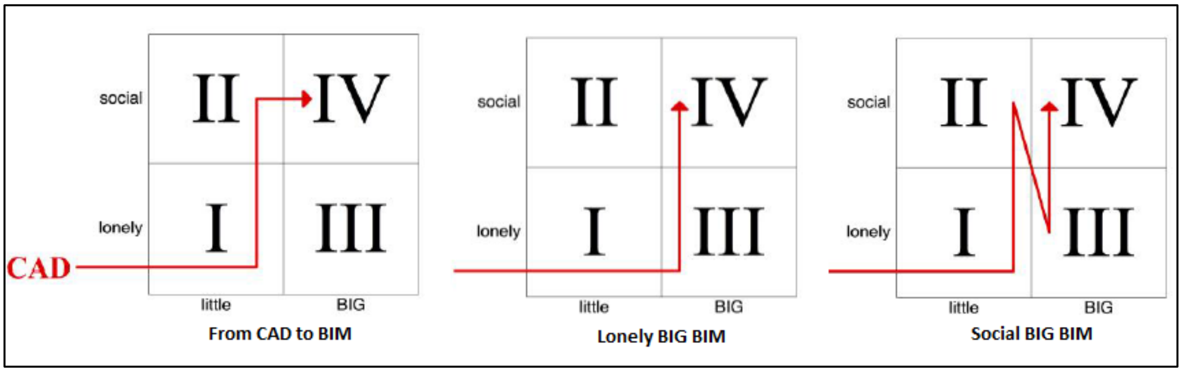

Figure 2-5 Different BIM Approaches – BIM Flavours- (Suwal et al., 2013).

The focus in this research is to help to eliminate the barriers of BIM uses from level 1 or lonely little BIM to level 2 and 3, or Social BIG BIM where models are used as a collaborative tool. These matters are considerate in the literature review and is generally accepted the difficult of this implementation. For this thesis, the second classification - BIM Flavours- is going to be used to avoid misunderstanding.

Actual Chilean industry can be classified in level 1 or lonely little BIM. For two main facts:

- BIM is not used as a collaborative tool; when BIM is used, a singular company takes all the data that need to be modeled and integrated.
- The most BIM uses are: Project Visualization and Digital Interference Check, for this BIM Models are not complete require, a 3D model could be enough.

2.4.BIM Implementation Factors

To analyze the implementation of BIM on a project, it is important to understand what are the most important factors that affect the implementation, which is why, a comprehensive review of the factors affecting the implementation was done. These can be listed as follows. The factors are observed in case studies of various investigations, not aim to be all, but the most important and conducive to the research of this thesis. The factors could be classified by a Process-Organization-Technology ontology (I. J. Chen & Popovich, 2003; Khosrowshahi & Arayici, 2012), Factors 1 to 6 are Process related , 7 to 11 Organization related, and 12 to 15 Technology related.

Table 2-1 BIM Implementation Factors

Factors	Flood et al. 2003	Migilinskas et al. 2013	Homayouni et al. 2010	Nawari 2011	Rowlinson et al. 2010	Gu and London 2010	Arayici et al. 2011	Hartmann et al. 2012	Homayouni et al. 2010	Slevin and Pinto 1987	Manning and Messner 2008	Digby Christian et al. 2008	Khanzode's et al. 2008
1. Document to support the BIM implementation.		x		x			x	x					x
2. Uncertainty of implementation results.		x				x							
3. Existence of clear objectives.					x					x			
4. Clarity in the BIM Process.				x	x	x	x			x			x

5. Bottlenecks in the transfer of information.						x					x		
6. Communication and collaboration among actors.			x							x			
7. Existence of supporting actor for implementation.						x		x	x				
8. Ability to change the work process.		x			x	x	x					x	
9. Training to BIM participants.	x	x				x	x					x	
10. Clarity of roles and responsibilities.					x	x	x		x				
11. Support of owners.		x					x	x					
12. Lack of Parametric contained in BIM Models.											x		x
13. Cost for the use of software and hardware.	x											x	
14. Interoperability of Software.		x											
15. Cost of BIM implementation.		x										x	

The factors Processes and People have more attention in this thesis, this, mainly because they respond to the social aspect of the BIM implementation, in turn, literature takes over the areas of technology, such as the use of software and interoperability between them.

Although social aspects aren’t well answered by the literature, in the organization and companies level, BIM implementers are developing documents to support its implementation considering these aspects, as discussed in the following sections and mainly in chapter 3 of this thesis.

2.5.BIM Support Documents and Literature Content Classifications

It is important to note that as the level of collaboration increase, BIM relations between enterprises becomes more complex. More organizations that used BIM methodology for long time, developed Procedures and Standards (Support Documents) to help the relationships between actors of a project and to allow the level of collaboration and objectives been achieved as support the BIM process in different aspects.
BIM support documents have grown in number and content based on their purpose and authors, making it difficult to assess their value and the need for them. Therefore, there is a need for a better understanding about the contents and types of existing BIM documents.

Several authors identify three key dimensions in any technology implementation: technology, people and processes (I. J. Chen & Popovich, 2003; Khosrowshahi & Arayici, 2012). BIM literature also uses these dimensions (Khosrowshahi & Arayici, 2012; Nepal, Jupp, & Aibinu, 2014; Staub-French, Forgues, et al., 2011) to analyze factors to be considered in BIM implementations. These three dimensions provide a broad classification framework for content related to any technology and, in particular, to BIM methodology.
In a more specific level, Mead and Sattineni (Sattineni & Mead, 2013) describe a guidelines document and compare it with other five guidelines. As part of this comparison, this work identifies four content issues at a general level and five issues at a more project-specific level (Figure 2-6).

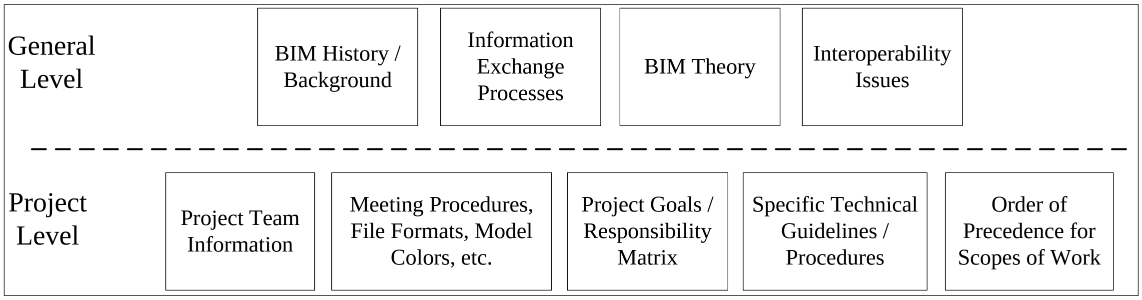

Figure 2-6 Structure of guidelines, specification and standards issues (Sattineni & Mead, 2013)

Staub-French et al (Staub-French, Forgues, et al., 2011) present a very detailed classification structure as part of a BIM best practices report that aims at capturing the essence of the international efforts in BIM documentation, by exploring 15 BIM support documents. This content classification structure groups a long list of items in the three domains of technology, organization, and process, plus a general domain (Figure 2-7).

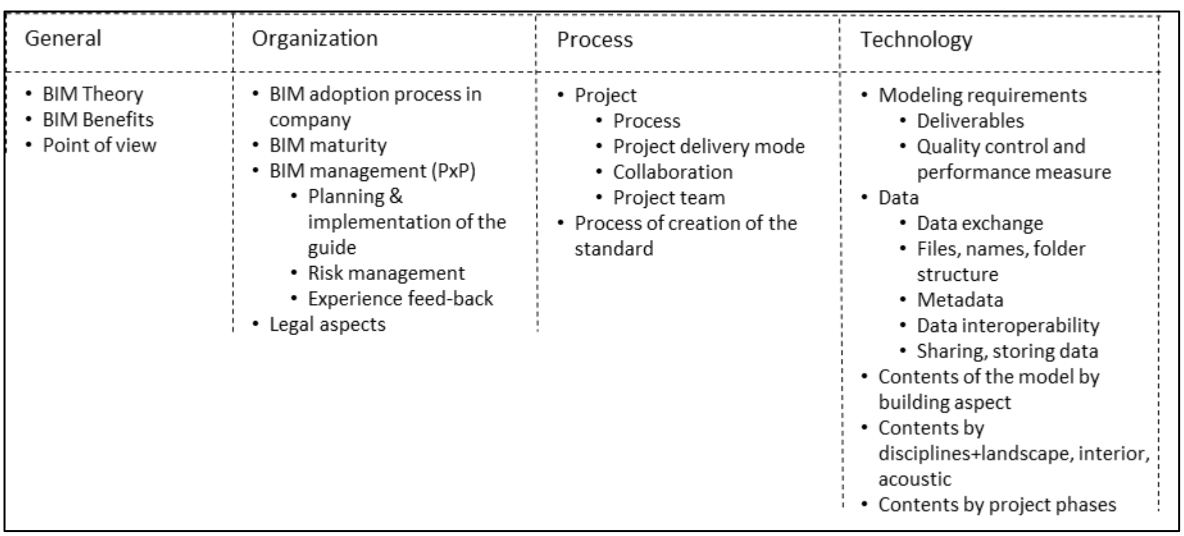

Figure 2-7 Structure for Guidelines and Standards (Staub-French, Forgues, et al., 2011)

Staub-French has a classification that covers a lot of contents of the literature review, being very complete to analyze BIM documents. Of course, there is a partial overlap between these two classifications but the one presented by Staub-French et al (Staub-French, Forgues, et al., 2011) considered more contents. However, this classification is not considering explicitly relevant issues in BIM projects, for example: The project team information, given that in the review of documents made was considered to be quite relevant. Also the amount of detail (3 levels of contents) could make confuse the analysis for a bigger amount of documents.

The content structures discussed in these studies range from very broad to very detailed, and the detailed ones were proposed based on the review of a small number of BIM documents. On the other hand, none of these classifications analyze BIM documents based on their contents and purposes simultaneously. However, the integration of these classifications is a good starting point for our analysis.

2.6.Healthcare Projects

This thesis is framed specifically on healthcare projects. Perhaps no other building types benefit more from BIM than healthcare facilities, in which the coordination of all systems is a challenging effort for all parties involved in the project (C. Chen, Dib, & Lasker, 2011). The type of project is review in detail, determining its characteristics by the literature in order to provide context for the study.

Buildings healthcare projects are essential for society and the general public. A good design environment is conducive to good health. So, good design can be critical, and can support personal, social and technical services. Also being the requirement of end users should take full account to make an ideal building health. (Chan, 2004)

One of the main characteristics for information management in these projects is the big amount of project participants in the design, construction and management process.

The main participants in these projects are the different designers for the development of it.

A list of designers involved in the development of a standard project are: Architecture, Structural Engineers, Energy Efficiency, Electric Installation, Illumination, Power Saving, Thermal installation, ventilation, acclimatization, sewerage, cold and hot water, securities systems, vertical mechanical circulation system, rainwater, hospital vulnerability, structured cabling installation, weak currents, centralized control system and automation, fuel gas, clinical gases, hospital waste management, pneumatic mail, soundproofing.

In Healthcare projects, often the architectural projects is made first, this considerate all de design criteria and definition of spaces according to the amount of people of the city and other criteria, then the other disciplines get involved.
The coordination of these participants is one of the main reasons why BIM is a suitable methodology of work to get the best results of the hospital infrastructure construction project.

Some others reasons why BIM is beneficial in healthcare projects are based on (Manning & Messner, 2008):

- Increased communication through the project development team
- The facility layout is important to minimize the potential for transfer of disease: A good visualization of the design is a big benefit of BIM.
- Electrical, mechanical and plumbing equipment are complex and require coordination geometry: Digital coordination is often a requirement in these projects.
- As-Built accurate information can be important for future renewals.
- Instant 3D visualization spaces and alternatives that can quickly be evaluated by technical and non-technical team. Additionally increase the information available for decision support in the process of project development.
- Parametric attributes enable scheduling information is quickly compiled for comparison with the original authorization documents with a high degree of confidence in their accuracy.

- Increased confidence in completing the scope developed in programming
- Simulations of light, energy, indoor air quality are required.
- Significant budget Restrictions.

2.7.BIM requirements in a Healthcare project lifecycle in Chile

The Chilean government (Ministry of public Infrastructure and Ministry of Health) has been very interested in generating better projects, where the project cost and lead time does not vary greatly in magnitude. Therefore, the organizations are in charge on impulse the innovation with good results in project. One of these innovations is BIM methodology, which is nowadays is requested in public projects.

Below there is an example on BIM requirements in hospital infrastructure project.

BIM requirements have increased over the years. These requirements are extracted from the Chilean tender documentation “FORMATO TIPO DE BASES DE LICITACIÓN PARA CONCESIONES DE ESTABLECIMIENTOS DE SALUD” 2011 and the projects information obtained from the owner(CCOP, 2015).

2.8.Case study literature review in public healthcare projects

The implementation of BIM affect different areas of the process of a project, it is so that the research methods to understand in greater depth the problem are complex, one of these is the case study that allows holistically analyze a project and thus understand best complex processes that happen.

The literature identifies several case studies relevant for analyzing BIM implementation process in construction projects. However, these studies tend to focus on explaining what was done not considering the troubles to reach the BIM benefits. This section analyses two issues: Case studies of healthcare projects and public agencies strategies.

2.8.1. Healthcare Projects

Manning and Messner (Manning & Messner, 2008) review two projects: Expeditionary Hospital Facility and Medical Research Lab (MRL). It investigates the benefits of using BIM in the early conceptual stage(Olofsson, Lee, & Eastman, 2008). Using BIM tools as a communication help, increasing the collaboration succeed, also, some parametric attributes of BIM was used to obtain fast calculations. In both projects, the primary challenges found were information transfer bottlenecks, current lack of parametric content for significant project vender products, unfamiliarity of BIM's breadth of ability and associated experience of application in programming, and a lack of understanding of interoperability limitations and abilities.

Digby Christian et al. review in the project Sutter Medical Center, Castro Valley, California(Eastman, Teicholz, Sacks, & Liston, 2008). It investigates the benefits of BIM model-based cost estimating as they are using Target value design (TVD). The BIM tool was used to rapidly obtain cost after design changes. The main challenges were the cultural shift and training required and the cost for the transition from one software system to another

Dave and Flórez: Maryland General Hospital (Eastman et al., 2008). Review the use of BIM for clash checking and then subsequently for tracking the closeout process, to capture field data including documentation about equipment, and it was eventually handed over to the client for facilities management. The main challenge was the creation of an interoperable database for facility management. Khanzode's, Fischer's and Reed's(Khanzode et al., 2008) discusses the benefits and lessons learned of implementing Building VDC Technologies for Coordination of MEP Systems on a Large Healthcare Project. The lessons the team learned include the level and type of details team members need to include to achieve benefits from the use of BIM / VDC tools for the coordination of MEP systems. Finally, Jaruhar (Jaruhar, 2013) review the use of BIM at Northwestern Memorial Hospital, where a number of lessons have been learned that are helpful to consider when implementing BIM at an organizational level. There is a need to detailed anticipated BIM processes, expectations and close out deliverables. Also verify internal resources, management commitment and internal communication and build a critical mass for BIM.

Most case studies found, focus primary in describing what was done and not in the problems found and how could be improve the process for next projects. Also the principal motivator of using BIM is on project participants and is not a requirement imposed by the owner.

2.8.2. Public Projects

As governments are very interested to increase de quality, reduce the cost and the execution time of the projects, they are constantly worried to learn from modern working methodologies as BIM. This methodology has proven positively affect large-scale projects; improving quality, reducing time and cost(Azhar et al., 2008).

Various public infrastructure agencies of countries including USA, UK, Singapore, Hong Kong, South Korea, Netherland, Finland, Denmark, Norway, have or are planning to require using BIM in their projects. This requirement comes with government strategies and intentions for an implementation in certain amount of years (Wong et al., 2009).

For a historical context, few strategies were reviewed and summarized in Table 2-2. As it can be seen, BIM implementation is not an easy problems and required most of the time an organization which guides the implementation, particular BIM tools and a Roadmap of a couple of years to reach an specific objective.

Table 2-2 Country BIM Strategies

Country	Summary
USA	In 2003, the GSA established the National 3D-4D-BIM Program based on a BIM guides series. It allow to more effectively meet program, design quality, and construction requirements(Yee, Matta, Kam, Hagan, & Valdimarsson, 2010). U.S. Army Corps of Engineers (USACE) in 2006 develop a BIM Roadmap, contractual language and others BIM documents(Brucker et al., 2006).

UK	The BIM Industry Working Group in the U.K. and IUK has prepared a BIM strategy to increase BIM use over a five-year period by 2016. Mandating BIM Level 2 from 2016.(Khosrowshahi & Arayici, 2012) In 2003 the CIC has produced a BIM Protocol, which has been drafted to enable the production of building information models at defined stages of a project.(Fraser, 2013)
Singapore	BCA published BIM promotion plan (BIM Roadmap) in 2015 with a focus on to more than 80% of the construction industry will use BIM by 2015. BCA also led a multi-agency effort in 2008 to implement the world’s first BIM electronic deliverable submission (e-submission) (Chidambaram et al., 2011).
Hong Kong	Hong Kong’s Housing Authority sets a target to apply BIM in all new projects by 2014.(Wong et al., 2009) It developed a set of modeling standards and guidelines for effective model creation, management and communication among BIM users.
South Korea	Public Procurement Service will make the use of BIM compulsory for all projects over S$50 million and for all public sector projects by 2016. (Wong et al., 2009)
Netherland	In 2012 the Dutch Ministry of the Interior (RGD) requires BIM for large building maintenance project(Wong et al., 2009)
Finland	The state property services agency, Senate Properties, requires the use of BIM for its projects since 2007. It start running pilot projects using BIM and IFC(Wong et al., 2009)
Denmark	State clients such as the Palaces & Properties Agency, the Danish University Property Agency and the Defense Construction Service require BIM to be used for their projects.(Wong et al., 2009)
Norway	The civil state client Statsbygg decided to use BIM for the whole lifecycle of their buildings. By 2010, all of Statsbygg projects were using IFC/IFD based BIM. In addition The Norwegian Homebuilders Association has encouraged the adoption of BIM and IFC.(Wong et al., 2009)

The lack of literature that analyze the problems of implementing BIM on a project, in particular in public healthcare projects, generated a need to study in more depth this type of projects, identify common problems that exist and to consider a set of strategy for public deployment of BIM in a healthcare project. BIM is a methodology inside the project traditional process. In order to analyse BIM problems, the process should be studied.

3. UNDERSTANDING CONTENT AND PURPOSES OF BIM DOCUMENTS

Various organizations have developed different documents to support their BIM implementations, avoiding interpretation, responsibility, competency and scope problems, among others. Organizations that are new to BIM can choose between developing their own documents and trying to use or adapt existing ones. However, these documents have grown in number and content based on their purpose and authors, making it difficult to assess their value and the need for them. Therefore, there is a need for a better understanding about the contents and types of existing BIM documents. This research reviews publicly available BIM documents, describes their content and purpose, proposing a content classification, and discusses the relation between them. The analysis identifies the BIM project execution plan as an important benchmark document and confirms the consistency between the documents content and types (BIM Guide, Use-specific Guide, BIM Standard, BIM Modeling Guidelines, BIM Execution Plan and Legal Addendums).

3.1. Introduction

The use of Building Information Modeling (BIM) is increasing worldwide because, among other reasons, several owners in different countries are starting to require BIM in their projects (Chidambaram et al., 2011; Khosrowshahi & Arayici, 2012). This increasing BIM use is also slowly moving from a lonely little BIM to a social BIG BIM (Jared, 2013), where the biggest benefits of using this methodology are (Grilo et al., 2012). This increased and more complex use of BIM faces many challenges such as the misalignment of objectives within the industry – where each stakeholder seeks its own benefits hindering cooperation and integration (Hartmann et al., 2012) – and the lack of organized and standardized information that support the social BIG BIM processes (Howard & Bjork, 2008).

To face these challenges, various organizations have generated different BIM support documents that aim at avoiding interpretation, responsibility, competency, and scope problems, among others. In the context of this research, a “BIM support document” is not a deliverable produced from a BIM model but it refers to documents (in various formats such as text and spreadsheet) that provide guidance, reference or some type of definition for the use of BIM in a company, project or industry. Some examples of BIM support documents are software manuals, standards, project guidelines, legal documents, and execution plans.

As more organizations are implementing BIM, these support documents have grown in number and content based on their purpose and the organizations who create them. Their scope is very broad (Sattineni & Mead, 2013), ranging from general guidelines (Bew & Richards, 2013; GSA, 2007) to detailed instructions (BCA, 2013a, 2013d) or legal addendums (AIA, 2013a; BCA, 2013b), with contents as diverse as BIM history, project goals, file structures and security protocols. An organization that is planning to implement BIM could create their own support documents or modify existing documents. In any case, existing BIM support documents present a valuable reference from where these organizations can learn. However, the broad range of existing documents makes it difficult for these organizations to select what content and document types should choose for their respective context. Therefore, there is an opportunity and need for a better understanding about the contents and types of existing BIM support documents.

This study reviews publicly available BIM documents to describe their content and purpose, propose a content classification, and discuss the relation between document types and their contents.

3.2.Existing Content Classifications

Several authors identify three key dimensions in any technology implementation: technology, people and processes (I. J. Chen & Popovich, 2003; Khosrowshahi & Arayici, 2012). BIM literature also uses these dimensions (Khosrowshahi & Arayici, 2012; Nepal et al., 2014; Staub-French, Forgues, et al., 2011) to analyze factors to be considered in BIM implementations. These three dimensions provide a broad classification framework for content related to any technology and, in particular, to BIM methodology.

In a more specific level, Mead and Sattineni (Sattineni & Mead, 2013) describe a guidelines document and compare it with other five guidelines. As part of this comparison, this work identifies four content issues at a general level and five issues at a more project-specific level (Figure 3-1).

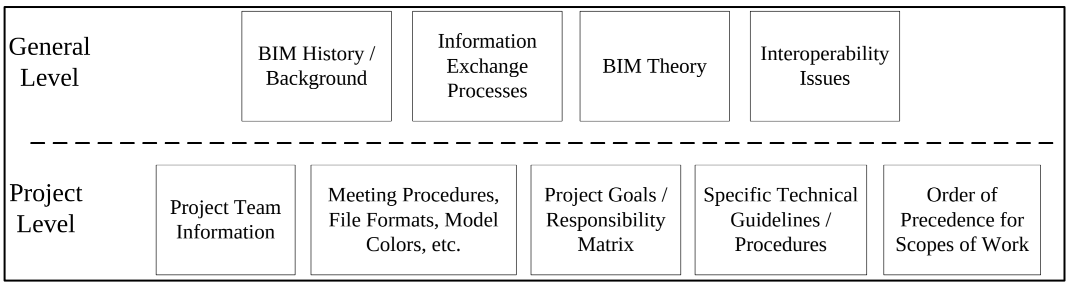

Figure 3-1 Structure of guidelines, specification and standards issues (Sattineni & Mead, 2013)

Staub-French et al (Staub-French, Forgues, et al., 2011) present a very detailed classification structure as part of a BIM best practices report that aims at capturing the essence of the international efforts in BIM documentation, by exploring 15 BIM support documents. This content classification structure groups a long list of items in the three domains of technology, organization, and process, plus a general domain (
Figure 3-2).

General	Organization	Process	Technology

• BIM Theory
• BIM Benefits
• Point of view
	• BIM adoption process in company
	• BIM maturity
	• BIM management (PxP)
	  • Planning & implementation of the guide
	  • Risk management
	  • Experience feed-back
	• Legal aspects
		• Project
		  • Process
		  • Project delivery mode
		  • Collaboration
		  • Project team
		• Process of creation of the standard
			• Modeling requirements
			  • Deliverables
			  • Quality control and performance measure
			• Data
			  • Data exchange
			  • Files, names, folder structure
			  • Metadata
			  • Data interoperability
			  • Sharing, storing data
			• Contents of the model by building aspect
			• Contents by disciplines+landscape, interior, acoustic
			• Contents by project phases

Figure 3-2 Structure for Guidelines and Standards (Staub-French, Forgues, et al., 2011)

Staub-French has a classification that covers a lot of contents of the literature review, being very complete to analyze BIM documents. Of course, there is a partial overlap between these two classifications but the one presented by Staub-French et al (Staub-French, Forgues, et al., 2011) considered more contents. However, this classification is not considering explicitly relevant issues in BIM projects, for example: The project team information, given that in the review of documents made was considered to be quite relevant. Also the amount of detail (3 levels of contents) could make confuse the analysis for a bigger amount of documents.

The content structures discussed in these studies range from very broad to very detailed, and the detailed ones were proposed based on the review of a small number of BIM documents. On the other hand, none of these classifications analyze BIM documents based on their contents and purposes simultaneously. However, the integration of these classifications is a good starting point for our analysis.

3.3.Methodology

This study is based on a concept-centric literature review (Webster & Watson, 2002) of 56 documents that aims at supporting the document categorization. This methodology includes the following steps.

1. Develop a logical approach to grouping and presenting the key concepts uncovered.
2. Synthesize the literature by discussing each identified concept.
3. Compile a concept matrix as articles are read.
4. Categorize articles and documents based on a scheme that helps define the topic area.

Figure 3-3 describes the main research activities and how they relate to the above steps. The diagram also shows the outputs of some of these activities.

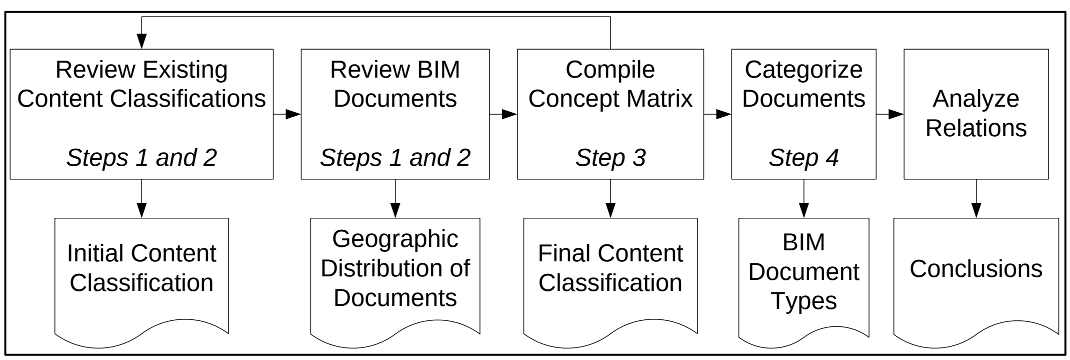

Figure 3-3 General Research Methodology

Based on the review of existing content classifications, the authors defined an initial content classification for BIM support documents that was then used to review 56 BIM documents of a total of 61 documents founded. This review verified the contents of these documents in order to compile a concept matrix. This was an iterative process so, when an important subject in a document was not properly addressed by the content structure, the initial content classification was modified. The list below describes the main considerations for the document review.

- The documents considered in this study were publicly available in internet and dated from 2006 to 2014.
- Most of the documents were written in English, but there were also documents in Spanish, Portuguese and German. Five documents which are written in languages other than Spanish or English were not analyzed but they were considered for the geographic distribution analysis (see Figure 3-5).
- Different versions of the same document were not considered unless they had important content differences. Documents that are part of a series were counted as one document (for example GSA BIM Guide Series(GSA, 2007)).

3.4.Proposal of Content Classification for BIM Documents

The final classification structure for the documents content resulted from reviewing the documents and iterating the initial classification structure, which was based on a combination of the structures discussed in section 3.2.

Legal aspects and security have trouble parties interested in BIM (Haynes, 2009). However, in others classifications this content can be found inside other topics, but their relevance in projects and in the reviewed documents is big enough to be considered as a topic alone. Also, certain contents that were considered relevant and were implicitly present in previous classification structure were spelled out in this new classification (for example: Users and authors of the model which is implicit in project team information) .Finally, in order to have a classification the most useful and complete for a big amount of documents; it was simplified in levels and topics, so in some cases some contents were group (for example: Level of development and detail, and security and files protocols).

Figure 3-4 shows the final structure and highlights the elements that were part of the previous structures.

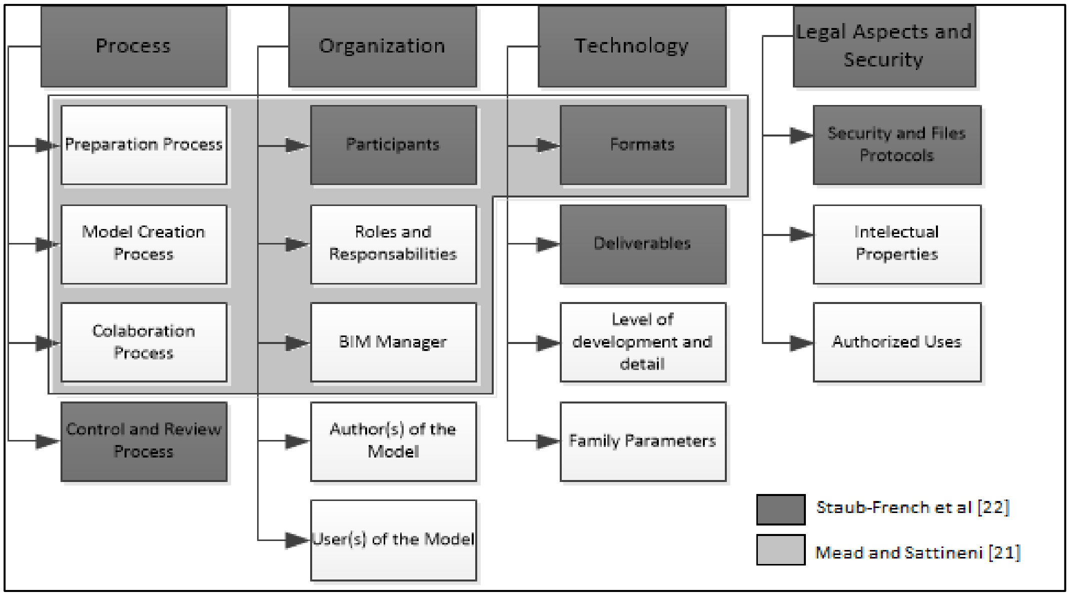

Figure 3-4 Final Content Classification Structure

The explanations below aim at clarifying the content elements in the proposed structure.

1. Process
    a. **Preparation process:** Information about the process for preparing the BIM implementing in a project or organization. It includes process such as the selection of participants.
    b. **Model Creation:** Information of how to create the model; how it is divided and process of modeling. It includes software tool tutorials, stages of the modeling process and divisions of tasks.
    c. **Collaboration process:** Information about how the information would travel along the project work and any other information which implicate collaboration for the benefits of the project. It includes meetings between participants, file exchange process and methods of interaction (internet, emails, and phone calls).
    d. **Control and revision process:** Information of how to control the status of the models and the use of those models. This process includes but it is not limited to model quality assurance.

2. Organization
   a. **Participants:** Information of who is or should be in the project. Contractors, Designers, architects are examples.
   b. **Roles and Responsibilities:** Information of who need to be in the project, and what responsibilities it has along the project. It includes roles like Project Manager and coordinator common used in BIM projects.
   c. **BIM manager:** This is the most important Role in a BIM project. In some documents there is a different treat of this role and in others this role is the only defined. The information of this role can be identified alone.
   d. **Author(s) of the model(s):** Who is the author of some part or element of the model, or any deliverable where model need to be built.
   e. **User(s) of the model(s):** Who will use any element, part or deliverable of the model for any analysis or continuing the modeling process.
3. Technology
   a. **Formats:** Models are built with specific softwares. For this the file extension of the deliverables or model elements is important for the interoperability of the tools. It includes IFC format, PDF, DWF. Not all the information is in the BIM model.
   b. **Deliverables**: It focuses in what should contain the model deliverable. It includes Elements, family information, or any other content of deliverables.
   c. **Level of development and detail:** Any information of content in any stages and the specific elements that the model need to have is considered in this topic. It includes LOD (Level of development) because is an important definition of deliverables content. It is present in important documents as AIA E202, E203 and others.
   d. **Family parameters:** Any information of the content of families (BIM objects) is considered in this topic. This includes parameters for identification and analysis.
4. Legal aspects and security

a. **Intellectual properties:** Information about who is the model owner, which responsibilities have the model creator or who control the model. It includes information of legal remedies.
b. **Security and files protocols**: Files are essential for saving the information. Some protocols like names, structures of files, backups, system control files and the way of ensuring the information is considered in this topic.
c. **Authorized uses:** Any information of different uses intended for the model. It also includes which uses are no authorized.

3.5.Geographic and Temporal Distribution of Documents

Part of the outcomes of this research is a set of snapshots of the geographic distribution of the reviewed documents at different times (Figure 3-5). Although these snapshots are limited by the time frame and languages considered in the analysis, they show a fair view of the temporal evolution of the areas where BIM has reached higher maturity. Figure 3-5 is also a reference for the scope of this research and the documents that are publicly available through internet.

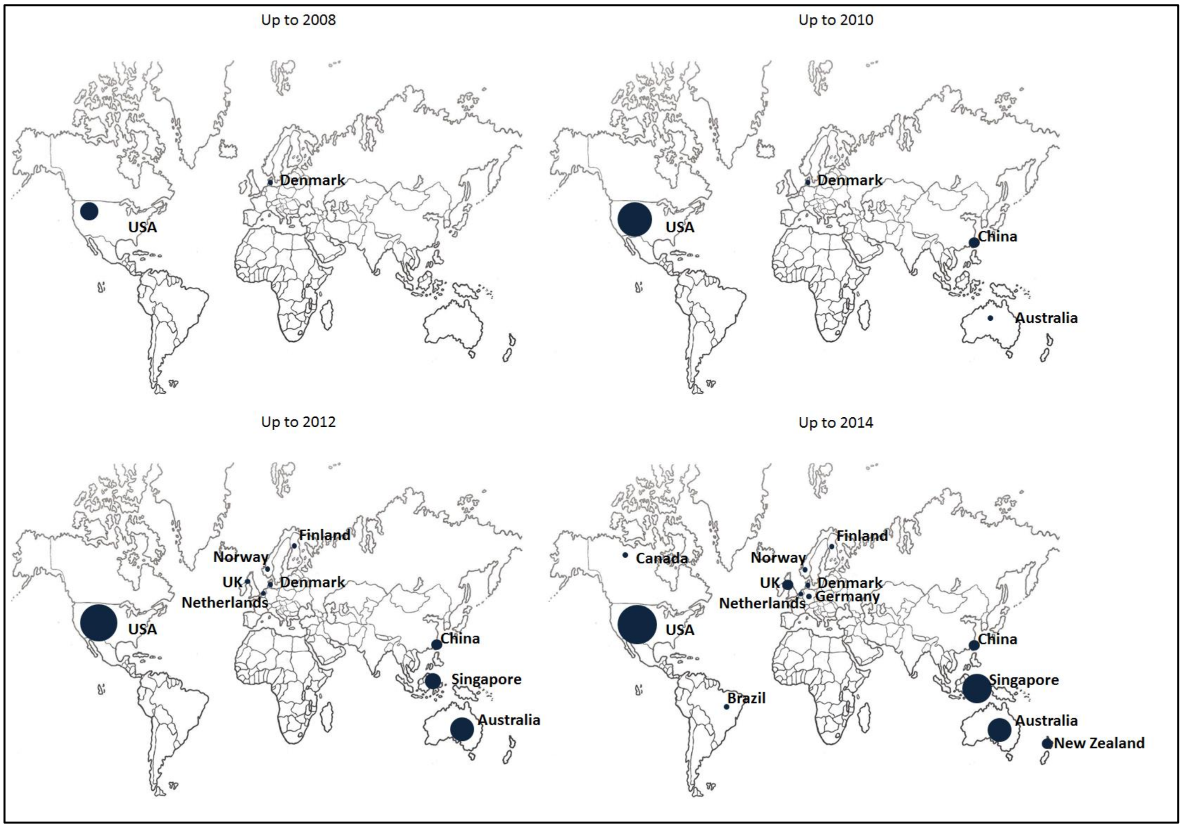

Figure 3-5 Geographic distributions of BIM documents. The circle size (non-linearly) represents the number of documents in each location.

The countries with documents considered in this analysis and the respective number of documents – between parentheses – are: Australia (6), Brazil (1), Canada (1), China (2), Denmark(1), Finland (1), Germany(1), Netherlands (1), New Zealand (2), Norway(1), Singapore(8), United Kingdom (2), United States of America (34). All continents have BIM documents with the exemption of Africa. Europe has a BIM document (Inpro BIM) (Commission & Programme, 2010) that is not shown in the map because is developed by a group of countries. The countries with the oldest BIM documents are USA and Denmark. In recent years some countries have achieved a lot of documents showing their interest in using this methodology. USA, Singapore, UK, New Zealand were those who grew up with higher number of documents. Singapore's growth is remarkable as in 2012 begins to position itself as the second country with the largest number of documents. Similarly, Australia has an important increment in the number of documents in 2010. Additionally, it is noteworthy that, in the last years, BIM documents became more global, reaching countries such as Canada, Brazil, Germany and New Zealand, this last one with an important amount.

Some countries have a national standard so they have only one document or group of documents (e.g., UK and Singapore) while other countries, in addition to national standards, have other documents developed by several organizations. In particular, USA is where more documents were found as many states and different organizations within the country have their own documentation. Some examples of these documents are the GSA (General Services Administration) BIM series (GSA, 2007) and the National BIM Standards (NIBS, 2007). However, it is important to note that a country with more documents do not necessarily imply more content as several documents include an important content overlap. In fact, there seems to be many overlaps between documents from different organizations. Some organizations even recognize that their BIM support documents are based on others but with modifications to fulfill their organization/project requirements. Also, there are cases where an organization develops its own core document which references BIM support documents from other organizations for specific tasks. These overlaps and relations are discussed in the next section.

3.6.Documents Types and Contents

The authors compiled a concept matrix to analyze the contents of different BIM documents based on their specific objectives. Most of the time, these objectives were defined in the documents themselves but in other cases, the authors derived the objectives from the document. The identified objectives led to the following document types. The number in parenthesis indicates the number of analyzed documents that fall into that category.

- BIM Guides (26): They provide general information to introduce BIM as a working method. These documents explain, from a practical standpoint, the terms that are necessary for orientation in the BIM projects, and shows different uses and activities of BIM methodologies. It also answers the essential questions in order to facilitate a successful and correct implementation of the BIM method.

- Use-Specific BIM Guides (9): Documents dedicated to bounded uses. They are more detailed than the BIM guides as they only include topics relevant to the use of the guide. However, they have the same objective of BIM Guides.
- BIM Standards (19): Specify the owner's requirements about, among other things, the BIM procedures that should be used, how the model should be created, and model content and structure. This category doesn't include intern companies' standards. There are General Standards (16) and also exist BIM Modeling Guidelines.(3); which are BIM standards with an specific intention to suggest modeling procedures in developing BIM models to meet the requirements of the project (BCA, 2013d)
- BIM Project Execution Plan Templates/Guides: Guide project teams in the process of generating a project execution plan, providing explanations, examples and templates to define goals, BIM deliverables, roles and responsibilities of the project members, BIM uses, etc.
- Legal Attachment Templates/Guides: Guide in the formulation of contractual addendums that address legal and contractual issues that affect parties interested in using BIM. These documents are specifically drafted to complement existing design and construction contracts (Haynes, 2009).

There are four other document types that were not analyzed in this study. Two of them (Software Manuals, BIM Books), because their focus is too broad or their purpose is too specific. The other two (BIM Project Execution Plans and BIM Legal Attachments), even though they are crucial for the use of BIM in projects, were not included because, in general, they are not publicly available. Figure 3-6 shows a hierarchical structure and the relations among the document types, including the ones not considered for the study.

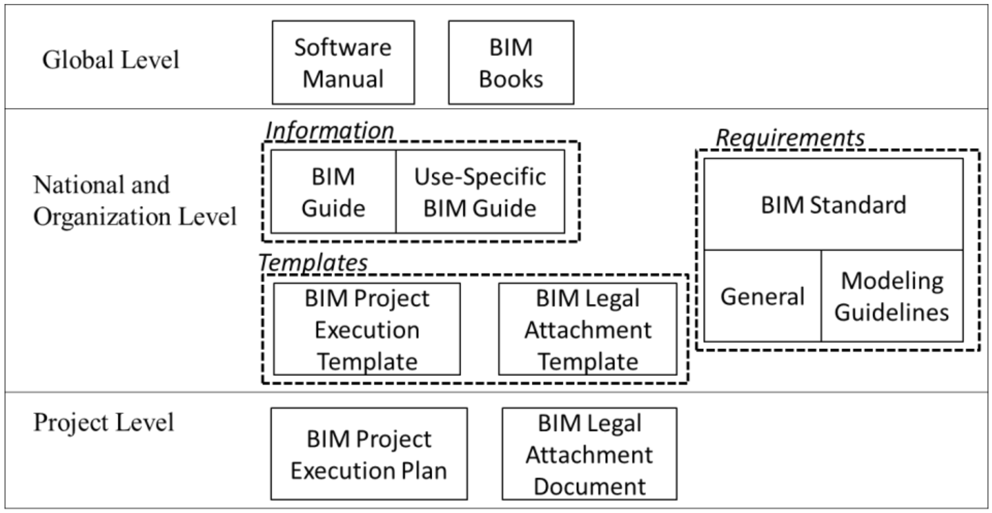

Figure 3-6 Relationship between documents

The document types are divided in three levels: Global, national and organization, and project. Documents in the global level aim at educating in BIM aspects. These documents are not related to the purposes of a particular project, organization or group of organizations, therefore they were not included in the analysis below.

Documents in the national and organization level are the main documents for supporting BIM processes in a project, organization or group of organizations. They are not intended to be used in one project only but they intend to formalize and standardize the procedures of an organization or group of organizations. Within this level, there are documents that provide information (BIM Guides and Use-Specific BIM Guides), establish requirements or expectations (BIM Standards), and provide templates to support the production of project-specific documents (BIM Project Execution Templates and BIM Legal Attachment Templates).

The project level documents are created for the particular conditions of a specific project. The BIM project Execution Plan is the central document for supporting the BIM processes on a project and it can be a legal document or be supported by a BIM legal attachment in order to have legal power. Despite the relevance of the project level documents, they were not included in the analysis as, in general, they are not publicly available.

The analyzed documents do not necessarily fall into one single category of document type. Sometimes, documents fulfill more than one role, directly including the contents of more than one document type or referring to other documents. Tables 1 through 6 show the concept matrices by document type including each of the reviewed documents. The documents that fall in more than one category are included in all the respective tables.

Table 3-1 Concept Matrix for BIM Guides

			Process				Organization					Technology				Legal and security aspects		
Name of Document	**Year**	**Country/Zone**	**Preparation Process**	**Model Creation Process**	**Colaboration Process**	**Control and revision process**	**Participants**	**Roles and Responsabilities**	**BIM Manager**	**Authors of the model**	**User of the model**	**Formats**	**Deliverables**	**Level of detail and development**	**Family parameters**	**Intellectual property**	**Files and security protocols**	**Authorized uses**
The Contractor's guide to BIM V2	2009	USA	1	1	1	1	1	1		1	1		1	1	1	1	1	
Singapore BIM Guide v2	2013	Singapore	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
BIM essential Guide (Architects, Contractors, Consultants, MEP)	2013	Singapore	1	1	1	1	1	1	1	1	1	1	1	1	1			1
Modeling Guide Series - Overview v0.6	2007	USA	1									1				1		
InPro Buildign Information Model	2010	EUROPE			1							1			1	1		1
BIM Guidelines	2012	USA	1	1	1		1	1	1	1	1		1	1	1			1
BIM Guidelines & Standards for Architects, Engineers and contractors	2012	USA	1	1	1	1	1	1		1		1	1	1		1		
NATSPEC National BIM Guide	2011	Australia	1		1	1	1	1	1			1	1	1		1		1
National Building Information Modeling Standard v2	2012	USA	1	1	1		1					1	1		1	1		
State of Ohio building information modeling protocol	2011	USA	1	1	1		1	1	1	1	1	1	1	1		1		1
LACCD BIM Standards v3	2010	USA	1	1	1	1	1	1	1			1	1	1	1	1	1	1
New Zealand BIM Handbook	2014	New Zealand	1	1	1	1	1	1	1		1	1	1	1		1	1	1
Supplement 1 . BIM Implementation Guide for Military Construction	2012	USA	1	1	1	1	1	1		1	1		1	1			1	1
PAS 1193:2013	2013	Britain	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AEC (CAN) BIM Protocol v1	2013	Canadá	1	1	1		1	1	1	1	1	1	1	1		1	1	1
BIM Implementation: An owner's Guide to Getting Started	2010	USA	1		1		1	1					1			1	1	
The VA BIM Guide	2010	USA	1	1	1		1	1		1	1	1	1	1		1	1	1
BIM Project Specification	2011	Hong Kong	1	1	1		1	1				1	1	1				
BIM Planning guide for Facility Owners	2013	USA	1	1	1					1	1	1	1	1		1		1
The Uses of BIM	2013	USA	1				1	1		1	1		1	1				
Project Execution Planning Guide	2010	USA	1	1	1		1	1	1	1	1	1	1	1		1	1	1
BIM guidelines and standadrs for architects and engineers	2009	USA	1	1	1		1	1	1				1	1				
BIPS 3D Working Method	2006	Denmarck	1	1	1		1	1					1	1	1			
Common BIM requirements 2012	2012	Finland	1	1	1		1						1					
Caderno BIM VERSAO	2014	Brasil	1	1	1		1	1				1	1	1		1	1	
AEC (UK) BIM Protocol v2	2012	Britain	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1

BIM Guide is the most popular document type – with 26 documents – found in this review. Table 3-1 shows that most of the documents in this category are very complete as they cover most of the topics in the proposed content structure. This was expected as BIM guides are one of the first documents that novice users check and their purpose is to give an overview of the BIM processes. Moreover, organizations start their BIM implementation creating this document, which works as the basis for other BIM documents (Figure 3-6) and also to disseminate BIM inside the organization. Regardless the importance of this document, it only describes the organization objectives and general information that supports those objectives but it does not specifies how the project processes should be executed.

The content topics with smallest coverage by BIM guides are family parameters, files and security protocols, and control and revision process; which is consistent with our definition because these are specific topics that are not usually discussed in a general document. Almost all the countries that have a BIM document, have BIM guides. Documents from USA, UK, Australia, New Zealand and Singapore are more complete than the BIM guides from the other countries.

Table 3-2 Concept Matrix for BIM Use-Specific Guides

			Process				Organization					Model				Legal and security aspects		
Name of Document	**Year**	**Country/Zone**	**Preparation Process**	**Model Creation Process**	**Colaboration Process**	**Control and revision process**	**Participants**	**Roles and Responsabilities**	**BIM Manager**	**Authors of the model**	**User of the model**	**Formats**	**Deliverables**	**Level of detail and development**	**Family parameters**	**Intellectual property**	**Files and secutity protocols**	**Authorized uses**
MEP Spatial Coordination Requierements for BIM	2009	USA			1		1	1	1			1						1
BIM essential Guide for BIM Execution Plan	2013	Singapore	1	1	1		1	1		1			1					
BIM essential Guide for BIM Adoption in an Organization	2013	Singapore	1		1	1	1	1	1							1		
Modeling Guide Series - Spatial program validation v0.96	2007	USA		1								1		1	1			
Modeling Guide Series - 3D Imaging v1	2009	USA	1	1		1							1				1	
Modeling Guide Series - 4D Phasing v1	2009	USA	1			1	1	1	1					1				
Modeling Guide Series - Energy Performance v2	2012	USA		1	1							1	1	1				
BIM Primer Report 1	2012	USA		1	1					1	1		1				1	1
PAS 1193:2013	2013	Britain	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Use-Specific Guides are not as complete as BIM Guides because they focus on specific uses of BIM therefore, these guides only consider the topics relevant to the use or thematic to which they are focused. Some of the studied documents are part of both categories, BIM Guides and Use-Specific Guides, since they are comparable with other BIM Guides in their general sections but they also include sections with more specific information for certain BIM uses(e.g., PAS 1193:2013 (Institution, 2013)). Countries where BIM is or will be mandatory for public projects (e.g., United States of America(GSA, 2007), Singapore(Chidambaram et al., 2011), United Kingdom.(Khosrowshahi & Arayici, 2012)) are the main producers of Use-Specific Guides. BIM guides and BIM use-specific guides are essential references for developing a Project Execution Plans for a specific project.

Table 3-3 Concept Matrix for BIM General Standards

			Process				Organization					Technology				Legal and security aspects		
Name of Document	Year	Country/Zone	Preparation Process	Model Creation Process	Colaboration Process	Control and revision process	Participants	Roles and Responsabilities	BIM Manager	Authors of the model	User of the model	Formats	Deliverables	Level of detail and development	Family parameters	Intellectual property	Files and security protocols	Authorized uses
The Contractor's guide to BIM V2	2009	USA	1	1	1	1	1	1		1	1		1	1	1	1	1	
Design Object Library Guide	2012	Singapore		1									1		1			
Statsbygg BIM Manual 1.2.1	2011	Norway		1		1						1	1	1				1
Architectural/Enginering Guidelines	2012	USA										1	1					
Attachment F : BIM Requirements	2012	USA	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MHS FLCM BIM minumun Requirements	2014	USA	1		1							1	1		1			1
A/E Submission Requirements for VA Medical Center	2013	USA	1	1			1			1	1	1	1	1			1	1
Rgb BIM Standard	2012	Netherland										1	1	1	1			
National Building Information Modeling Standard v2	2012	USA	1	1	1		1					1	1		1	1		
LACCD BIM Standards v3	2010	USA	1	1	1	1	1	1	1			1	1	1	1	1	1	1
AEC (CAN) BIM Protocol v1	2013	Canadá	1	1	1		1	1	1	1	1	1	1	1		1	1	1
The VA BIM Guide	2010	USA	1	1	1		1	1		1	1	1	1	1		1	1	1
BIM guidelines and standadrs for archs. and eng.	2009	USA	1	1	1		1	1	1				1	1				
Caderno BIM VERSAO	2014	Brasil	1	1	1		1	1				1	1	1		1	1	
AEC (UK) BIM Protocol v2	2012	Britain	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1
PAS 1193:2013	2013	Britain	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Standards complement BIM guides as guides show alternative or general procedures and standards specify which procedure should be used and how should be used.

The BIM General Standards do not focus only on the model itself but also include other deliverables that are generated from the model such as drawings and schedules.

In some cases, General Standards and BIM Guides are part of a single document.

BIM General Standards mostly focus on process and technology content items.

Table 3-4 Concept Matrix for BIM Modeling Guidelines

			Process				Organization					Technology				Legal and security aspects		
Name of Document	**Year**	**Country/Zone**	**Preparation Process**	**Model Creation Process**	**Colaboration Process**	**Control and revision process**	**Participants**	**Roles and Responsabilities**	**BIM Manager**	**Authors of the model**	**User of the model**	**Formats**	**Deliverables**	**Level of detail and development**	**Family parameters**	**Intellectual property**	**Files and secutity protocols**	**Authorized uses**
Singapore BIM Guide v2	2013	Singapore	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
BIM e-submission guideline	2011	Singapore		1		1		1				1	1	1	1			1
BIM template Training (Revit, Archicad)	2013	Singapore		1		1		1				1	1	1	1			1

Singapore is the only studied country that provides information specific for the modeling process. This information becomes a requirement to submit public projects although some guidelines are only recommendations. This group of documents also includes templates to increase productivity and standardization in the deliverables.

BIM Modeling Guidelines focus mainly in how the model should be done and this is reflected in full coverage of the technology content area, Singapore has developed specific guidelines for different software packages.

Although the authors found just three documents that can be classified as Modeling Guidelines, their review is important because they fulfill a specific and important role in the BIM process.

Table 3-5 Concept Matrix for BIM Project Execution Plan Templates/Guides

			Process				Organization					Technology				Legal and security aspects		
Name of Document	Year	Country/Zone	Preparation Process	Model Creation Process	Colaboration Process	Control and revision process	Participants	Roles and Responsabilities	BIM Manager	Authors of the model	User of the model	Formats	Deliverables	Level of detail and development	Family parameters	Intellectual property	Files and security protocols	Authorized uses
BIM Project Execution Plan Template	2010	USA	1	1	1		1	1	1	1	1	1	1	1		1	1	1
IU BIM Execution Plan Template	2012	USA	1	1	1	1	1	1	1	1			1	1		1		1
Project BIM Brief	2011	Australia	1				1	1	1				1					1
NATSPEC BIM Scheduling guidelines	2010	Australia	1	1	1										1			
Appendix M: BIM Planning and Coordination	2012	USA	1				1						1					
AIA E203-2013	2013	USA	1	1	1		1	1	1	1			1			1	1	1
USACE BIM PXP	2012	USA	1	1	1													
Project Execution Planning Guide	2010	USA	1	1	1		1	1	1	1	1	1	1	1		1	1	1

Some organizations have developed their own templates and guides to produce BIM Project Execution Plans and other organization use external templates such as the Penn State's Project Execution Plan Guide (The Pennsylvania State University, 2010). There also cases where the BIM Project Execution Plan Guide was included in a Use-Specific Guide, like in Singapore's guides.

Table 3-5 shows documents that are independent of other type of guides.

The increasing relevance of BIM Project Execution Plans is evident as the other BIM documents usually refer to these plans. Also, the 2008 version of AIA's (American Institute of Architects) did not commented about these plans but the 2013 version created a specific document for describing the BIM execution Plan (i.e.. E203-2013 (AIA, 2013b)).

Table 3-6 Concept Matrix for Legal Attachment Templates/Guides

			Process				Organization					Technology				Legal and security aspects		
Name of Document	Year	Country/Zone	Preparation Process	Model Creation Process	Colaboration Process	Control and revision process	Participants	Roles and Responsabilities	BIM Manager	Authors of the model	User of the model	Formats	Deliverables	Level of detail and development	Family parameters	Intellectual property	Files and secutity protocols	Authorized uses
BIM Particular Condition	2012	Singapore						1	1	1						1		1
New Zealand BIM Schedule	2014	New Zealand					1		1	1		1				1		1
CONSENSUSDOCS 301 BIM ADDENDUM	2008	USA					1	1	1	1			1			1		
AIA E202-2008	2008	USA	1				1	1	1	1		1	1	1		1	1	1
AIA E203-2013	2013	USA	1	1	1		1	1	1	1			1			1	1	1
AIA G201-2013	2013	USA	1		1		1					1					1	1
AIA G202-2013	2013	USA	1	1	1		1	1		1			1	1				1

These documents are specifically drafted to complement existing design and construction contracts. In some countries, BIM Legal Attachments only refer to Project Execution Plans but in other countries they replicate most of the content of Project Execution Plans. In USA the AIA organization created the E202-2013 BIM protocol that is both a project Execution Plan and a Legal Attachment.

Figures 3-7, 3-8 and 3-9 summarize the coverage of the content elements by the different document types. In this context, coverage refers to the fraction of documents that include a particular content element. Figures 3-7 and 3-8 focus at the content areas while Figure 9 includes the content topics within each area. These figures show that there is no document that fully covers all the content areas. In fact, BIM Modeling Guidelines is the only document type where all the documents reviewed covered all the content in one area – technology – which is consistent with its definition as this document type focuses on the technology. The document type with higher average coverage is the BIM Guide as is the only document that covers more than 50% in every area of the content classification structure.

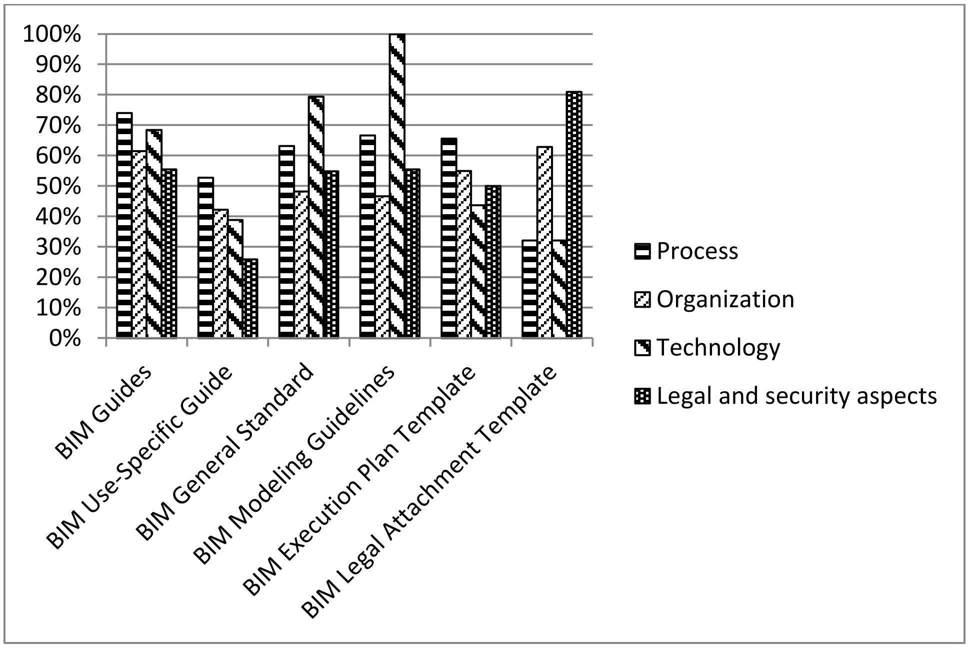

Figure 3-7 Relation between BIM document types and content areas – Classified by document type

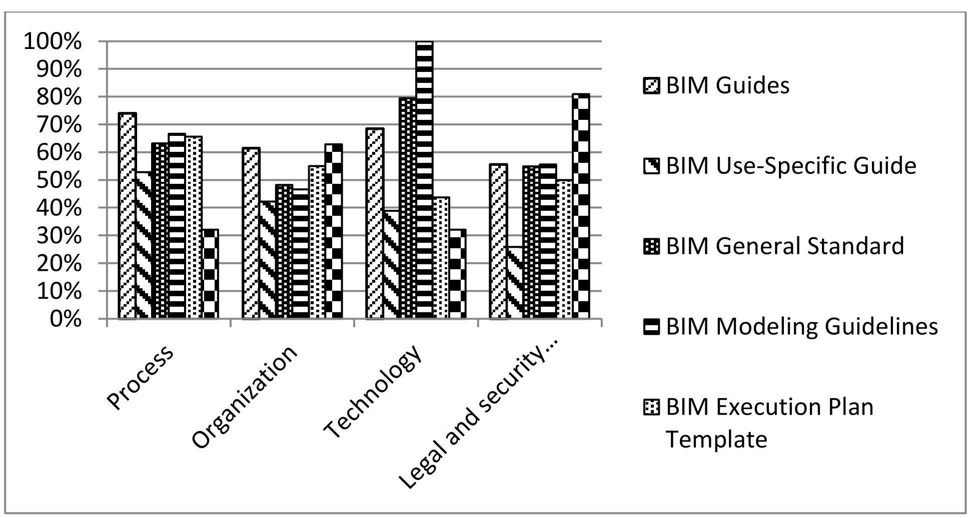

Figure 3-8 Relation between BIM document types and content areas – Classified by content area

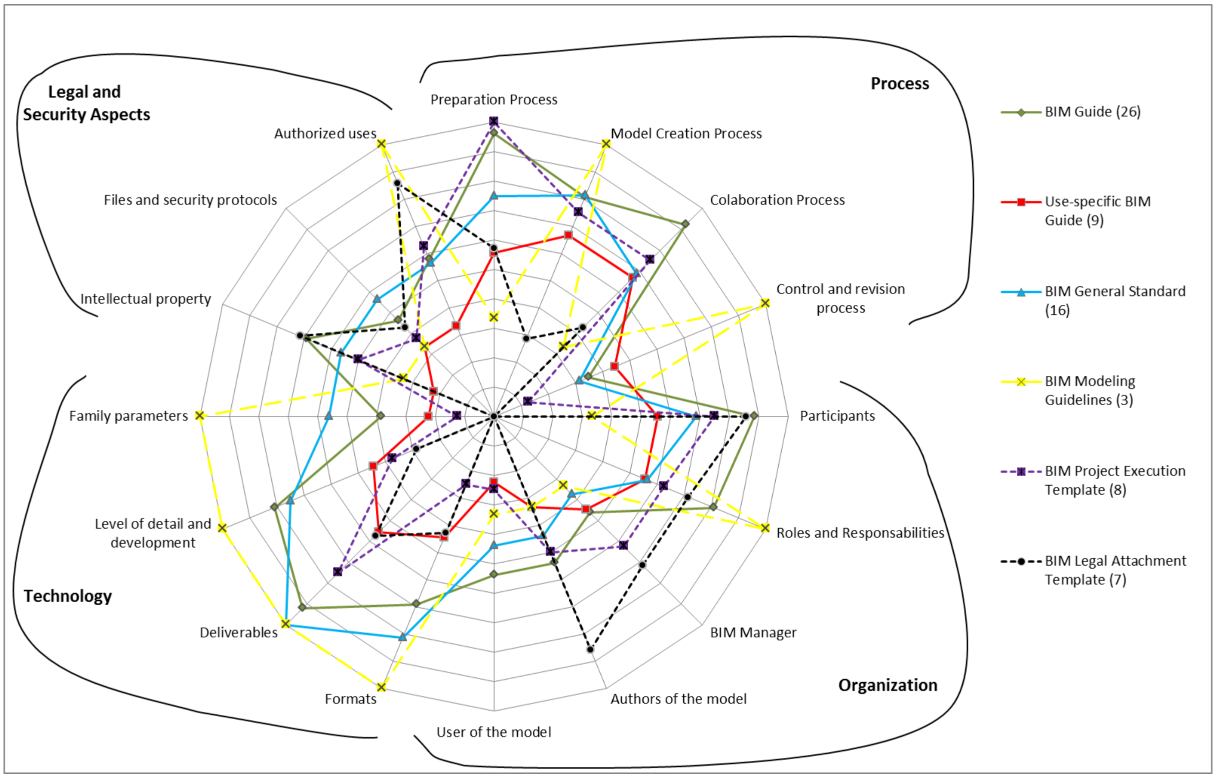

Figure 3-9 BIM documents and content items

Table 3-7 summarize the BIM support document types by the different organizations. This table shows that BIM Guide and BIM Standards are the most common document as 77% and 45% of all organizations review have these types of document respectively. Also, BIM Modeling Guidelines and BIM Project Execution Plan Templates/Guides is the less common with a 3% and 13% each.

Table 3-7 BIM Support Documents of Organizations

	BIM Support Documents					
Organization	**BIM Guide**	**Use-Specific BIM Guide**	**BIM General Standard**	**BIM Modeling Guidelines**	**BIM Project Execution Plan Templates/Guides**	**Legal Attachment Templates/Guides**
CanBIM	X		X			
AEC(UK)	X		X			
The Associated General Contractors of America	X	X	X			
The American Institute of Architects					X	X
Federal Office for Building and Regional Planning	X					
Building and Construction Authority	X	X	X	X		X
Penn State Computer integrated Construction	X				X	
Digital Constructuon BIPS	X					
BRANZ						X
British Standards Institution	X	X				
Building Value	X					
COBIM	X					
ConsensusDocs						X
CURT	X					
New York City Department of Design & Construction	X					
Department of Defense			X			
State of Wisconsin	X		X			
European Commission	X					
General Services Administration & Public Building Service	X	X				
Governo de Santa Catarina	X		X			
Hong Kong Institute of BIM	X					
Indiana University	X					
Los Angeles Community College District	X		X			
Natspec BIM	X					X
National BIM Standard & Building Smart Initiative	X		X			
OHIO State architect's Office	X					
Ministry of the interior and Kingdom Relations			X			
STATSBYGG			X			
Texas Facilities Commission			X		X	
U.S. Army Engineer Research and Development Center	X	X	X		X	
Department of Veterans Affairs	X		X			

3.7.Conclusions

This study contributes to a better understanding of BIM documents through a review of their contents and purposes. In the context of this review, the authors classified BIM documents in 9 classes grouped in three levels: Software Manuals and BIM Books, at the global level; BIM Guide, BIM Use-Specific Guide, BIM Standard (General Standards and Modeling Guidelines), BIM Execution Plan Guide and Template, and Legal Attachment Template, at the national and organization level; and BIM Project Execution Plan and BIM Legal Attachment, at the project level. The study focused only at the national and organization level because the other levels either did not directly supported BIM processes or were not publicly available.

The following points summarize the main observations and conclusions from the relation between BIM document types and contents.

- The content topics “Model users” and “Files and security protocols” are poorly covered since less than 60% of the documents of each document type include these topics.
- “Family parameters” and “Control and revision process” are covered by all the documents classified as BIM Modeling Guides and Templates. However, the rest of the document types have a small coverage of these content topics.
- The irregular shape for the BIM Modeling Guides and Templates in Figure 9 is due to the small number of documents in that category.
- Use-Specific Guides cover all the content topics but with small percentages. This is due to the varied nature of these guides as each of them may focus on different BIM uses and, therefore, emphasizes different content topics.
- The BIM Legal Attachment Templates do not cover several of the content topics because these documents are very specific.
- The fact that different documents within a document type present variation in their contents is an indication that there is no clear standard about what a particular BIM document should address. However, this does not mean that a standard is necessary as different organizations may want to emphasize different contents.
- Not all the organizations that created the analyzed documents have all the document types found in this review. This may happen because some organizations use documents produced by other organizations but also some organizations may not be BIM-mature enough to produce their own documents.
- BIM Guide and BIM Standards are the most common support documents with a 77% and 45% of all organizations having one of these documents respectively.

The document review showed that BIM Project Execution Plan is an essential document because almost all the other documents – and the respective organizations who produced them – suggest/require to create one. Several of the organizations have their own template for this document and the others cite existing templates, being the most cited one the Project Execution Planning Guide and Template from Pennsylvania State University.

The main limitations of this study are the sample scope – defined by the language (English and Spanish) and time frame (up to 2014) – and the review parameters. The authors consider that, although there has been new documents since 2014 and there are documents in other languages, the sample scope is representative of the universe of BIM documents. Regarding the review parameters, the study considered only the coverage (presence or absence) of the different content topics by the different document types. The depth with which each document covered the content topics was not evaluated due to the complexity of this assessment and the time that would require this assessment for this number of documents. The reduced review parameters may conceal other conclusions especially regarding how well the different content topics are covered and the potential relation with challenges on BIM implementations.

Future work should complement this study with other parameters such as the coverage depth and the experience and profile of the organizations that create the documents. Also, the study could be complemented with assessments from project stakeholders about the usefulness and challenges of the different BIM documents.

4. CHALLENGES AND STRATEGIES FOR USING BIM IN PPP HOSPITAL PROJECTS: A CHILEAN CASE STUDY

Due to their complexity, the use of BIM (Building Information Modeling) is becoming a requirement both in public and private healthcare projects. However, despite the evident and documented benefits, there is still a lack of understanding of the challenges involved, especially in public healthcare projects. This paper presents a case study that explores the use of BIM in a Chilean PPP (Public Private Partnership) hospital project. The research methodology includes the active participation in the project design and construction, the application of control instruments to assess the BIM requirements achievement, and interviews to the project's main stakeholders. The findings indicate that the main challenges of the BIM application are: (1) A lack of appropriate specifications in the BIM requirements, (2) a lack of penalties for noncompliance, (3) inefficient BIM procedures, (4) poor objectives alignment among the stakeholders, and (5) a lack of proper BIM knowledge. Based on these findings and the literature, a set of strategies are proposed: (a) Include a formal evaluation of BIM deliverables, (b) develop public national standards with the public agencies objectives, (c) require the development of a BIM project execution plan for every new project and (d) generate BIM guides as well as an agency in charge of maintaining a long-term BIM vision.

Keywords: Public Projects, Health Projects, BIM Process, BIM Requirements Specification, Case study.

4.1. Introduction

Healthcare projects are very complex, and failures in meeting their quality, budget and schedule goals can have enormous social, economic and political consequences (Chan, 2004; Henjewele, Sun, & Fewings, 2014; Phelps, 2008). Because of this high complexity and risk, different organizations in many countries are implementing Building Information

Modeling (BIM) in these projects (Khosrowshahi & Arayici, 2012; Wong et al., 2009). Public healthcare projects – and other public infrastructure projects in general – are not an exemption to this trend. Public agencies in countries such as United States, Great Britain, Singapore, and Spain, are or will be (in the near future) requiring BIM in their projects (Chidambaram et al., 2011; Khosrowshahi & Arayici, 2012). The Chilean Ministry of Public Works (MOP, by its Spanish acronym), particularly its Public-Private Partnership (PPP) division, started requiring the use of BIM in its projects in 2008, and other public agencies such as the Health Ministry (MINSAL) are also including similar requirements. Table 4-1 shows BIM requirements for the main Chilean PPP projects.

Table 4-1 BIM Requirements in Public PPP Projects in Chile

Project Name	BIM Requirements													Tender Documents Date
	Existing Conditions Modeling	BIM Modeling	BIM Coordination	BIM 4D Planning	As-Built Model	Design Plans with Geo-referenced elements	Coordination Plans from BIM models	BIM Control project planning	Allow Design Supervision	Integration with performance evaluation	Web access to BIM system	BIM database extraction	Asset Management	
Hospital Maipú y la Florida		X	X											12-2009
Hospital de Antofagasta		X	X	X	X									12-2011
Hospital El Salvador Geriatrico		X	X	X	X	X	X	X	X	X	X	X	X	12-2011
Hospital Félix Bulnes		X	X	X	X	X	X	X	X	X	X	X	X	12-2011
Autopista Américo Vespucio Oriente Tramo 1		X	X	X		X		X		X	X	X	X	7-2013
Aeropuerto Internacional Arturo Merino Benítez		X	X	X		X		X	X	X	X	X	X	5-2014
Camino Nogales-Puchuncaví	X	X		X		X		X	X		X		X	6-2014

However, despite the increasing BIM requirements, the use of BIM does not always yield the expected results, in part due to the particular context of these projects – e.g., contractual limitations, bureaucracy, and very limited resources – and also to improper implementation strategies such as BIM subcontracting, and the coexistence of traditional and BIM processes. Furthermore, the increasing BIM requirements are pushing the expectations from a little-lonely BIM to a big-social BIM (Jernigan, 2007; Suwal et al., 2013), which increases the complexity in the BIM stakeholders' interactions. At the same time, PPP projects offer an interesting opportunity as the BIM requirement is at the owner level.

To address these problems and opportunities, this case study aims at understanding the main challenges in using BIM in PPP hospital projects and propose consequent implementation strategies.

4.2.BIM Use in Healthcare and Public Projects

Previous case studies have explored the use of BIM in healthcare. Manning and Messner (2008) review two projects (Expeditionary Hospital Facility and Medical Research Lab) where BIM was used in the early conceptual stage to support communication, collaboration, and some analyses. In both projects, the primary challenges were information transfer bottlenecks, lack of information in parameters for significant project vender products, unfamiliarity of BIM's scope in application in programming, and a lack of understanding of interoperability limitations. Digby Christian et al. (2008) review the Sutter Medical Center Project (Eastman et al., 2008) where BIM was used to support quick cost estimating after design changes in the target value design (TVD) process. The main challenges were the cultural shift, the training, and the cost for the transition from one software to another. Dave and Florez (2008) study the Maryland General Hospital Project (Eastman et al., 2008) where BIM was used for clash checking and tracking, to capture field data including documentation about equipment, and it was eventually handed over to the client for facilities management. The main challenge was the creation of an interoperable database for facility management. Finally Khanzode, Fischer and Reed (2008) discuss the benefits and lessons learned from implementing VDC (Virtual Design and Construction) for the MEP coordination on a large healthcare project. The challenges focused on the information structure and the process for a better integration of the project stakeholders' models. In summary, the main challenges identified in these studies are the following.

- Information transfer bottlenecks
- Lack of information in parameters
- Lack of understanding of interoperability limitations
- Difficulty for cultural shift from traditional projects to BIM projects
- Lack of training required to fulfill the project requirements
- Increased cost by the change from one software to another

These challenges are a good point of departure but they lack a deeper analysis of the causes and the potential strategies that could help companies deal with the challenges. Also, these studies include only private healthcare projects, which present a very different context compared with PPP projects.

On the other hand, BIM strategies can be obtained from more general studies (not necessarily in healthcare projects) and from the practice observed in the implementation initiatives of several public infrastructure agencies of countries such as USA, UK, Singapore, Hong Kong, South Korea, Netherland, Finland, Denmark, and Norway.

Literature of BIM implementation include some recommendations focused on the process; for example the virtual coordination meetings and clash detection (Krieger, 2013), and the use of a BIM execution plan (Mayo, Giel, & Issa, 2012); and also focused on the organization, explaining the importance to know subcontractors BIM experts capabilities before the process is defined, to increase the benefits and avoid problems for lack of experience. Most of the literature on BIM implementation sees the BIM process as a socio-technical process, but as Miettinen and Paavola say, BIM implementation requires local experimentation and continuous learning, because it is an open-end expansive process (Miettinen & Paavola, 2014).

Regarding the practice of public infrastructure agencies, the National 3D-4D-BIM Program of the GSA (General Services Administration, USA) developed the BIM guides series that allows to more effectively meet their projects' program, design quality, and construction requirements (Yee et al., 2010). Similarly, the U.S. Army Corps of Engineers (USACE) developed a BIM Roadmap, contractual language and other BIM documents (Brucker et al., 2006); the CIC (Construction Industry Council) produced a BIM Protocol to facilitate the production of building information models at defined stages of a project.(Fraser, 2013); the BCA (Building and Construction Authority, Singapore) published a BIM promotion plan (BIM Roadmap) and led a multi-agency effort to implement the world's first BIM electronic deliverable submission system (e-submission) (Chidambaram et al., 2011); Hong Kong's Housing Authority developed a set of modeling standards and guidelines for effective model creation, management and communication among BIM users (Wong et al., 2009); Finland's Senate Properties (the state property services agency) is running pilot projects using BIM and IFC (Industry Foundation Classes) (Wong et al., 2009); and the Norwegian Homebuilders Association has encouraged the adoption of BIM and IFC (Wong et al., 2009). From these cases, the following strategies can be derived.

- Get time to know subcontractors' BIM capabilities before the BIM process is defined.
- Consider local experimentation and continuous learning for the implementation.
- Use of documents (e.g., project execution plans, contractual addendums, and BIM guidelines) that support the implementation and use of BIM.
- Develop long-term strategies through a BIM Roadmap.
- Use exchange formats (e.g., IFC) to facilitate the collaboration between project's stakeholders.

As mentioned before, these challenges and strategies are a good point of departure to understand the context of PPP hospital projects but they do not address the specificities of these projects. The following case study will assess the challenges and strategies in a Chilean PPP hospital project and analyze the relation with the ones found in the state of art and practice.

4.3.Case Study

The case study is the Antofagasta Hospital, whose design and construction was mandated by the MINSAL and managed by the MOP in Antofagasta, Chile. This is a highly complex project of more than 114,000 m^2 of constructed area. Table 4-2 describes the project's main stakeholders.

Table 4-2 Description of project's main stakeholders

Stakeholder	Description
(1) Public Works Inspector	Professional that works for the MOP and is responsible for developing, coordinating and controlling all technical aspects of the project, and the relationship with internal and external users, regional authorities and other public institutions.
(2) Inspection advisor	Private consultant in charge of advising the Public Works Inspector in all his/her activities related to the PPP contract. Among their responsibilities are: Review the project, and monitor compliance with PPP contracts.
(3) Preliminary project designers	Company responsible for developing the preliminary design which is the reference for the detailed design.
(4) Concessionary	Company or group of companies responsible for developing the detailed design, and for building, operating and maintaining the infrastructure. It also is in charge of selecting the architecture,

engineering, and construction companies.

The research methodology included the review of the project documents, active participation in the project, and interviews. Table 4-1 depicts the main research tasks and methods used in the case study

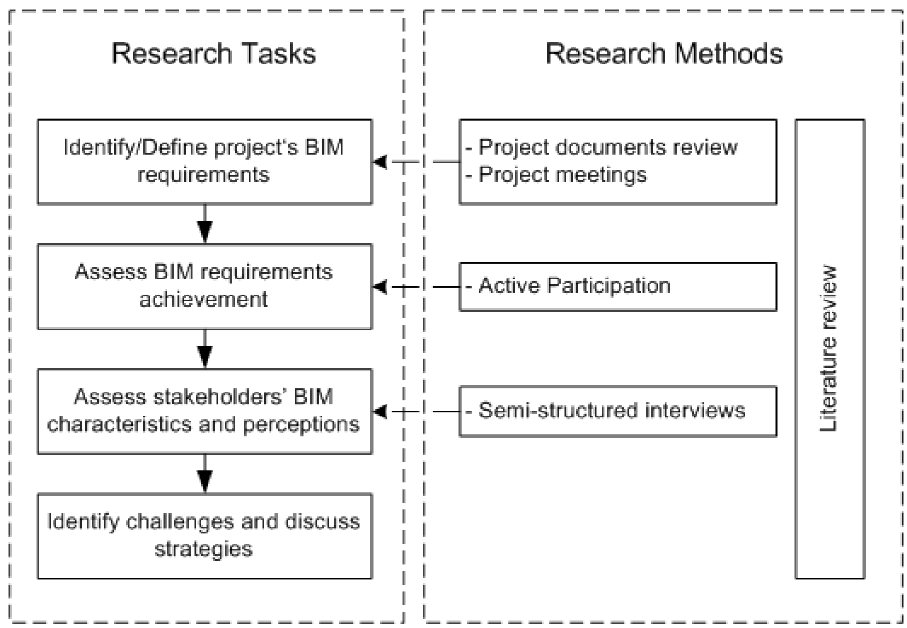

Figure 4-1 Research methodology

The first task was to identify/define the project's BIM requirements. Although these requirements were stablished in the bidding documents, they were copied from other MOP projects and their redaction was not clear so both the public works inspector and the concessionary of the case study had a weak and different understanding of these requirements. A detailed review of the project documents and literature, and meetings with the inspector, inspection advisor and concessionary allowed to reach a consensus about the BIM uses, process and deliverables.

The second task consisted on the assessment of the achievement of the BIM requirements as they were previously defined. One of the researchers actively participated in the project

– as part of the inspection advisor's organization – which allowed him to develop and apply control instruments (checklists) to assess the deliverables that the concessionary had agreed upon. This assessment included a root cause analysis of the observed problems (Wilson, Dell, & Anderson, 1996).

The third task used semi-structured interviews to assess the perceptions that the main stakeholders had about the BIM process and results, and the BIM characteristics of these stakeholders in three dimensions: knowledge, interest and use.

focusing in three non-technical elements: (1) Level of use, (2) knowledge, (3) and interest of BIM across all AEC disciplines and project participants for a BIM adoption as they are important for implementation analysis.(Gu & London, 2010)

Finally, the fourth task consisted on analyzing the information gathered from the case study and literature to identify the main challenges and discuss relevant strategies.

4.3.1. Project's BIM Requirements

Table 4-3 describes the BIM model uses defined for this project.

Table 4-3 BIM uses in the case study

Use	Description
Coordination	To integrate different disciplines models to eliminate the major design conflicts prior to installation.
Design review	To showcase the design to the stakeholders to evaluate the program, and set criteria such as layout, sightlines, lighting, security, ergonomics, acoustics, textures and colors.
4D Planning and monitoring	To use a BIM model to produce a 4D model (3D model plus the time dimension) to support the planning of the facility construction, improving the visualization of the construction sequence and resource requirements on a building site.

Project Progress Control	To Use a 4D model to show the construction progress and compare it with the planned progress.

The design review is the only BIM use that was not declared on the bidding documents but the public works inspector decided to add it to facilitate the reviews from non-technical stakeholders. This addition did not require work from the concessionary so there was no contractual problems.

The above BIM uses and the deliverable description contained in the bidding documents allowed the researchers to define the basic process map shown in Figure 4-2.

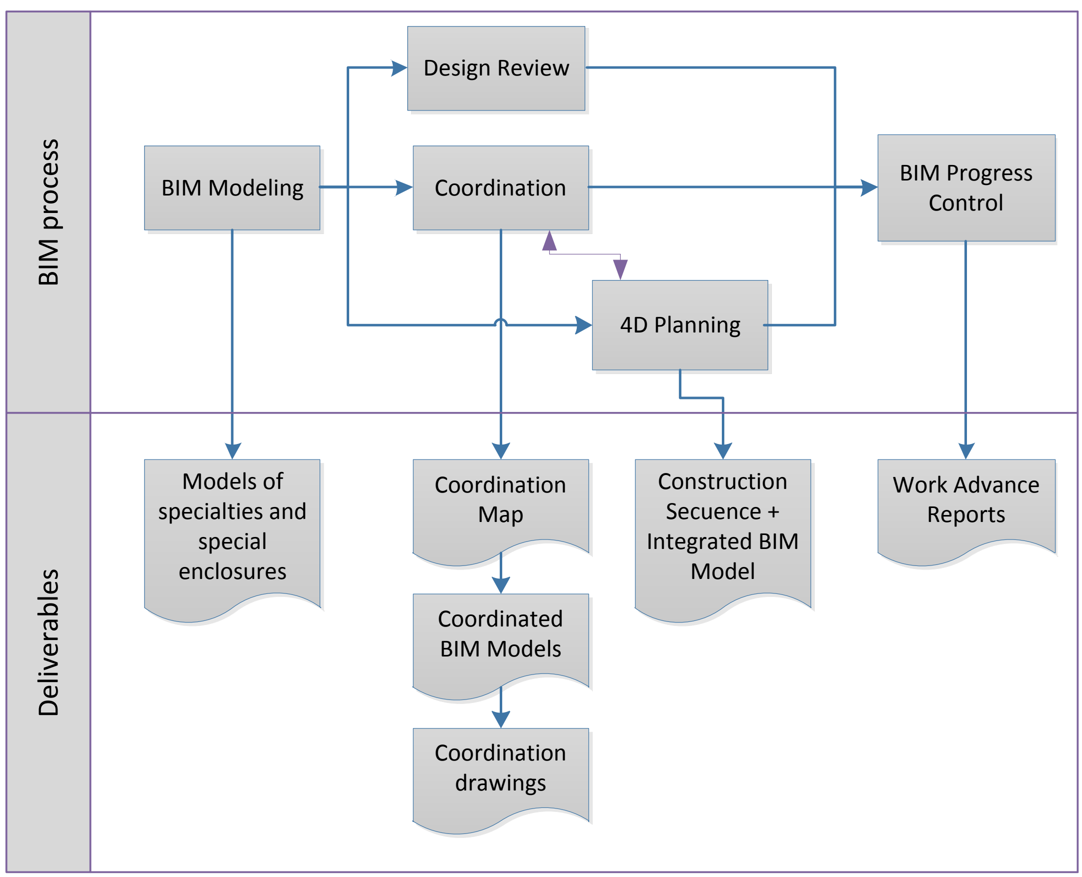

Figure 4-2 General BIM process and deliverables

The BIM process starts with the BIM modeling activity, which was subcontracted by the concessionary to the structural design office. Within this organization, the BIM modelers worked in parallel with the structural designers. After the modeling, the public works inspector, through the inspection advisor, uses the BIM model to allow other stakeholders (such as the MINSAL) to better assess the design and provide valuable and timely feedback. This task does not have any formal deliverable. In parallel to the design review, the BIM coordinator (member of the concessionary) uses the BIM model to coordinate the specialties, process that has the following three deliverables.

- Coordination map: document the highlights the detected coordination problems and the respective solutions.
- Coordinated BIM models: models that already include the coordination solutions so they do not contain any coordination issue.
- Coordination drawings: drawings generated from the coordinated BIM models.

Also in parallel, the 4D planning requires the coordinated BIM models to spatially describe the construction sequence, although the concessionary could deliver previous versions with non-coordinated models (not requested but recommended). The coordination drawings, together with the 4D model is required to approve the final design.

During the construction phase, the inspection advisor uses the coordinate BIM models to assess and communication the work progress through monthly reports.

4.3.2. Requirements Achievement

The researchers iterated with the public works inspector and the inspection advisor to define checklists for each of the BIM deliverables depicted in Figure 4-2. The purpose of these checklists was to assess the achievement of the deliverables. The assessment criteria contained in these checklists come from the bidding documents interpretation and a literature review on BIM documents and standards (Riquelme, 2016). Figure 4-3 shows a fragment of one of these checklists. Besides the assessments for each of the criteria, the checklist requires a general assessment of the deliverable (not shown in Figure 4-3).

Checklist of Content Models			
Rewever			
Date			
Definitive Project	*Evaluation could be: Aproved, Rejected or Pending.*		
Category	**Criteria**	**Eval.(A/R/P)**	**Comments**
Administrative: **F**ormal and administrative elements.	The model was delivered in rvt and nws formats.		
	Name and content are clear in the file.		
Contents: The model contains all the elements identified in the matrix of information exchange. It is recommended to check from lower to higher levels, in ascending order, and from north to south in each level.	The model contains all the scope defined in design drawings.		
	The model is consistent with information exchange matrix.		
	The model uses the proper families.		
	Family naming is consistent.		
Accuracy: The models represent exactly the design in the drawings.	Level checking (Instances and elevations).		
	Grid checking.		
	Building elements checking..		
	Origin checking		

Figure 4-3 Model Content Checklist (Fragment)

Table 4-4 summarizes the general assessment of the achievement for each BIM deliverable after the application of the checklists in several deliver instances of the project. This assessment includes the main observed problems and an analysis of the potential causes.

Table 4-4 Assessment of BIM deliverables

Deliverables	**Observed Problems**	**Potential Causes**
BIM Modeling	1. The model did not contained all the expected building elements and the level of detail was not proper for the analyses.	The deliverable was not correctly specified: there was no specification of content, level of detail, file structure, naming convention, visualization details, or information to be

	2. Lack of consistency in the names of the model components and files. 3. The model components did not include information necessary to facilitate exploration and identification.	included in the model.
	4. There is no explicit relation between the model and drawing versions.	Modeling procedure did not register or communicate the relation between versions of drawings and models.
	5. Inconsistency between drawings and models.	Communication between modelers and designers was inefficient.
Coordination	1. There was not enough time to review the coordination deliverables before the construction started.	There was no specification or requirement for fractioning the deliverable so the coordinated model was delivered for the entire project.
	2. The coordination map did not include all the coordination issues that had been solved which hinder the inspection advisor's work of checking the deliverables. 3. There is no distinction between conflicts that are real and have to be solved and conflicts that are caused by a modeling decision. 4. The conflicts are not organized by relevance. 5. The tolerance used for the analysis is unknown.	The coordination process was not specified.

	6. Coordination drawings are not fully coordinated.	Concessionary did not give the required attention to the coordination.
4D Planning	1. The 4D model is too general. 2. The 4D model is delivered too late to be used to support planning.	Levels of detail and information structure of the schedule and BIM model are not consistent. Although the 4D BIM model is required, there is no a specific date or moment for this deliverable. The planner did not use the 4D model to assess the schedule.
Project Progress and Control	1. The 4D model is not used for this purpose. 2. The level of detail of the model is too general to represent the progress.	The use of 4D models is still not a common practice so there is lack of knowledge to support this use. The bidding documents do not specify scope and level of detail for the 4D model. Furthermore, these documents do not describe the relation between the BIM and the traditional progress control processes.

The last two BIM uses in Table 4-4 were reproved, which means that they were not successfully implemented and their respective deliverables were not used in the project. As Table 4-4 describes, one of the main reasons for 4D planning failure is the unsuitable level of detail of the schedule. For example, the structural floor was not divided according to the concrete pouring sequence. The delivered 4D model only allowed for general analyses. Consequently, project progress control could not be done with the 4D model.

4.3.3. Stakeholders' BIM Characteristics and Perceptions

Semi-structured interviews allowed to assess characteristics and perceptions of stakeholders that play different roles in the BIM process. The interviewees include one representative of each of the relevant BIM stakeholders: public works inspector, inspection advisor, BIM modeler, BIM coordinator, concessionary's technical office, and architect. This group of stakeholders differs from the one in Table 4-2 because the focus of this group is in the BIM uses and not in the entire project.

The interview was conducted by telephone, at the middle of project, and contained 6 main questions (Table 4-5) plus the context questions (person´s name, e-mail, and project role; and company´s name and type).

Table 4-5 Questions for general analysis

N°	Questions
Q1	1. What is your level of knowledge about the BIM methodology?
Q2	2. What is your level of interest in using BIM in the projects that your company is part of?
Q3	3 What is your company's level of BIM use? And why do you think that?
Q4	4. What level of benefits do you think you will have in BIM projects?
Q5	5 How do you assess the Challenge to properly use the BIM methodology in your projects?
Q6	6. Do you use BIM as part of the best practices of your company?

Questions 1 through 4 were quantified in a 5-point likert scale where 1 is a very low level and 5 is a very high level. Questions 5 and 6 provide qualitative information about the stakeholders' perception about the challenges and their BIM use. Figure 4 summarizes the quantitative data.

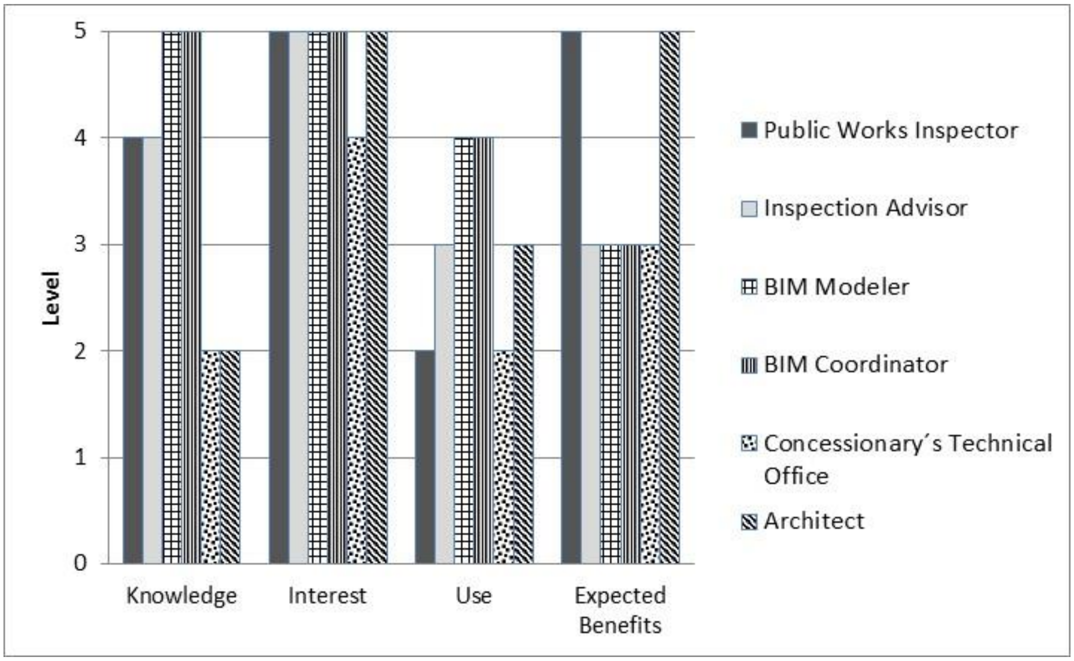

Figure 4-4 Stakeholders’ BIM characteristics

The stakeholders that declare to have more BIM knowledge are BIM modelers and coordinators, which is consistent with their role as they have to directly interact with BIM tools and models. This is reflected also in the BIM use as they declare the highest level. On the other hand, the stakeholders that declare to have less (and very low) BIM knowledge are key stakeholders for a proper BIM use (concessionaire´s technical office and architect). The interview qualitative answers showed that they focused on BIM as a requirement (BIM deliverables) but not as a work methodology that could help them from the beginning of the project. Both the public works inspector and the inspection advisor declared an important level of BIM knowledge but they still lack understanding of BIM procedures, which hinders their capacity to control the project’s BIM process.

Regarding their interest in the use of BIM, all participants declared a high level with only the concessionary’s technical office having a slightly lower level.

It is in interesting that the BIM modeler and coordinator are expecting few benefits from the BIM use even though they declare to have a high knowledge and interest in BIM. Their qualitative answers show that this low expectation is a consequence of their perception of how the other stakeholders value their BIM work as most of times they had to be the ones that drive the correct use of the methodology. In contrast, the public works inspector and the architect have the highest expectation of benefits but they have a low use and knowledge of BIM.

Regarding the expected benefits of particular BIM uses, 4D planning and project progress control were considered to have very low benefits. The concessionary´s technical office also declared that these BIM uses are only useful for non-technical stakeholders. This view is aligned with the results obtained from the application of the checklists for those deliverables.

4.4.Analysis

Problems obtained can vary greatly from project to project and are highly dependent on the actors involved in the project. However, understanding the root cause of these problems and defining feasible strategies are a point of departure to avoid the repetition of these problems in future projects (Forbes & Ahmed, 2010). Table 4-6 consolidates the problems identified in the active participation and through the interviews in this case study.

Table 4-6 Root Problems

Root Problems	**Description**	**Consequences**
1- Lack of penalties for noncompliance	There are no penalties associated with the failure in executing BIM deliverables, leaving the option of postponing them –even forever– without major consequences.	Failure in BIM deliverables.
2- Lack of proper requirement specification	BIM requirements are very general, allowing different interpretations that produce deliverables with low value for	Failure to comply with expectations due to lack of process

	the project. Furthermore, due to the difference in the level of use and knowledge among the stakeholders, there is a misalignment in their processes. Finally, BIM uses that are not common (e.g., 4D modeling) require more specification.	alignment and BIM knowledge.
3- Inefficient BIM processes	There is no requirement to carry out a BIM execution plan with stakeholders (standards definition, work protocols), reducing efficiency, interest and therefore the usefulness of BIM.	Communication problems along the project, increasing difficulties in using BIM.
4- Poor objective alignment between the stakeholders	BIM is not intended to support the work of the participating companies, losing chances of improvements. BIM objectives are not clear.	Reduced motivation to use BIM properly. Unmet expected benefits.
5- Lack of proper BIM knowledge	The use for certain purposes BIM is not common knowledge and the terms of references have not specific requirements to avoid these problems. Also the first stakeholders supporting the process are the less BIM skilled.	Increased difficulty to use BIM in all the project process.

It also important to notice that only 50% of the BIM objectives were accomplished. Design review and BIM coordination are commonly used but 4D planning and project progress control require a knowledge that is not so common. Also these last two uses require a better process alignment because they include not only the design but also the construction process. Through the interviews, it was clear that there was lack of initial meetings to plan these BIM uses. Also, the project structure used an outside firm to develop BIM models with the main focus in coordination, and with modeling delays that affect all the later uses of BIM.

4.5.Strategies

Figure 4-5 depicts the main problems described above and a set of strategies that the researchers propose based on the literature and their experience in the project.

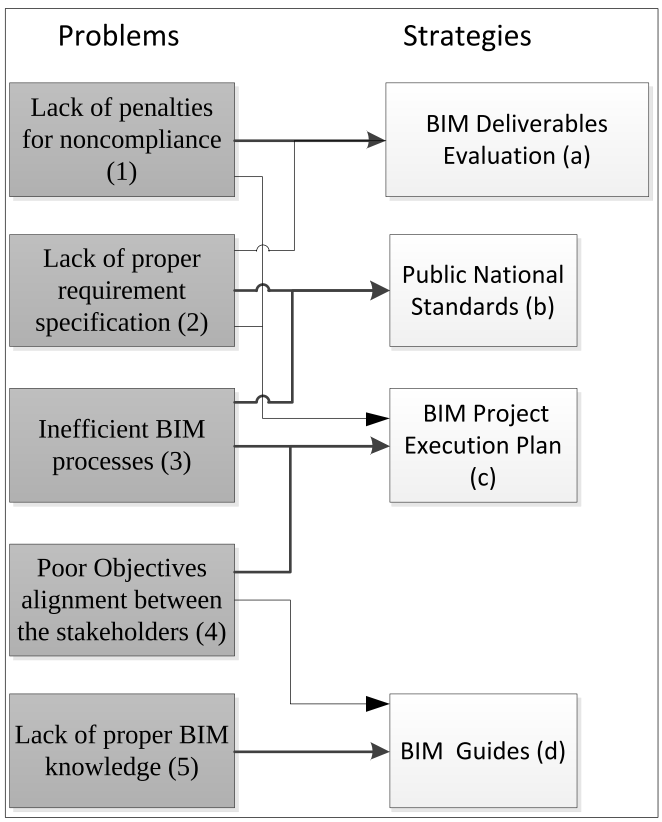

Figure 4-5 Case study’s problems and strategies

(a) BIM objectives should be correctly defined and their degree of achievement should be measured. This measurements should be accompanied by proper penalties when the stakeholders fail in meeting the deliverables. A continuous revision of the objectives could help avoiding the misunderstanding of them.

(b) In order to define correctly the BIM requirements, supports documents should be created by public agencies. Previous investigations show global common practices that are the basis for this recommendation. BIM standards are documents that aim at supporting the requirements specification. These documents should contain at least these elements:

- **Process aspects:** Preparation process as a development of a kick-off meeting for creating a project execution plan which will define the collaboration process (communication tools, ways to send BIM models, etc.) and model creation process (model structure, levels definition, etc.). Control and revision process is not a common practice but, as the case study showed, it is necessary to measure the success of the BIM objectives and to improve the BIM processes.
- **Organization aspects:** Definition of the BIM participants that a particular project should have, specifying their role and responsibilities in the BIM process.
- **Technology Aspects:** The documents should clearly define the BIM deliverables and their formats (for example, spreadsheets, 3D models, text documents, drawings, etc.). This definition must include the level of development and detail of every BIM model in each deliverable, and also the family parameters that should have according to the different BIM uses.
- **Legal and Security Aspects:** These are elements that aims at avoiding problems between the stakeholders. Some examples are the intellectual property over the models and the information contained in them, and files and security protocols to avoid misuse or loss of information.

(c) Aligned with the standards but at a more project-specific level, a BIM project execution plan must be created to specify the BIM process for that particular project.

(d) The public agencies must provide a basis to increase and align the stakeholders' BIM knowledge through BIM guides and BIM use-specific guidelines. Some very complete examples are the PAS1193:2013(Institution, 2013) and the Singapore BIM Guide (BCA, 2013c).

All the above strategies must be supported and framed by the public agency´s vision. This vision defines the long-term objectives and a roadmap to achieve them. This roadmap must include BIM promotion and training. In order to execute this roadmap, the public agency needs BIM champions (Eastman et al., 2008) who assess the implementation and provide support to key stakeholders.

4.6.Conclusions

Despite the increasing evidence of the benefits of using BIM in healthcare projects, several PPP healthcare projects are not achieving the expected results, as the BIM implementation is a complex process that requires not only good planning but also controlling its progress.
The case study analyzed showed that the lack of formalization in the process is the main reason for unmet expectations. In this study, only half of the required BIM uses were finally achieved. The study identified the main problems as: Lack of proper requirement specification, lack of penalties for noncompliance, inefficient BIM processes, poor objectives alignment between the stakeholders and lack of proper BIM knowledge.
The results and the literature revised allowed to explore and propose several strategies to cope with these challenges. One of these strategies is the use of BIM support documents: BIM project execution plan, public national BIM standards and the BIM guides are the main ones that help in the difference of BIM knowledge, defining a common language to communicate between stakeholders and define a process from the very beginning to make an efficient BIM process aligned with the project process. The other strategy is the continuous evaluation of the BIM deliverables to control differences in the interpretation of the BIM requirements and reduce their noncompliance. Additionally, there has to be a strategic vision supported by a public organization in charge of promoting the BIM use, and a Roadmap to define the process to meet the goals defined by that vision.

An important limitation of this case study is that started after the bidding process so it was not possible to change the contract documents or the BIM requirements defined the bidding documents. This made it possible to introduce a deeper intervention of the BIM process. As a future work, this study's recommendations should be implemented in a project and the success of the BIM implementation should be assessed.

5. CONCLUSIONS

The study focuses on two principal research tasks: BIM support documents analysis and Antofagasta Hospital project case study review. Big amount of documents are created by public and private organizations in order to help in the implementation process, aiming to avoid interpretation, responsibility, competency, and scope problems, among others. For this, publicly available BIM documents were reviewed, a content classification was proposed and the relation between document types and their contents was discussed. The case study was selected as an excellent way to do an holistic study of the implementation of BIM. For this Hospital of Antofagasta project was reviewed in design and construction phases. It was used checklists as a review tool, semi-structured interviews to obtain opinions of BIM direct participants and finally, with all the information gathered, it was analyses the main challenges of BIM implementation, and some suggestions where developed supported mainly by the literature review and BIM support documents analysis.

The first part of the investigation, the study of BIM support documents, contributes to a better understanding of BIM documents through a review of their contents and purposes. In the context of this review, the authors classified BIM documents in 9 classes grouped in three levels: Software Manuals and BIM Books, at the global level; BIM Guide, BIM Use-Specific Guide, BIM Standard (General Standards and Modeling Guidelines), BIM Execution Plan Guide and Template, and Legal Attachment Template, at the national and organization level; and BIM Project Execution Plan and BIM Legal Attachment, at the project level. The study focused only at the national and organization level because the other levels either did not directly supported BIM processes or were not publicly available. The following points summarize the main observations and conclusions from the relation between BIM document types and contents.

- The fact that different documents within a document type present variation in their contents is an indication that there is no clear standard about what a particular BIM document should address. However, this does not mean that a standard is necessary as different organizations may want to emphasize different contents.

- Not all the organizations that created the analyzed documents have all the document types found in this review. This may happen because some organizations use documents produced by other organizations but also some organizations may not be BIM-mature enough to produce their own documents.
- BIM Guide and BIM Standards are the most common support documents with a 77% and 45% of all organizations having one of these documents respectively. Its purpose is to inform and require respectively.
- BIM Project Execution Plan is an essential document because almost all the other documents – and the respective organizations who produced them – suggest/require to create one. Several of the organizations have their own template for this document and the others cite existing templates, being the most cited one the Project Execution Planning Guide and Template from Pennsylvania State University.

In the second part of the investigation, the case of study analysis, was a complex task which requires not only good planning but also measurements to analyze at each stage the problems and the possible solutions.

In the case study, BIM objectives were determined: BIM Modeling, BIM Coordination & Design review, BIM 4D (Phase Planning) and BIM Project Control Progress. Also, a reviewing tool was developed. That was the basis for measuring and evaluating every BIM use. The following points summarize the main observations and conclusions from the case study:

- The review process was a very effective tool to recognize the most important problems of the BIM process in a project and to measure BIM use achievements. As a result, only 50% of the targets was achieved, which according to the main analysis does not reach the expected benefits and use.
- BIM 4D and BIM Project Control Progress were not correctly implemented avoiding potential benefits to the construction project, caused principal for a lack of

proper requirements and initial process planning, and communication between stakeholders.

- BIM design review could be used as a more powerful use in the construction stage, reaching to more benefits for the project. Followed by this, a series of semi-structured interviews showed that there is a low level of use and knowledge that affects mainly in BIM uses that have been poorly defined in the tender documents.
- In general, there is a difference in level of knowledge, use and expected benefits. However, almost all have an important level of interest in BIM use. Modelers and coordinator, which are the closest companies to BIM tools, have the fewer expectations of its benefits, as consequence to see their effort is not fully considered for the rest of the stakeholders and most of times had to be the ones that drive the correct use of the methodology.

The principals root problems identified were: Lack of proper requirement specification, lack of penalties for noncompliance, inefficient BIM processes, poor objectives alignment between the stakeholders and lack of proper BIM knowledge.

The results and the literature revised allowed to explore and propose several strategies to cope with these challenges. First include the use of BIM support documents: BIM project execution plan, public national BIM standards and the BIM guides are the mains ones to help in the difference of BIM knowledge, letting a same language to communicate between stakeholders and define a process from the very beginning to make an efficient BIM process aligned to the project process. These, to improve de communication and responsibilities assignments among the stakeholders and to align the BIM objective to the business process of all stakeholders. Second, change de BIM project requirement, focusing in evaluation deliverables success as a BIM process checklist. Finally there has to be a strategic vision supported by a public organization in charge of promoting the BIM use, by capacitation, publicity and defining a Roadmap of BIM implementation

5.1.Limitations

The main limitations of this study are:

- The sample scope of the support documents – defined by the language (English and Spanish) and time frame (up to 2014) – and the review parameters. The authors consider that, although there has been new documents since 2014 and there are documents in other languages, the sample scope is representative of the universe of BIM documents.
- Regarding the review parameters of the support documents, the study considered only the coverage (presence or absence) of the different content topics by the different document types. The depth with which each document covered the content topics was not evaluated due to the complexity of this assessment and the time that would require this assessment for this number of documents. The reduced review parameters may conceal other conclusions especially regarding how well the different content topics are covered and the potential relation with challenges on BIM implementations.
- The case study methodology allows a deep analysis of the study, but doesn't allow generalized to others cases. The interviews and the data gathered are representative to the case study. Also, only qualitative information was obtained and no validation of the recommendation was performed.
- The study considers the design and construction phases of the project, and this last one wasn't completed at the moment this thesis was finished.

5.2.Future Works

Based on the performed research, new questions are proposed in order to increase knowledge of BIM implementation in hospital projects:

- Future work should complement the study of BIM support documents, with other parameters such as the coverage depth and the experience and profile of the organizations that create the documents. Also, the study could be complemented with assessments from project stakeholders about the usefulness and challenges of the different BIM documents.
- The recommendations and suggestion of improvements in this research should be validated in a future project and, in this way, assess the success of BIM implementation. Also should be considered, as research methods, other instrument for statistical measurement.
- It should be define a full process definition of different BIM Uses considering all the actors, support documents and tools required to facilitate the implementation to a greater degree.
- Finally, the BIM process should define some key performance index to evaluate, during the project, and understand how the BIM process is functioning in order to improve its result.

REFERENCES

Contract Document G202:2013, Building Information Modeling Protocol Form, (2013a).
AIA. (2013b). Guide, Instruction and Commentary to the 2013 AIA Digital Practice Documents.

Azhar, S., Hein, M., & Sketo, B. (2008). *Building information modeling (BIM): Benefits, risks and challenges.* Paper presented at the Proceedings of the 44th ASC National Conference.

Ballard, G., & Howell, G. (1994). Implementing lean construction: stabilizing work flow. *Lean construction*.

BCA. (2013a). BIM Essential Guide *For BIM Adoption in an Organization*. Singapore: Building and Construction Authority.

BIM Particular Conditions Version 1, (2013b).

BCA. (2013c). Singapore BIM Guide. Singapore: Building and Construction Authority.

BCA. (2013d). Training of Architectural BIM e-Submission Templare (for Revit Users Only). Singapore: Building and Construction Authority.

Bew, M., & Richards, M. (2013). PAS 1192 - Specification for information management for the capital/delivery phase of construction projects usign building information modeling. *British Standard Institution*.

Brucker, B. A., Case, M. P., East, E. W., Huston, B. K., Nachtigall, S. D., Shockley, J. C., . . . Wilson, J. T. (2006). *Building Information Modeling (BIM): a road map for implementation to support MILCON transformation and civil works projects within the US Army Corps of Engineers*. Retrieved from

CCOP. (2015). Proyectos en Construcción. Retrieved from http://www.concesiones.cl/proyectos/Paginas/construccion.aspx

Chan, P.-l. A. (2004). *Critical success factors for delivering healthcare projects in Hong Kong.* The Hong Kong Polytechnic University.

Chen, C., Dib, H., & Lasker, G. (2011). Benefits of implementing building information modeling for healthcare facility commissioning. *Computing in Civil Engineering (2011)*, 578-585.

Chen, I. J., & Popovich, K. (2003). Understanding customer relationship management (CRM) People, process and technology. *Business process management journal, 9*(5), 672-688.

Chidambaram, Palanisamy, L., Leong, N. K., Wee, T. K., Leong, T. K., Kwang, T. W., & Jun, Z. H. (2011). All Set for 2015: The BIM Roadmap. *BuildSMART, Singapore*.

Commission, E., & Programme, S. F. (2010). InPro Building Information Model *Open Information Environment for collaborative Process throughout the lifecycle of a building*. Europe.

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2008). *BIM Handbook* (J. W. Sons Ed.). Hoboken, New Jersey.

EMB, C. (2013). Los avances del BIM en Chile. *One Touch EMB Construcción, Septiembre 2013*, 32-33.

Forbes, L. H., & Ahmed, S. M. (2010). *Modern construction: lean project delivery and integrated practices*: CRC Press.

Fraser, S. (2013). The adoption of BIM within the Public Works Contracts (PWC) suite of construction contracts in Ireland. *Proceedings of the CITA BIM Gathering*, 159-162.

Garcia, A. C. B., Kunz, J., Ekstrom, M., & Kiviniemi, A. (2004). Building a project ontology with extreme collaboration and virtual design and construction. *Advanced engineering informatics, 18*(2), 71-83.

Ghio Ca, V. A., & Bascuñan Walker, R. (2012). INNOVACIÓN TECNOLÓGICA EN LA CONSTRUCCIÓN AHORA ES CUANDO. *Revista Ingeniería de Construcción*(14), 9-18.

Grilo, A., Zutshi, A., Jardim-Goncalves, R., & Steiger-Garcao, A. (2012). Construction collaborative networks: the case study of a building information modelling-based office building project. *International Journal of Computer Integrated Manufacturing, 26*(1-2), 152-165. doi:10.1080/0951192x.2012.681918

GSA. (2007). GSA Building Information Modelling Guide Series *Overview*. Washington DC, United States of America.

Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction, 19*(8), 988-999.

Hartmann, T., Van Meerveld, H., Vossebeld, N., & Adriaanse, A. (2012). Aligning building information model tools and construction management methods. *Automation in Construction, 22*, 605-613.

Haynes, D. (2009). A tale of two exhibits - A comparison of hte CD301 and E202 BIM exhibits. *Construction Watch, No. 3-09*.

Henjewele, C., Sun, M., & Fewings, P. (2014). Comparative performance of healthcare and transport PFI projects: Empirical study on the influence of key factors. *International Journal of Project Management, 32*(1), 77-87.

Howard, R., & Bjork, B.-C. (2008). Building information modelling - Expert's views on standardisation and industry deployment. *Advance Engineering Informatics, 22*, 271-280.

Institution, B. S. (2013). Specification for Information Management for the Capital/Delivery Phase of Construction Projects Using Building Information Modelling *BS PAS 1192-2:2013*. UK: BSI Standards Limited.

ISO. (2010). ISO 29478-1:2010 Building information modeling -Information delivery manual - Part 1: Methodology and format. *1*, 34.

Jared, B. (2013). There are Four BIM Flavors. Retrieved from http://www.shoegnome.com/2013/01/31/there-are-four-bim-flavors/

Jaruhar, S. (2013). Mandating BIM At Northwestern Memorial Hospital. Retrieved from http://www.healthcaredesignmagazine.com/article/mandating-bim-northwestern-memorial-hospital

Jernigan, F. (2007). BIG BIM little bim. *The practical approach to Building*.

Khanzode, A., Fischer, M., & Reed, D. (2008). Benefits and lesson learned of implementing Building Virtual Design and Construction (VDC) technologies for coordination of mechanical, electrical, and plumbing (MEP) systemas on a large healthcare project. *ITcon, 13*.

Khosrowshahi, F., & Arayici, Y. (2012). Roadmap for implementation of BIM in the UK construction industry. *Engineering, Construction and Architectural Management, 19*(6), 610-635.

Krieger, J. (2013). 'My BIM journey' - 6 lessons from a BIM/VDC expert. *Building Design & Construction*.

Linderoth, H. C. J. (2010). Undestanding adoption and use of BIM as the creation of actor networks. *Automation in Construction, 19*, 66-72.

Loyola Vergara, M. (2013). Encuesta Nacional BIM 2013: Informe de Resultados.

Lu, N., & Korman, T. (2010). Implementation of building information modeling (BIM) in modular construction: Benefits and challenges. *Construction Institute of ASCE Reston, VA*.

Lu, W., Peng, Y., Shen, Q., & Li, H. (2013). Generic Model for Measuring Benefits of BIM as a Learning Tool in Construction Tasks. *Journal of Construction Engineering and Management, 139*(2), 195-203. doi:doi:10.1061/(ASCE)CO.1943-7862.0000585

Manning, R., & Messner, J. (2008). Case studies in BIM implementation for programming of healthcare facilities: ITcon.

Mayo, G., Giel, B., & Issa, R. (2012). *BIM use and requirements among building owners.* Paper presented at the Proceedings of the International Conference on Computing in Civil Engineering, Clearwater Beach, FL, USA.

Miettinen, R., & Paavola, S. (2014). Beyond the BIM utopia: Approaches to the development and implementation of building information modeling. *Automation in Construction, 43*, 84-91.

Nepal, M. P., Jupp, J. R., & Aibinu, A. A. (2014). Evaluations of BIM: frameworks and perspectives. *Computing in Civil and Building Engineering (2014)*, 769-776.

NIBS. (2007). National BIM Standard *Version 1 - Part 1: Overview, Principles, and Methodolgies*. United States of America.

Olofsson, T., Lee, G., & Eastman, C. (2008). Editorial-Case studies of BIM in use. *IT in construction-Special Issue Case studies of BIM use, 13*, 244-245.

Phelps, A. F. (2008). *LEAN INFORMATION FLOW IN COMPLEX HEALTHCARE PROJECTS AND THE ROLE OF THE "INTEGRATOR" AS INFORMATION FLOW MANAGER.* Architectural Engineering.

Riquelme, F. (2016). *Towards Social Big BIM in Hospital Projects.* (Master of Science), Pontificia Universidad Católica de Chile, Chile.

Saldías Silva, R. O. L. (2010). Estimación de los beneficios de realizar una coordinación digital de proyectos con tecnologías BIM.

Sattineni, A., & Mead, K. (2013). Coordination Guidelines for Virtual Design and Construction. *International Association for Automation and Robotics in Construction*, 1491-1499.

Serpell, A. (2012a). Innovación tecnológica en la construcción. *Revista Ingeniería de Construcción*(3), 1-15.

Serpell, A. (2012b). Innovación y desarrollo tecnológico: una estrategia de competitividad. *Revista Ingeniería de Construcción*(16), 53-62.

Staub-French, S., Forgues, D., Iordanova, I., Kassaian, A., Abdulaal, B., Samilski, M., . . . Nepal, M. (2011). *An investigation of "Best practices" through case studies at regional, national, and international levels*. "Best Practices" Project Report. Alberta BIM Centre of Excellence (ACE), Productivity Alberta, Western Economic Diversification. Canada.

Staub-French, S., Fourgues, D., Iordanova, I., Kassaian, A., Abdulaal, B., Samilski, M., . . . Nepal, M. (2011). *An investigation of "Best practices" through case studies at regional, national, and international levels*. "Best Practices" Project Report. Alberta BIM Centre of Excellence (ACE)

Productivity Alberta
Western Economic Diversification. Canada.
Suwal, S., Javaja, P., & Porkka, J. (2013). *Social BIM perspectives.* Paper presented at the Proc., 30th CIB W78 International Conference.

The Pennsylvania State University. (2010). BIM Project Execution Planning Guide – Version 2.0. *Computer Integrated Construction Research Program, University Park, PA, USA.*

Webster, J., & Watson, R. T. (2002). Analyzing the past to prepare for the future: Writing a literature review. *Management Information Systems Quarterly, 26*(2), 3.

Wilson, P. F., Dell, L. D., & Anderson, G. F. (1996). Root Cause Analysis: A Tool for Total Quality Management. *Journal for Healthcare Quality, 18*(1), 40.

Wong, A., Wong, F., & Nadeem, A. (2009). Comparative roles of the major stakeholders for the implementation of BIM in various countries. Hong Kong.

Yee, P., Matta, C., Kam, C., Hagan, S., & Valdimarsson, O. (2010). The GSA BIM story. *Journal of Building Information Modeling*, 20-21.

A P P E N D I C E S

Appendix A - List of BIM documents and their URL addresses

1	Project BIM Brief	http://bim.natspec.org/index.php/natspec-bim-documents/national-bim-guide
2	NATSPEC National BIM Guide	https://vdcscorecard.stanford.edu/sites/default/files/NATSPEC_National_BIM_Guide_v1.0.pdf
3	NATSPEC BIM Reference Schedule	http://bim.natspec.org/index.php/natspec-bim-documents/national-bim-guide
4	NATSPEC BIM Object/Element Matrix	http://bim.natspec.org/index.php/natspec-bim-documents/national-bim-guide
5	BIM Management Plan Template	http://bim.natspec.org/index.php/natspec-bim-documents/national-bim-guide
6	NATSPEC BIM Scheduling guidelines	http://bim.natspec.org/images/NATSPEC_Documents/BIM_Scheduling_project_report_Dec_2010.pdf
7	Caderno BIM VERSAO	http://www.coordenar.com.br/caderno-bim-santa-catarina/
8	AEC (CAN) BIM Protocol v1	http://s3.amazonaws.com/canbim-production/vol/www/apps/canbim_production/releases/20121021065404/en/public/documents/documents/original_63.pdf?1352735902
9	BIM Project Specification	http://www.hkibim.org/?page_id=1386
10	BIPS 3D Working Method	http://changeagents.blogs.com/Linked_Documents/BIPS%203D%20Working%20Method.pdf
11	InPro Building Information Model	http://www.inpro-project.eu/
12	Common BIM requirements 2012	http://www.en.buildingsmart.kotisivukone.com/3
13	BIM Guide for Germany	http://www.aec3.com/de/downloads/BIM-Guide-Germany.pdf
14	Rgb BIM Standard	http://www.rijksvastgoedbedrijf.nl/expertise-en-diensten/b/building-information-modelling
15	New Zealand BIM Handbook	http://www.building.govt.nz/UserFiles/File/Publications/Building/Technical-reports/nz-bim-handbook.pdf
16	New Zealand BIM Schedule	http://www.building.govt.nz/bim-in-nz/sites/default/files/NZ-BIM-Schedule.pdf
17	Statsbygg BIM Manual 1.2.1	http://www.statsbygg.no/Files/publikasjoner/manualer/StatsbyggBIM-manual-Ver1-2-1-2013-12-17.pdf
18	Singapore BIM Guide v2	https://www.corenet.gov.sg/media/586132/Singapore-BIM-Guide_V2.pdf
19	BIM Particular Condition	http://www.aces.org.sg/pdf/058-2012_DRAFT_BIM%20Conditions.pdf
20	Design Object Library Guide	https://bimsg.files.wordpress.com/2012/08/dol-guide-draft-v0-6.pdf
21	BIM essential Guide (Architects, Contractors, Consultants, MEP)	https://www.corenet.gov.sg/integrated_submission/bim/BIM/Essential%20Guide%20Archi.pdf
22	BIM essential Guide for BIM Execution Plan	https://www.corenet.gov.sg/media/586149/Essential-Guide-BEP.pdf
23	BIM essential Guide for BIM Adoption in an Organization	https://www.corenet.gov.sg/media/586143/Essential-Guide-Adoption.pdf
2	BIM e-submission guideline	https://www.corenet.gov.sg/integrated_submission/bim/bime_submission.ht

4		m
25	BIM template Training (Revit, Archicad)	https://www.corenet.gov.sg/integrated_submission/bim/bime_submission.htm
26	PAS 1193:2013	http://shop.bsigroup.com/forms/PASs/PAS-1192-2/
27	AEC (UK) BIM Protocol v2	https://aecuk.files.wordpress.com/2012/09/aecukbimprotocol-v2-0.pdf
28	The Contractor's guide to BIM V2	http://www.tpm.com/wp-content/uploads/2013/02/AGC_Guide_to_BIM.pdf
29	MEP Spatial Coordination Requirements for Building Information Modeling	http://bimforum.org/wp-content/uploads/2011/02/MEP-Spatial-Coordination-Requirements-for-Building-Information-Modeling.pdf
30	Modeling Guide Series - Overview v0.6	http://www.gsa.gov/portal/content/105075
31	Modeling Guide Series - Spatial program validation v0.96	http://www.gsa.gov/portal/content/105075
32	Modeling Guide Series - 3D Imaging v1	http://www.gsa.gov/portal/content/105075
33	Modeling Guide Series - 4D Phasing v1	http://www.gsa.gov/portal/content/105075
34	Modeling Guide Series-Energy Performance v2	http://www.gsa.gov/portal/content/105075
35	BIM Guidelines	http://www.nyc.gov/html/ddc/downloads/pdf/DDC_BIM_Guidelines.pdf
36	BIM Guidelines & Standards for Architects, Engineers and contractors	http://www.indiana.edu/~uao/docs/standards/IU%20BIM%20Guidelines%20and%20Standards.pdf
37	IU BIM Execution Plan Template	http://www.indiana.edu/~uao/docs/standards/IU%20BIM%20Execution%20Plan%20Template.doc
38	National Building Information Modeling Standard v2	https://www.nationalbimstandard.org/
39	State of Ohio building information modeling protocol	http://das.ohio.gov/Portals/0/DASDivisions/GeneralServices/SAO/pdf/SAO-BIMProtocol.pdf
40	LACCD BIM Standards v3	http://projects.buildingsmartalliance.org/files/?artifact_id=3350
41	Architectural/Engineering Guidelines	http://www.tfc.state.tx.us/divisions/facilities/prog/construct/formsindex/01%20-%202012%20A-E%20GUIDELINES.pdf
42	Appendix M: BIM Planning and Coordination Document	http://www.tfc.state.tx.us/divisions/facilities/prog/construct/formsindex/09%20-%202012%20A-E%20Guidelines%20(Appendix%20M)%20BIM%20Planning%20Doc.xls
43	ConsensusDOCS 301 BIM Addendum	http://isites.harvard.edu/fs/docs/icb.topic747693.files/Consensus%20BIM%20Addendum.pdf
44	AIA E202-2008	http://www4.fm.virginia.edu/fpc/ContractAdmin/ProfSvcs/BIMAIASample.pdf
45	AIA E203-2013	http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab099084.pdf
46	AIA G201-2013	http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab099085.pdf
4	AIA G202-2013	http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab099086.pdf

7		
48	BIM Primer Report 1	http://acwc.sdp.sirsi.net/client/search/asset/1008481
49	Attachment F : BIM Requirements	http://mrsi.usace.army.mil/rfp/Shared%20Documents/attachmentF.pdf
50	Supplement 1. BIM Implementation Guide for Military Construction	http://acwc.sdp.sirsi.net/client/search/asset/1019860
51	The USACE Roadmap for Life-Cycle BIM	http://codebim.com/wp-content/uploads/2013/06/ERDC-SR-12-2.pdf
52	USACE BIM PXP	http://mrsi.usace.army.mil/rfp/Shared%20Documents/USACE_BIM_PXP_TEMPLATE_V1.0.pdf
53	MHS FLCM BIM minimum Requirements	http://www.tricare.mil/ocfo/_docs/BIM-UFC-RequirementDetails.pdf
54	BIM Implementation: An owner's Guide to Getting Started	http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab085571.pdf
55	A/E Submission Requirements for VA Medical Center	http://www.cfm.va.gov/til/ae/aesubmin.doc
56	The VA BIM Guide	http://www.cfm.va.gov/til/bim/BIMguide/downloads/VA-BIM-Guide.pdf
57	BIM Planning guide for Facility Owners	http://bim.psu.edu/Owner/Resources/contact_info.aspx
58	The Uses of BIM	http://bim.psu.edu/uses/the_uses_of_bim.pdf
59	Project Execution Planning Guide	http://bim.psu.edu/Project/resources/contactinfo.aspx
60	BIM Project Execution Plan Template	http://bim.psu.edu/Project/resources/contactinfo.aspx
61	BIM guidelines and Standards for architects and engineers	ftp://doaftp1380.wi.gov/master_spec/BIM%20Guidelines%20&%20Standards/BIM_Guidelines_and_Standards%206-09.pdf

Appendix B – Reviewing Checklists

Table B–1 Checklist of Contents of Model

Checklist of Contents of Models			
Revewer	Fabián Riquelme		
Date	6/01/2015		
Definitive Project	*Evaluation could be: Aproved, Rejected or Pending.*		
Category	**Criteria**	**Eval.(A/R/P)**	**Comments**
Administrative: **F**ormal elements	The model was delivered in rvt and nws formats	A	delivered in 30-10-2014
	Name of desing is clear in the file	A	Delivered, also an specification document with the clarification of the nomenclature used was delivered.
Contents: all the elements identified in the matrix of information exchange modeling is found. It is recommended to check from lower to higher levels, in ascending order. From north to south in each level.	All the content define in worksheet is in the BIM model	A	This item was accepted because a lack of definition
	The model correspond at was require in the Matrix of information exchange.	A	It was not define in the beginning, but all whats is modeled is ok with what was talk.
	Families are adecuated to the model	A	Families was correctly used
	Nomenclature of families are clear and consistent.	P	Families doesn't have the correct naming
Accuracy: The models represent exactly what the worksheet raise	Levels check (Instances and elevation)	A	Levels are Ok and correctly used in all models.
	Grill Check	A	Model organize
	Elements positions	P	
	Origin Check	A	The origen is defined
Updated Models: The model must be updated to the latest version of the worksheet	The model is uptade to the last version of official worksheets os designs	A	Represent worksheets of 30-10-2014

Level of Detail: Compared with model elements to the array of information exchange	The elements have the correct detail previusly declare	A	No exchange information matrix was developed but is acceptable.
Delivery is approved?	SI		NO
Comments	To ensure that the model is a greater contribution, the same information and names are essential. Additionally additional criteria: Legend specialty items, surface, line (color and type)		

Table B-2 Checklist of Coordination Deliberables

Checklist of Coordination Deliberable			
Revewer	Fabián Riquelme	Stage of coordination level -1	
Date	6/01/2015		
Definitive Project	*Evaluation could be: Aproved, Rejected or Pending.*		
Category	**Criteria**	**Eval.(A/R/P)**	**Comments**
Administrative: **F**ormal elements	The model was delivered in rvt not coordinated (Stage A)	A	delivered in 30-10-2014
	Dwg files not coordinated were delivered (Stage A)	A	delivered in 30-10-2014
	BIM model with interference analysisi and report (Stage A)	A	List of RFI
	Coordinated BIM model was delivered (Stage B)	R	Problems between architeture and Structure, Floors, water sistems.
	Dwg with detail of passing because of interferences (Stage B)	A	Drilling dwg, ANTOF-EJES.dwg and CONTORNOS.dwg
	Coordinated DWG (Stage B) (individual and gruop) (Stage B)	R	Not delivered
	BIM Model with all conflicts resolved (Stage B)	R	Not all conflicts were resolved

Contents: all the elements identified in the matrix of information exchange modeling is found. It is recommended to check from lower to higher levels, in ascending order. From north to south in each level.	Nwd file with conflicts analysis and Classified (Reals/No Reals) (Stage A)	R	Only Real conflicts, no nwd file was delivered
	Nwd with comments of conflicts	R	Nwd was not use
	Nwd with views of the conflicts	A	Se utilizaron bien las familias
	Conflicts found in stage A are resolve in stage B (nwd)		There are no images
	BIM Models (rvt) are coordinated in this stage (B)	P	Not all the conflicts were resolved
	Coordination 2D files are extracted from de BIM Model	P	There are some, but is not complete
	2D files are extracted from BIM model	P	Not new file were delivered
Accuracy: The models represent exactly what the worksheet raise	There are conflicts not reviewed because there are not "Reals"(Stage B)	A	They are not reviewd
	A tolerance level was define (Stage B)	-	No naviswork is used
	The coordinated model, not change a prevously correction	A	Not change
Delivery is approved?	SI		NO
Comments	The model is not coordinated wich is the main objective, it should be corrected		

Appendix C – BIM Antofagasta Project Process

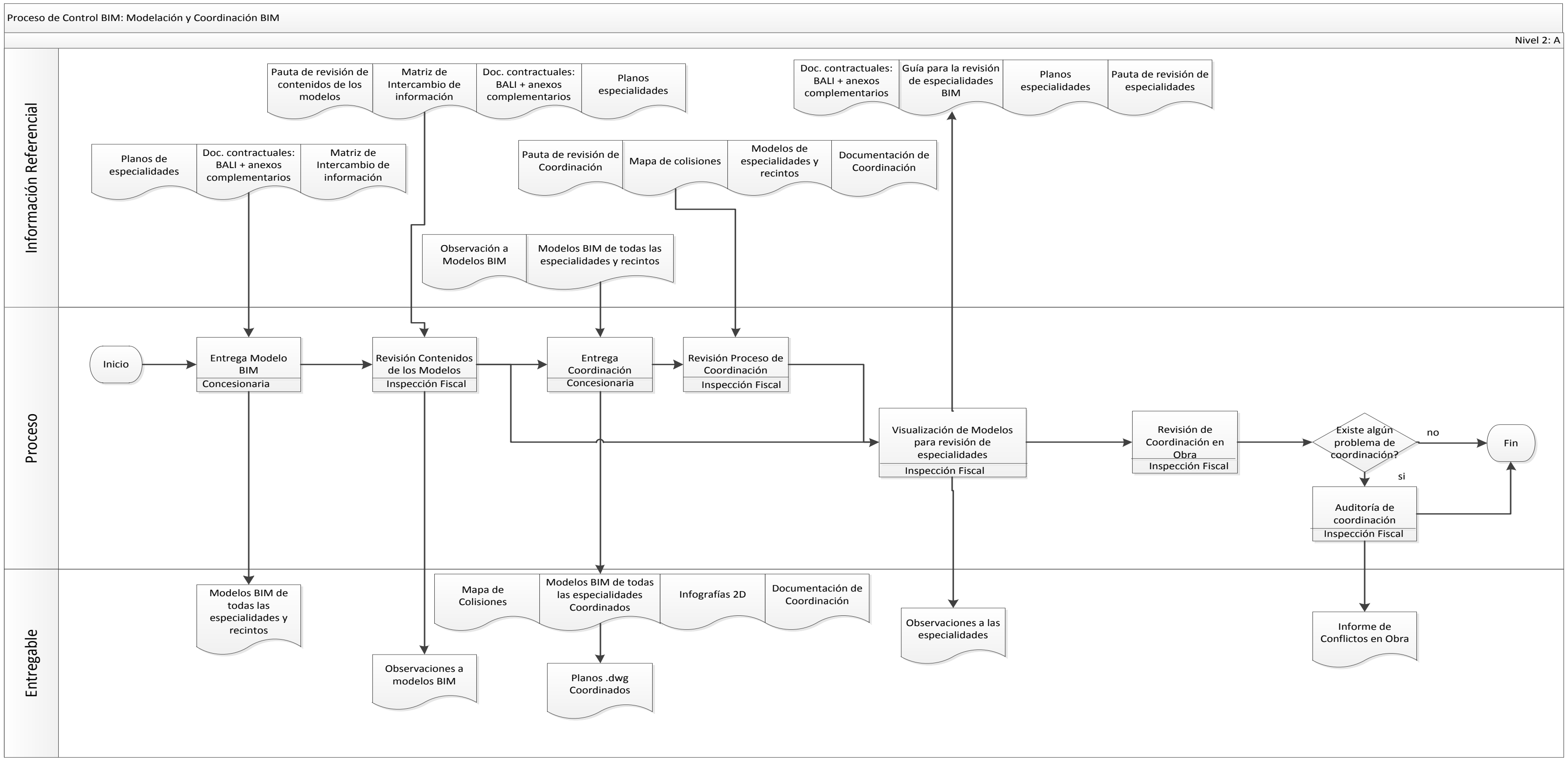

Figure C-1 Review Process: Modeling and Coordination