Concepts for the Use of Digital Information in a Construction Project Life Cycle

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Abstract

BIM technologies and information technologies have transformed the construction industry. They have enabled the creation of digital environments digital environments that sustain exchanges of information and enhance the digitalization of the processes involved. These changes force the clear definition of processes and digital models to support and manage that information. On the other hand, so that the information acquires real value, the application must be in fields that can capitalize on it, like asset management and facility management is necessary.

This dissertation proposes concepts that enable the standardisation of these exchanges of digital information through the project life-cycle, having in mind these two management areas: asset management and facility management. Therefore, based on international standards, existing Portuguese legal documents and interviews made with professionals from these two areas, concepts are defined and proposed that make the project life-cycle an integrated cycle based on digital information which is enhanced by information technologies.

Key words: Construction projects, Life cycle, Digital information, BIM, Operation, Asset Management

1 Introduction

Recently, the Portuguese construction industry has faced a plethora of problems: weak productivity, insufficient innovation, lack of consistent procedures, disconnected suppliers and fragmentation (WEF, 2016). These problems are mainly due to the absence of standardised procedures, refusing to modernise and adopt new technologies. This work intends to stimulate the adoption of technologies combined with their corresponding standardisations in order to ensure the compatibility between specialties and organisations. In Portugal, one of the new technologies that is gradually being used is the Building Information Model technology, BIM. This technology uses the information in digital form, associating it with a geometrical model making it richer, describing assets in a more detailed way. Creating and managing these models produce information that has value to organisations if used by the correct individuals. A project involves the construction of assets which will be managed by professionals specialised in their management. There are two specialities focused in this type of management: asset managers and facility managers. These specialties manage the information created in the project phase and add more information as the management of the asset occurs. The use of digital information must be tailored with these management disciplines in mind, since they will be the ones extracting value from the information.

Other countries have standardised the use of digital information in projects based on BIM technologies. They have defined concepts and methodologies for their use so that it can be efficient and systematic. While creating new concepts for the use of BIM technologies, these existing documents must be kept

in mind since they are already proven concepts. However, simply applying international documents without the reality of the country where they will be applied in mind is not adequate, their concepts and processes must be applied in accordance to the way they are used to work. The industry culture must be studied and portrayed. One way of achieving this is through interviews: inquiring professionals about their needs and which tools they use in their day to day responsibilities. The conclusions from those inquiries will characterise the way asset managers work in Portugal. Though valuable, the conclusions from this interviews aren't enough, the related countries legal documents should also be contemplated to guarantee proximity and accordance with portuguese legal requirements. Using existing documents, amalgamating them with the Portuguese related national documents and with the professional reality of asset and facility manage in mind, concepts can be created that stimulate the good use of information in the operation of an asset. The sequence of the work done can be seen on figure 1.

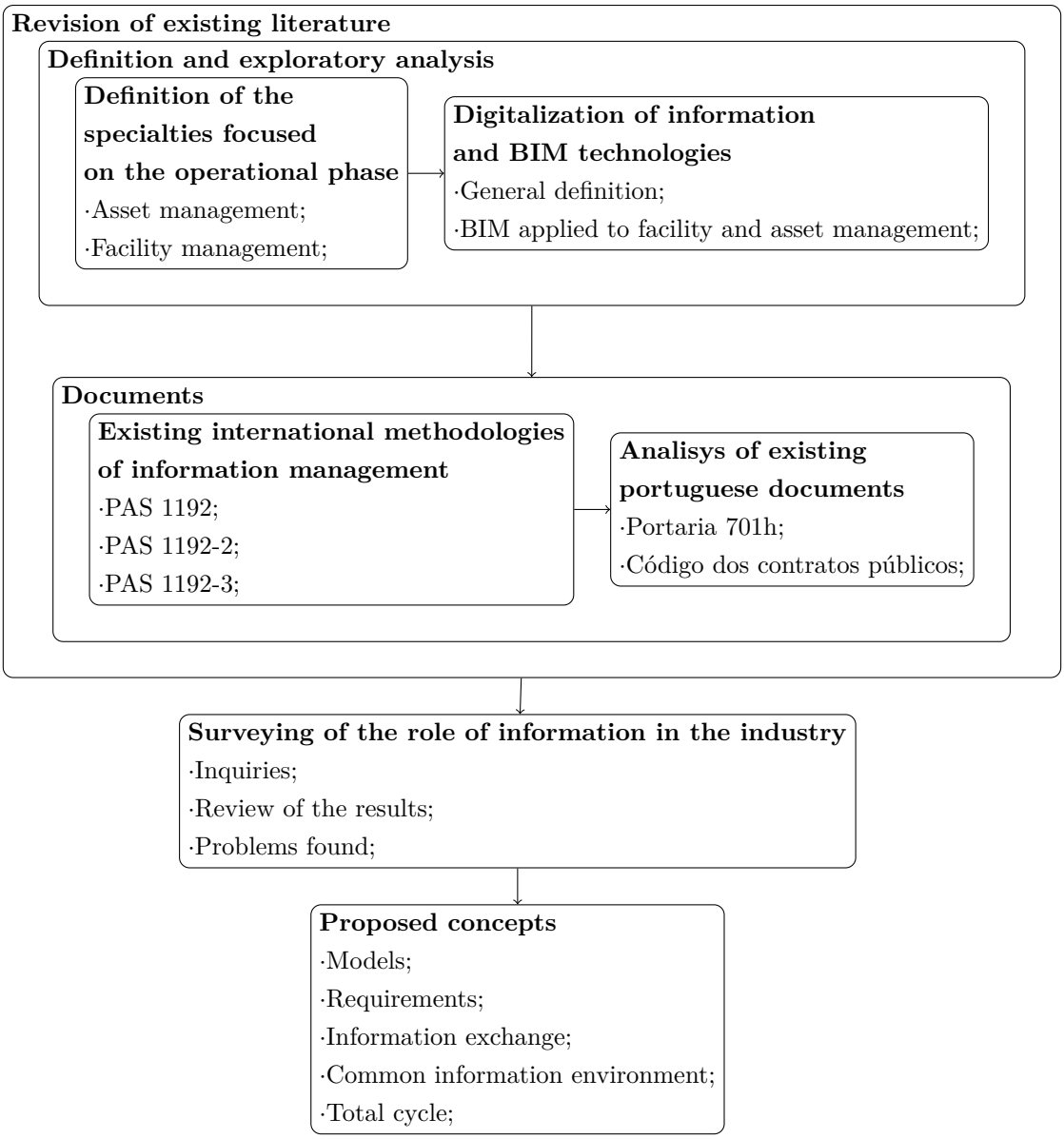

Figure 1: Adopted method in the realisation of this work

2 Asset and Facility Management

There are two disciplines concerned with the management of assets during their operational phase: asset management and facility management. Asset management has the objective of realising value from assets while facility management, as the name implies, manages the facilities of an asset. Both occur during the operational phase. There are standards in place that describe these activities, asset management is described by the ISO 55000:2014 and facility management by the EN 15221:2011.

ISO 55000:2014 defines asset management as "coordinated activity of an organisation to realise value from assets". An asset is "an item, thing or entity that has potential or actual value to an organisation", also defined by ISO 55000:2014. There is a great variety of assets bu only physical ones will be focused on. The management of physical assets is the meeting point between the technical and the management fields (Lloyd, 2010). The ISO states that for the good management of assets a management system is needed. The asset management system is used by the organisation "to direct, coordinate and control asset management activities" (*ISO 55000 - Asset management - Overview, principles and terminology* 2014). An important concept that will be used later.

Facility management is defined by (*EN 15221:2011 - Facility Management* 2011) as "the integration of processes inside an organisation to maintain and develop the agreed services that support and improve the efficiency of the primary activities, (...)". Hormigo (2015), a portuguese author specialised in this area defines it as "Professional activity which coordinates assets and services using multidisciplinary skills of engineering, management and others, so that the demands are satisfied, optimising costs and performance of those activities and services." A similar definition to the one made in the standard, but enunciating the importance of optimising cost and performance. Roper and Payant (2014), add another important feature to the previous stated definition: "professional field that includes various disciplines that must guarantee the functionality of the built environment integrating people, places, processes and technology". Technology is an important part of this discipline having two new intrinsic technologies to its functionality are being used more commonly: BIM and Internet of Things, IoT.

The operational phase will consist in the management of the information created in project. It's in this phase that the asset managers will create value from the assets and that the facility managers will support the main activity of the asset. Thought not required, the digital information will mainly be used through the usage of BIM technologies, so these technologies have a central part in this work.

3 Digital Information and BIM technologies

The cheaper processing power and storage capacities have brought a digital age to all engineering fields. Pushed by this new way of producing information in digital form a new technology has appeared in the construction industry, Building Information Models. This new technology has enormous capabilities. It associates digital information with a design model, creating a richer description of the physical asset it intends to describe. His capabilities have the power to change the way management of information works through the project life-cycle (Eastman et al., 2011). Associated with it, there are many libraries and tools that can support designers and constructors in the most various ways (Eastman et al., 2011).

The uses of BIM in construction and design phase have been thoroughly studied, but its application in the operational phases is not as notorious. Though not being well known, their use in operation is

advantageous, they are an excellent tool for the maintenance and operation of an asset (Simões, 2013), with some published works detailing its application in this phase. Some of them include the application of RFID tags for identification of equipment (Motamendi et al., 2013), applying the information gathered from the instrumentation of an asset to 3D models (Ferreira, 2011) and using QR codes to associate the maintenance manuals to the respective equipment through the use of tablets and phones (Fontes, 2014). These are interesting applications suitable for practical use, but the processes of application must also be defined, so that the information used and created by tools like these follows a standardised process and is allocated to the correct places.

The reality in Portugal is different. The construction industry is old-fashioned, it is rigid when it comes to adopting new technologies. Due to this, adopting BIM has been slow but there are other factors that have contributed to its slow adoption: there's a lack of standard concepts and processes. There are some international standards that defined them, but they are not made with the portuguese industry in mind. The international standardised concepts must be integrated with the portuguese project life cycle in mind, with the integration of both as the final objective.

4 Public Available Specifications and Portuguese documents

The British Standards Institution, BSI, have issued a series of Public Available Specifications, PAS, intended to standardise the use of BIM technologies in the UK. The documents analysed were *PAS 1192:2007 - Collaborative production of architectural, engineering and construction information - Code of practice*, *PAS 1192-2:2013 - Specification for information management for the capital/delivery phase of construction projects using building information modelling* and *PAS 1192-3:2014 - Specification for information management for the operational phase of assets using building information modelling.* The first defines the important concept of a Common Data Environment, CDE, which exists to enable simultaneous collaborative work, the second defines the phases and information used in a project life cycle using BIM and the third one is about the use of BIM in the operation phase. The concepts in these documents served as base for the concepts defined in this work. Though valuable and realistically usable, the concepts need to be integrated with related portuguese documents. The documents chosen for the integration were Portaria 701h and Código dos Contratos Públicos.

The *Portaria 701h/2008* was published in the *Diário da República* to define the fees for public works projects, the phases in which the project should be developed and the information that must appear in the documents drawn up (*Portaria n.o 701-H/2008*). This document defines the following phases of project:

***Programa Preliminar*:** document provided by the owner to the designer for definition of the objectives, characteristics and constraints. It also defines the costs and deadlines to keep in mind;

***Programa Base*:** document prepared by the designer,particularising the preliminary program that checks the feasibility of the project. Serves as the basis for the later stages of project;

***Estudo Prévio*:** document prepared by the designer, after approval of the *programa base*, which uses the option that best fits the program;

***Anteprojecto* or *Projecto Base*:** develops the solution of the previous study approved, contains pieces written and drawn;

***Projecto de execução*:** develops the base project approved, consisting of a coordinated set of written and drawn information;

***Assistência técnica*:** guaranteed by the designer, which consists in the clarification of doubts about the project, provision of information and project monitoring.

This document also defines the concept of *telas finais* which are the set of final drawings of the project, integrating the corrections and amendments made in the course of work and translate what was actually built.

The *Código dos Contratos Públicos* aims to guide the public acquisitions and was published in *Decrete-Lei 18/2008 de 29 Janeiro 2008* (*Código dos Contratos Públicos*). Public procurement is a cross-disciplinary field involving the exchange ratio between values. It must comply with the conditions of rationality in the management of the organisation that buys and the rationality of social and economic inherent in the society for which it is pursuing the public interest (Tavares, 2003). Initially, it is necessary to define the main characteristics of the object of hiring, so that it is possible to specify the specifications, standards and specifications applicable. To be able to perform this setting, an *ex-ante* evaluation should be carried out , which justifies the existence, characteristics and scale of the object of the contract. This assessment legitimises the main options (location, integration, typology, etc.), enables the realisation of (finance, environmental impacts, etc.) and choose the optimal levels of compromise between the ambition of the results and the allocation of necessary resources (Tavares, 2003). The following stages are (Dias et al., 2016):

Concurso/convite: choice of contractors for execution;

Apresentação das propostas: competitors present their proposals;

Análise das propostas: the entity examines the proposals;

Adjudicação: formalising the process of signature of the contract;

Consignação: provision of sites and complementary elements for the implementation of labour;

Preparação: preparation of various documents to the planning of actions to take place;

Execução: physical achievement of the work;

Receção: survey of the work performed in order to proceed to the temporary reception or non-reception.

There is also an evaluation phase, called *ex-post* evaluation. The results should be checked against expectations and they should include the results of internal and external audits performed (Tavares, 2003).

The vision of BSI is that of a integrated information life cycle and the alignment with this vision can bring considerable advantages in the post-conception phases. Its integration with portuguese documents makes it closer to a practical tool for the portuguese industry. The information will only be used correctly if it is used by the appropriate entities: the asset and facility management disciplines. These are the disciplines that make decisions, plan and operate the enterprise. The concepts of this work will be better if they are made with the current needs and problems of these disciplines in mind. To achieve that objective some interviews were made, inquiring the professionals of these areas.

5 Survey of the role of information in the perspective of asset management and facility management

It is expected to exist some differences in how each manager shall carry out their duties. The portrait of how these disciplines use the information cannot simply be based on normative documents, because it may not portray faithfully these disciplines of management. To achieve this definition, a semi-structured survey was made. Managers of various companies were interviewed to understand what problems they face when managing the information of an asset in the operational phase. The diversity of companies was considerable, all of them are big companies operating in Portugal: a health providing company, two energy companies, one telecommunications company, a infrastructures company and a industrial company.

Firstly, the scope was defined, aiming to define the functions performed by the interviewee, the existence of process maps, the relationship between departments and their influence on new works. Secondly the information architecture was defined. The questions defined were about the existence of maps of exchanges of information, the existence of encodings, the frequency of updating of information and the need for information from other departments or enterprises outside the responsibility of the respondent. The third part attempts to characterise the technological architecture used, if there are networks in the company, as they share the files and if you already use storage and sharing of files by cloud. The last part asks the opinion about future needs or problems, what challenges are you looking for overcoming, if BIM could bring benefits, if a model and global cycle would be easily applied, what difficulties this all would bring and that improvements could be made in the perspective of the respondent. The conclusions obtained from all the interviews can were the following:

- **Difference between functions and responsibilities**: There was a difference between functions and responsibilities, according to the specialisation of the manager. Some specialised in maintenance, others in space allocation, some in technology management, there wasn't a common distribution of functions and responsibilities;
- **Value of the operational phase**: The managers interviewed had their knowledge recognised and were valued in the realisation of new projects, that is, in projection and construction, the managers of the operational phase contribute in decision-making. Together, the companies interviewed have defined the cost reductions in operational phase as the stage that is financially more important;
- **Exchange of information**: The exchanges of information are carried out mostly by email. Some of the companies already using cloud systems for sharing and storing files, however, those who do not use, still make their exchanges of information by email;
- **Updating information**: The update of the information is often in all companies interviewed. When this information is related to assets with defined structure for this. In some companies, with assets, the update was not very often due to a lack of original information;
- **Encondings and nomenclatures**: Some of the respondents used their own classifications for all documents while others only for the most important ones. It is concluded that there is a concern in the encoding of the files but only on greater relevance. The encoding when there was in accordance with its own rules of the company, but it is believed that this encoding is based on normative documents adapted to the needs of each entity;

- **Software**: Most of the software used have proprietary licenses and are related to the management of operation. All companies have licenses of the software more common of computer aided design, (none possessed the version with capacity BIM) as well as the usual editing software for text and data sheets;
- **Information and models**: Those responsible for maintaining take advantages of a "as built" model, since the model would support the processes needed for the maintenance, facilitating the planning of work required. Currently, these models are not very common, or do not exist or have outdated information that do not effectively describe what is built;
- **Definition of required information**: Some of the companies already have well defined processes and the information required for the maintenance and creation of assets;
- **Energy consumption and environmental issues**: Environmental issues are of great importance for all companies and its an area related to energy consumption. The decrease of consumption contributes to a better environmental image of the company, which is something companies value.

From these conclusions some general aspects can be defined for the creation of the concepts: **universal** due to the difference of responsibilities and functions, **simple** to make information easily exchangeable, **useful and valuable** to boost the operation phase, **compatible** because of the different disciplines involved in is management, **central** to incentive integration and **secure** due to the handling of private and sensible information.

6 Concepts for an integrated management of information

The following concepts for the management of information in the portuguese construction industry were defined: **models**, **requirements**, **exchanges of information** and **common information environment**. These concepts were integrated with the phases of the portuguese documents as shown in figure 2 followed by the explanation of the concepts defined.

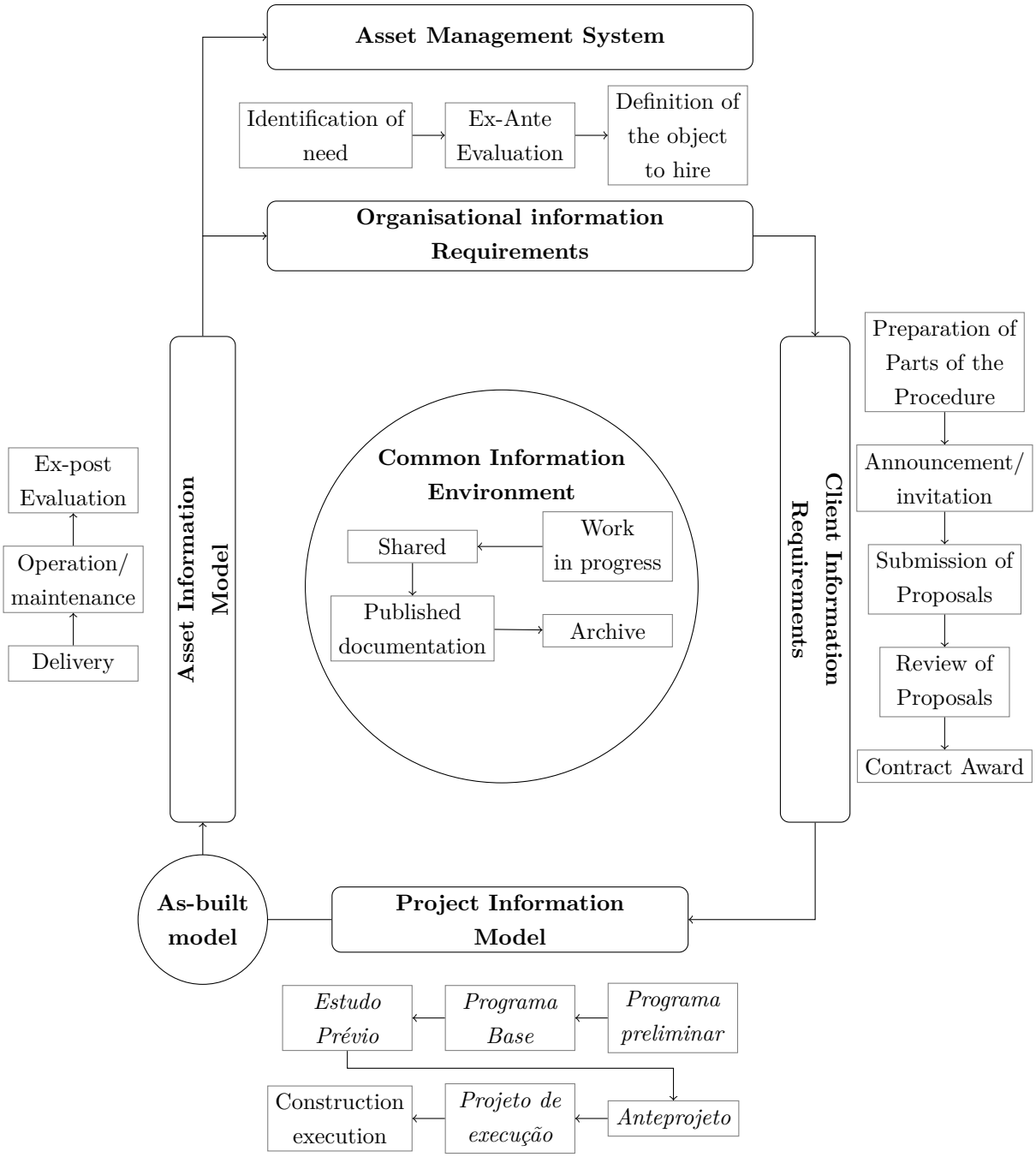

Figure 2: Total cycle of information

Models

The digital models can contain any type of information, and may not contain files in computer aided design, their goal is to describe the asset, regardless of the type of information that is used. Obviously, most models will contain drawn elements, but it is important to highlight this way of thinking, there is an enormous amount of information that describes an asset, this concept of a model emerges as recipient of this information. The BIM Technologies associate information to drawn elements, either in 2D or 3D, which is the most convenient way to describe an asset. However, it should be noted that neither the BIM technologies nor other type of design is required, if possible and practical an asset may be described simply by, for example, data sheets or data bases. The BIM technologies emerge as the ideal way to

apply this concept, not as the obligatory way to use it. One of the needs raised in surveys conducted was the lack of a centralised model with easy access. With this in mind, the existence of models inherent to the stages in which they are used is defined: the model to be used in a project, **Project Information Model** and the model to be used in operation, the **Asset Information Model**. It is a different title, in accordance with the phase in which they are employed, introduces a barrier that allows a better control of the cycle of information.

The **Project Information Model** and the **Asset Information Model** are repositories of information that will help making decisions and can contain all sorts of information: geometric, instruction manuals, documentation, description of components etc.. The usual cycle of building assets, in general, is design, construction and operation, respecting this cycle, the **Project Information Model** transfers its information to the **Asset Information Model**. However, the reverse can also occur because, at the end of life, the **Asset Information Model** continues to have information relevant to a new asset, for example, topographical information, meteorological etc.. Another of the conclusions drawn from the interviews was the need for reliability to what was actually built. The **As-built Model**, is a concept used in the PAS and its an important one. It is the model of the asset built exactly as it was built. In Portugal there is something equivalent, *telas finais*, which *are the set of final drawings of the project, integrating the corrections and amendments made in the course of work and translate what was actually built*, as defined in the *Portaria n.o 701-H/2008*. They are different, because the **model as built** defined in PAS has all the information associated with it. The *telas finais* are only information for the help of the interpretation of designs, the model as built may have more information associated, it is more comprehensive. Basically, all the information necessary to describe the asset may be contained in the model, while in the final screens it is not. Another important aspect is the respect for the "as built", which is essential, because it ensures trust and avoids future surveys on the asset. The *telas finais* are used in a lighter tone: small changes may not appear in what is delivered, although mandatory. To be able to blindly trust in the model there can't be any discrepancies between the model and what was built, hence the importance of the existence of a **As-built Model** at the end of the construction.

Requirements

The first requirements needed are the **Organisation Information requirements**, which are dependent on the way the organisation operates their requirements. There also should be defined the **Asset Information Requirements**, coordinated with the **Organisation Information requirements** but focusing on the assets. They define the necessary information for assets in order to produce value. The **Asset Information Requirements** are generated by the managers of information of the organisation. At this point, the focus is no longer the processes used, but the needs of the assets themselves in accordance with the defined within the asset management system, as defined in ISO 55000:2014, which depends on the context of the organisation, operation, performance evaluation and improvement.

The **Project Information Requirements** affect the project itself, which has needs different from a built asset already in operation. In the design phase the information is created from scratch, the informational needs are different. It is also common to exist external suppliers of information, which influences the informational needs. The definition of **Project Information Requirements** is performed by individuals outside the operation, informed by the organisation, that is who defines the processes inherent to how the projects are carried out.

The existence of only these requirements is not sufficient, there must be an intermediate requirements between the **Asset Information Requirements** and **Project Information Requirements**, So that

both the managers in operation and those responsible for new projects have equal involvement in the definition of requirements. To this end, there is the **Client Information Requirements**, which integrate both requirements previously defined. They are generated by those involved in project definition but with the intervention of the asset managers, in order to take into account input from both. These requirements will specify the **Project Information Model**, previously defined.

Exchanges of information

The exchange of digital information should be carried out in accordance with a single nomenclature. It can be normalised or defined by the company, depending on the company's needs. File formats should be defined according to the *software* used by the organisation. The exchanges between departments and individuals should be in accordance with the format defined for each type of exchange. Ideally it should be used an universal format, which is hard to achieve, the essential concept is the clear definition of how they should proceed. These are simple guidelines but necessary, the organisation should not neglect this aspect, since it can slow down the exchange of information and may negatively affect its operation.

Common Information Environment

The **Common Information Environment** exists to enable the production of information simultaneously. Civil engineering projects are complex, there are several different specialities that produce information. The production is often based in information already produced by other specialities, which can lead to errors and conflicts in the project. This concept tries to ease that with a defined cycle of production of information, its aim is to control versions of produced information. The initial information created is placed in the work in progress. When ready and checked by project leader is passed to the shared area. In this area, other specialities can use this information to production. After the client's approval it will then be published documentation, and the use of information by the other entities involved in the construction will be permitted. Finally, after verification of as-built it is passed to the archive where the information is exactly what it describes in reality. The use of a common environment of information and the definition of requirements allow the cycle of information in project work in the most efficient manner as possible regardless of the phase of the project in which it is used.

7 Conclusions and future works

The concepts proposed change the way information is created in project and how it is managed in operation. The concepts are a small first step toward this new era of information used in digital form. The portuguese construction industry cannot escape this change, this works aims to ease this inevitable change and provide tools for its use. Portuguese projects have specific complexities caused by the entrepreneurial culture of the country and by its economic and geographical factors, it is suggested that the concrete informational needs and demands are assessed, as they were not focused in this work. In spite of the technologies BIM being quite mentioned in the course of this work, it was not detailed their use in conjunction with existing software, a study about the use of these *softwares* in conjunction with concepts defined should present interesting conclusions. Recently task automation and sensors in homes have seen more common use. The sensors used will record the most varied information: temperature, humidity, atmospheric emissions, energy consumption, etc.. These applications will need information models: the sensors to allocate these new information recorded and the processes of automation will need the information contained in them. The concepts defined can contribute indirectly to these applications. It is suggested a study of the possible applications for these cases.

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