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INTEGRATION OF BIM AND E-PROCUREMENT IN THE CONSTRUCTION INDUSTRY: A SYSTEMATIC BIBLIOGRAPHIC REVIEW

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ABSTRACT: The procurement process virtualization tend to reduce transaction costs and expand supply chains, especially through e-procurement platforms. Concurrent advances in information and communication technologies such as Building Information Modeling (BIM) have proved to improve the typically hindered information flow of the construction industry. The aim of this research is to assess the current state of the art of the integration of BIM and the e-procurement process. Fifteen papers were correlated through a Systematic Bibliographic Review (SBR) and the result reveals real possibilities of integration of BIM and e-procurement. Great benefits can result from the integration, such as reduction of the fragmentation in this industry. However, there are still various barriers to overcome, mainly about the civil construction industry fragmentation and the systems interoperability. The most advanced researches were developed in Portugal, where there is a strong governmental foment for the e-procurement utilization. The government is recognized as the most influential agent for the effective implementation of e-procurement platforms, even more strongly than the role of the companies that will run this process.

Keywords: E-procurement. BIM. Formatação. Systematic Bibliographic Review.

RESUMO: A virtualização do processo de aquisição tende a reduzir custos de transação e ampliar cadeias de suprimento, especialmente através de plataformas de e-procurement. Avanços paralelos nas tecnologias de informação e comunicação, como Building Information Modeling (BIM) provaram melhorar o fluxo de informação normalmente falho da indústria da construção. O objetivo desta pesquisa é avaliar o estado da arte da integração entre BIM e e-procurement. Quinze artigos foram correlacionados através de uma revisão bibliográfica sistemática e o resultado revela possibilidades reais de integração entre BIM e e-procurement. Grandes benefícios podem resultar da integração, tais como a redução da fragmentação nesta indústria. No entanto, ainda existem diversas barreiras a superar, principalmente quanto à fragmentação da indústria da construção civil e à interoperabilidade dos sistemas. As pesquisas mais avançadas foram desenvolvidas em Portugal, onde há um forte fomento governamental para a utilização de e-procurement. O governo é reconhecido como o agente mais influente para a efetiva implementação de plataformas de e-procurement, com papel ainda mais forte do que o das empresas que serão executoras deste processo.

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Palavras-chave: E-procurement. BIM. Revisão bibliográfica sistemática.

1 INTRODUCTION

Mohsini (1993) define procurement as a process involving a sequence of decisions and/or actions that a client engages in as soon as the need to acquire a new facility arises. E-procurement is the virtualization of this process. The procurement processes in construction are conditioned to the nature of the usual information exchange process in this industry. Fragmentation and CAD drawing- and paper-based documentation hamper the procurement process, leading to extra costs for activities that could be avoided by the utilization of a more lean process. The great volume of elements and considerably specific projects also bolster the dependence on unstructured procurement.

The internal dimension of ICT in the construction sector has evolved strongly related to technical design and engineering applications (GRILO; JARDIM-GONÇALVES, 2009). Building Information Modelling is a work philosophy that emerged from the integration of different design and construction stakeholders based on the enrichment of 3D virtual models of buildings.

Research on application of new information and communication technologies (ICT) exposes the possibility of combination of BIM and virtualization of procurement processes, which could reduce costs by improving the information flow and increase access to suppliers. This research delineates the state of the art of the integration of BIM and e-procurement.

The aim of this research is to collect papers that address the integration of BIM and e-procurement process from four databases through a systematic method (Systematic Bibliographic Review - SBR), find the most relevant researches and delineate the state of the art on this subject. The integration of these concepts may improve the information flow and reduce the typical fragmentation of this industry, which may lead to cost savings.

The most advanced researches on this topic were developed in Portugal, fostered by the 2008 Public Contracts Code adoption, which obligates public purchasing through e-procurement. Grilo and Jardim-Gonçalves (2009) developed a model for e-procurement in which BIM is used from the first preliminary design of a project. These authors evolved into a case study, and implemented the incorporation of objects from virtual catalogues into the file during the detailing phase of architectural design and the link of information attached to model objects, such as PDF files (GRILO; JARDIM-GONÇALVES, 2011). Their work

evolved to a virtual marketplace (Cloud-Marketplace), where different procurement platforms were supported (GRILO; JARDIM-GONÇALVES, 2013).

Despite few researches emphasize barriers to overcome for the extensive use of the developed prototypes, the researches addressed in this SBR demonstrate the feasibility of e-procurement platforms that run based on BIM model sharing.

2 RESEARCH METHOD

The research was conducted by the application of a bibliographic review. According to Webster and Watson (2002), this is an essential resource of any academic work. It consists of the survey, analysis and synthesis of publications relating to certain subject. Gil (2002) highlights the exploratory nature of the bibliographic review, which is developed based on previous researches, mainly books and scientific papers. Through bibliographic review, theoretical and scientific basis - the state of the art – of the subject to explore is forged.

Conforto et al. (2011) contrast two types of bibliographic review. The narrative type consists of a simplified description of studies and definitions on a given subject based on material randomly selected by the author without well-defined criteria. It may result in excessively personal interpretations, with insufficient critical analysis (SHAW, 1995). The second type is the Systematic Bibliographic Review (SBR). Although SBR has also a narrative character, it requires the application of methods with more scientific rigor in the selection of bibliography.

The bibliographic review rigorous systematization enhances the achievement of better results, reducing the potential for error and bias of the researcher (COOK et al.., 1997). With systematization, it is possible to identify gaps in the theory, which can be exploited by other researchers, but have not been identified in similar studies due to lack of rigor. (CONFORTO et al., 2011). Rigor also fosters more reliable results, producing, according to Webster and Watson (2002), a benchmark for the conduction of future research.

2.1 Tool

In this research, a SBR was performed by applying a tool based on the SBR roadmap method, presented by Conforto et al. (2011), combined with the matrix of concepts presented by Webster and Watson (2002).

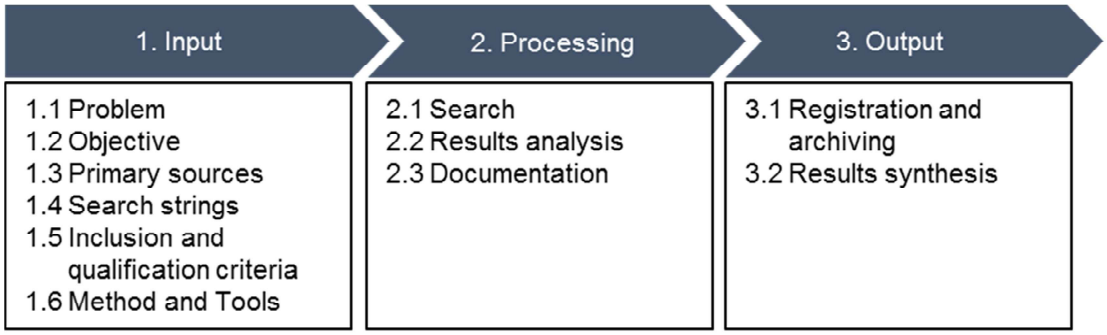

Figure 1 – SBR Tool: stages and steps.
Source: Developed by the authors

The aim of the tool application is to find papers with relevant approaches on the subject under study. There are three stages – input, processing and output – divided into steps. The SBR Tool is illustrated in **Erro! Fonte de referência não encontrada.**.

2.1.1 Tool

- Problem: the problem definition is the starting point of the SBR. The problem of this research is: "What is the state of the art of the integration of BIM and e-procurement in construction?".
- Objective: must be clear and feasible. Here, the objective is to define the state of the art of the integration of BIM and e-procurement in construction through the description of concepts raised in related research.
- Primary sources: databases to be explored in the search. Due the relevance of their publications in the research area, four databases were selected: Science Direct, Web of Science, Scopus and Periódicos.Capes. The search was restricted to papers that had been published in journals or presented at conferences.
- Search Strings: keywords and their combinations and the search rules. The keywords combinations were: (a) e-procurement, BIM; (b) electronic, procurement, BIM; (c) electronic, marketplace, BIM; (d) online, commerce, BIM; (e) cloud, procurement, BIM. All searches were restricted with the Boolean operator AND, so the resulting papers contained all keywords of each combination.
- Inclusion and qualification criteria: must take into account the research objectives. Papers to be qualified as results of the SBR should not necessarily address the problem directly, but to substantially contribute to its resolution. This can then be verified with the assessment of the articles through the matrix concepts described in stage 2.

- Method and Tools: bibliographic review was the applied method and SBR was its tool. After the collection of the first papers, the next step was to seek the elimination of repeated results. Non-repeated items were subjected to the first filter: reading of title, keywords and abstract. Articles with identified relevance were then subjected to the second filter: reading of introduction and conclusion. When relevance was confirmed, the article was approved for the analysis of results.

2.1.2 Stage 2: Processing

A matrix of concepts was developed for the analysis of results. This is the identification of the concepts covered by each approved paper and conception of a matrix by linking the concepts of the various papers. Thus, it was possible to identify the most common concepts, indicating the common path of research. The search results was documented by registration of titles, authors, year and journals and/or congresses and also the filter status (approved or rejected).

2.1.2 Stage 2: Processing

Stage 3 consists of paper registration and archive and finally the synthesis of the results. Webster and Watson (2002) propose the discussion of each concept identified in the matrix and its logical grouping.

3 RESULTS

247 papers resulted from the first search, which is detailed in Table 1. Science Direct platform has provided that most of the results (82.99%). The other three databases totalized only 17.01% of the results. Web of Science provided only 3.64% of them. The keyword combinations had more balanced results. Among them, the combination (b) electronic, procurement AND BIM was the one that provided more results, 34.41% of them.

Table 1 – Search Results

Keywords	Science Direct	Scopus	Web of Science	Periódicos Capes	Total
e-procurement, BIM	15	3	3	8	29 (11,74%)
electronic, procurement, BIM	72	5	3	5	85 (34,41%)
electronic, marketplace, BIM	26	2	1	1	30

					(12,14%)
online, commerce, BIM	57	3	0	0	60 (24,29%)
cloud, procurement, BIM	35	2	2	4	43 (17,40%)
Total	**205**	**15**	**9**	**18**	**247**
	83,00%	**6,07%**	**3,64%**	**7,29%**	**100,00%**

Source: Developed by the authors

With the registration of the results, it was possible to delete repeated ones. After the exclusion of repeated papers from the original 247 results, 159 papers were subjected to the first filter. From these, after reading of title, abstract and keywords, only 17 were qualified for the second filter. After its application by reading of introduction and conclusion, finally 15 articles were selected for analysis. From them, 12 were results from the Science Direct database, 5 from Scopus, 4 from Web of Science and 8 from Periódicos Capes. All combinations of keywords had selected papers.

After the full reading of the 15 papers, the matrix of concepts was developed, as presented in Figure 2.

The most frequently observed concepts are BIM and procurement / e-procurement. That is reasonable since these concepts correspond directly to the objective of the research. Interoperability is a problem that several authors have identified on the integration of BIM and e-procurement. This concept is the third most observed, together with projects of BIM and e-procurement integration. Then come the concepts of ICT in construction and government initiatives fostering e-procurement, both were identified in almost half of the papers. The cloud computing concept was observed in one third of them. Finally, only one paper addressed notably the concept of verification of viability of the use of e-procurement in construction. This is a negative revelation, since the studies may take into account assumptions that could be rejected by this concept.

Regarding to the geographical distribution of the publications, one third of them was carried out by a group of authors from Portugal. This concentration occurred because of the government incentives in this country for the use of public e-procurement. 9 from the 15 papers were produced in Europe, possibly because of its public regulations tending to the use of BIM and e-procurement.

Figura 2 – Matrix of Concepts

Source: Developed by the authors

Author	Concept: ICT in construction	Procurement / E-procurement	Verification of viability of the use of e-procurement in construction	BIM	Government initiatives fostering e-procurement	Cloud computing	Interoperability	Projects of BIM and e-procurement integration	Total
Grilo and Jardim-Gonçalves (2009)	■	■		■	■	■	■	■	7
Ajam et al. (2010)	■	■					■		3
Grilo and Jardim-Gonçalves (2011)	■	■		■	■	■	■	■	7
Tran et al. (2011)	■	■	■						3
Ren et al. (2012)		■		■			■	■	4
Redmond et al. (2012)				■		■	■		3
Costa and Tavares (2013)				■	■				2
Grilo and Jardim-Goncalves (2013)		■		■	■	■	■	■	6
Porwal and Hewage (2013)	■	■		■			■		4
Costa and Grilo (2014)		■		■	■			■	4
Chong et al. (2014)				■		■			2
Ibem and Laryea (2014)	■	■		■			■	■	5
Ciribini et al. (2015)		■		■	■			■	4
Naoum and Egbu (2015)		■		■					2
Li and He (2015)		■		■				■	3
Total	6	12	1	13	6	5	8	8	

■ Concept verified | Concept not verfied

4 CONCEPT DISCUSSION

Each concept was individually discussed below, with highlight of the most relevant information from the papers.

2.1 Information and Communication Technologies in construction

The Building and Construction industry is the major sector in which ICT is fragmented. The diversity and heterogeneity of systems and applications in place is large, making a scenario of strong intra- and inter-enterprise interoperability challenges (GRILO; JARDIM-

GONÇALVES, 2009). These authors indicate that, even with the domain of large companies, the dependence of small and medium enterprises (SME) is large. According to Tran et al. (2011) the SME often have a low degree of maturity to adopt, use and benefit from ICT, such as e-commerce.

Grilo and Jardim-Gonçalves (2011) explain that the construction industry is characterized by the procurement of unstructured goods and services, which makes the use of systems for this activity more difficult. This difficulty is reported particularly when the information necessary for contractual arrangements is not properly structured and is in a digital processing format. Usually the quantification of resources necessary for a project is based on CAD drawings. In cost estimate, Ren et al. (2012) described the vulnerability of traditional quantifications to human error and its spread.

4.2 Procurement / e-procurement

According to Mohsini (1993) apud Ibem and Laryea (2014), procurement is a process involving a sequence of decisions and/or actions that a client engages in as soon as the need to acquire a new facility arises. These authors also cite Alarcon et al. (1999) and their statement that in construction, these needs are to supply equipment, materials and other resources required for the implementation of a project, including the execution of bids and/or opening of competition for execution of services or delivery of products. Grilo and Jardim-Gonçalves (2011) point out that the scope of the procurement is broader than the purchasing process, as it involves strategic activities such as negotiating with suppliers and coordination with the research and development sector.

Grilo and Jardim-Gonçalves (2011) divide the procurement in two phases: contracting e settlement. Contracting, in turn, is divided into sourcing e availability to promise. Sourcing is the search for request information of products and services. Availability to promise is the flow of information with a supply chain, i.e. the availability of goods and delivery arrangements. This information flow is usually generated by the quotation and negotiation functions. The settlement phase is divided into transaction and delivery. Transaction is the payment of goods and services and delivery is its movement from seller to buyer.

Grilo and Jardim-Gonçalves (2011) describe also both types of procurement: structured and unstructured. Structured comprises a regular supply demand without changing specifications over time. A procurement process can be designed with more accuracy and long-term relationships with suppliers, which can reduce transaction costs. However,

construction processes also require products with highly irregular demand and high variable specifications. They generate customized needs and potential uncertainties, demanding procurement activities not covered by already defined and/or automated procedures, which can lead to high transaction costs for the acquiring company. This is the unstructured procurement. In each civil engineering product there is always need to purchase products and services with great standardization and routine use, particularly during the construction phase. However, many activities relate to the procurement of highly unstructured supplies, such as specialist subcontracting services and even one-off non-standardized construction products and equipment. (GRILO; JARDIM-GONÇALVES, 2011).

Ajam et al. (2010) indicate that the prevailing method of communication on procurement in construction is still based on paper due to legal restrictions and/or cultural or organizational defects. These authors also highlight the lack of quality control procedures and/or incompatibility of procedures between the various parties involved, as well as lack of integration of the information used by the various parties in construction bidding. Porwal and Hewage (2013) reported that the traditional method of procurement has been criticized for separating the design and construction processes, which obstructs the communication and coordination between teams responsible for these activities.

Ajam et al. (2010) indicate that communication, location, timing and control may be facilitated by the use of ICT tools forming virtual collaboration extranets to add value throughout the construction industry. In the procurement process, these authors list as potential benefits of these extranets time and cost save, improving communication between team members, contributing to the building of trust and transparency, the base of knowledge and organizational learning, better services and greater engagement with clients.

Grilo and Jardim-Gonçalves (2011) reported that the structured procurement has been the main target of existing procurement electronic platforms such as e-procurement systems and virtual marketplaces (e-marketplaces). The e-procurement systems seek to bring to virtual and shared environment the procurement processes that traditionally rely on paper documents and occur in a fragmented way. E-marketplaces are virtual spaces in an electronic network that provide buyers and sellers opportunities to exchange information on prices and product offerings, and an electronic trading platform. These spaces aggregate information from different suppliers and buyers. From the e-marketplace service provider perspective, each client, remotely and through the Internet, can have as many e-marketplaces as they need, and each client or each project is likely to have its own e-marketplace (GRILO; JARDIM-

GONÇALVES (2013). These systems have proved to provide positive impacts in the supply chain management and the range of benefits is diverse, from simple operational cost benefits to more strategic benefits like improvement of flexibility and responsiveness (GRILO; JARDIM-GONÇALVES, 2011).

The conventional phases of e-procurement listed by Costa and Grilo (2014) are:

- ex-ante e-evaluation: refers to multicriteria evaluation of needs and procurement strategies;
- e-noticing: concerning electronic publication of public procurement notices;
- e-submission: concerning electronic submission of proposals;
- e-decision: concerning electronic evaluation of proposals, subsequent communication of evaluation results, and discussion and analysis of results;
- e-award: concerning electronic contract awards to suppliers with the best proposals;
- e-ordering: concerning all activities, including sending an order document from public buyers to suppliers, to the transmission of delivery instructions for ordered goods and services;
- e-invoicing: concerning claim for payment for goods and services ordered and delivered under agreed upon conditions;
- e-payment: agreed electronic payment management and execution;
- e-contract management: refers to the use of electronic contract management instruments to monitor and improve contract performance and document management;
- ex-post e-evaluation: agreed multicriteria evaluation of the contract execution, and the eventual generation of KPIs to support future tendering processes.

According to Costa and Grilo (2014), in a fully integrated environment and without the use of printed documents, all these processes should be combined and all relevant information should be available electronically. Ibem and Laryea (2014) list as benefits of using ICT tools in procurement of construction projects the increased project quality, cost reduction, user satisfaction, increased responsiveness and productivity, market expansion and the effectiveness of project delivery.

4.3 Verification of viability of the use of e-procurement in construction

Most authors do not stuck in assessing the ability of the construction industry for the implementation of e-procurement. Some of them make brief remarks about the difficulties that the sector companies face in virtualization these processes, such as the reluctance of

senior workers to adopt new processes based on technology and the great range of products purchased through unstructured processes. However, only Tran et al. (2011) addressed the issue systematically.

Tran et al. (2011) define the ability of a company to implement e-procurement as its propensity in relation to e-procurement (perception of managers on e-procurement, history of successful implementation of a new operation or management philosophy) and its available internal capacity to implement and get noticeable benefits (human, technological and business resources). For these authors, the nature of aptitude is dynamic, i.e. it may increase or decrease with time. To measure it, they propose a structure that covers governmental, technological and business influences.

According to Uzoka et al. (2007) *apud* Tran et al. (2011), the role of government is to guide and support the adoption of innovation through its policies, regulations and benefits. The adoption of a national vision focused on modernization through e-procurement in the public sector boosts the private sector in the same direction. This includes not only the establishment of e-procurement for public acquisitions, but also efforts for training and education of professionals and directing funds for research in the area. Alzougool and Kurnia (2008) reported that in developing countries, the adoption of e-procurement has been conditioned by the quality, availability and cost of access to technology infrastructure. The management of the government's technological infrastructure can also affect this adoption by the private sector. For Tran et al. (2011) within the organization, since the highest levels of the hierarchy must have engaged perception and attitude toward e-procurement. Each type of business has different relationships with clients, contractors, consultants and suppliers, and the barriers to e-commerce are different according to each type and organizational culture. Tran et al. (2011) conclude that the role of government in the ability level for implementation of e-procurement has more influence than the company itself.

Wong (2007) reported that there are cases where the adoption of virtual collaboration extranets in fact further complicates the communication process. Grilo and Jardim-Gonçalves (2011) mentioned that the positive or negative impact of e-procurement depends on the characteristics of the product or service, and that it may not be suitable for some goods or services with high specification, in which close relationships between buyers and suppliers are essential. For these authors, this may be the case in the construction sector, in which many of the goods and services have complex levels of specification.

4.4 BIM

The internal dimension of ICT in the construction sector has evolved strongly related to technical design and engineering applications. (…) It has become possible to enrich the 3D models of buildings and structures with complementary data such as physical characteristics, unit costs, quantity take-offs, etc. (GRILO; JARDIM-GONÇALVES, 2009). This evolution is designated as the Building Information Model or Modelling (BIM). Grilo and Jardim-Gonçalves (2011) explain that BIM enables the creation of a composite model, in which the various specialties of a project can contribute interactively to build a model. With this, Ren et al. (2012) complete that it is possible then to store and extract model information such as specifications and operational requirements. When this information is updated or there are changes in any view of the model, automatically the whole model and its views are updated. According to Ren et al. (2012), the advantages over traditional systems based on drawings are minimizing manual work, facilitating communication, coordination and collaboration, reducing time and cost, resulting in fewer misunderstandings between parts, providing even greater accuracy in procurement processes.

For Redmond et al. (2012), this is a turning point, since this is not the automation of established processes, but the automation of synchronization of information across applications to speed workflows. This approach focused on the process level became the best practice recognized by the class, according to Grilo and Jardim-Gonçalves (2009). These authors made clear, however, that interactions involving components of models created by different software require interoperability, which becomes even more important when used in virtual platforms, such as e-procurement. Grilo and Jardim-Gonçalves (2009) also point out that the interface with the BIM introduces a new layer of complexity, mainly due to the heterogeneity of systems and applications.

4.5 Government initiatives fostering e-procurement BIM

Tran et al. (2011) report that in developing countries, the construction industry is characterized by small and medium companies, which often have a low level of ability for adoption and use with benefits of ICT, such as e-commerce. Thus, supportive regulations, legislation and government policies are considered very important in the adaptation and implementation of e-procurement.

Grilo and Jardim-Gonçalves (2009) present the Single European Electronic Market (SEEM) as a contribution to the vision of the Single European Information Space (SEIS) a

structured space based on the Internet, where companies can access a lot of information already available on various portals and corporate databases and use them for collaboration purposes. The focus of the implementation of the SEEM is basically linked to small and medium enterprises, which are still marginal to electronic commerce. For them, the SEEM vision is achievable with the appropriate provision of adequate Internet applications to manage processes, hiding the complexity of the technological infrastructure through simple interfaces and ensuring the interoperability of systems. In compensation to the database access, the condition for entry and operation in the market is to regularly upgrade and improve this database by companies.

In Portugal, e-procurement has become mandatory for the public sector with the Public Contracts Code adopted in 2008. (COSTA; GRILO, 2014; COSTA; TAVARES, 2012). The authors explain that, since then, significant improvements have been achieved by the use of electronic platforms, which proves that a considerable reduction in operational efforts is possible. Then, Costa and Tavares (2013) state that gradually the private sector recognizes its benefits and implement e-procurement. In the UK, all public projects should be in BIM by 2016 (PORWAL; HEWAGE, 2013).

4.6 Cloud Computing

Grilo and Jardim-Gonçalves (2009) described the cloud computing as a style of computing in which dynamically scalable and often virtualized resources are provided as a service over the Internet. Chong et al. (2014) identify it as an advanced technology in which hardware and software are available as a platform for collaborative services over the net. These authors state that users do not need to have the property nor even the knowledge about the technology infrastructure that supports these cloud services, but also have no control over it.

Because of its flexibility and scalability, Grilo and Jardim-Gonçalves (2009) and Chong et al. (2014) agree that cloud computing reduces the price of access for small and medium-sized enterprises to a digital infrastructure before only accessible by large organizations. Grilo and Jardim-Gonçalves (2009) add that the emergence of this concept can release companies from the complexity of ICT, which is a promising step in the development of electronic platforms.

Redmond et al. (2012) conducted a research with experts who apply cloud computing combined with BIM and found that the main barriers identified by them for using a cloud

platform are problems in the security of data and legal issues such as data ownership. Then there is the problem of connectivity, as some building sites are located remotely with no Internet access. On the other hand, the combination of BIM and cloud computing is associated with the efficiency due to cost reduction, leading to the integration of several disciplines.

4.7 Interoperability

According to Grilo and Jardim-Gonçalves (2011), e-procurement presents several technical challenges that create interoperability problems. These authors cite the example of european public procurement procedures, which require the submission of certificates and attestations from companies to prove compliance with the criteria for selection and exclusion. The interoperability required between electronic certificates has caused operation problems.

Ren et al. (2012) and Grilo and Jardim-Gonçalves (2010) reported that since the early 90's, there are efforts to develop standards for the definition of interoperability between BIM models. This means that it is necessary for all of them compatibility with models created by other softwares, so that all information objects can be correctly transferred. In most cases, it is a challenge for such translation to retain all the information contained in the model in its original file format. Despite the efforts from several companies to develop interoperable software, Grilo and Jardim-Gonçalves (2010) reported that most of the BIM applications of modeling and their complementary software tools address interoperability only among themselves, and not in relation to other vendors' applications.

Grilo e Jardim-Gonçalves (2011) added that the interoperability problem becomes even more acute when a combination of BIM functions with traditional e-procurement in virtual platforms is desired, in which objects (such as windows, doors, pipes, etc.), and 3D parametric information should contain request for proposals, orders and invoices. Porwal and Hewage (2013) defined that the cloud-marketplaces system architecture (different e-marketplaces integrated in cloud) should support interoperability between e-marketplaces located on heterogeneous platforms and with other application systems available on the network. Interoperability between platforms will allow the flow of trade opportunities between them and eventually electronic transactions.

4.7 Projects of BIM and e-procurement integration

The obligation of e-procurement in the public sector in Portugal led it to be a pioneer country in integrating BIM to this practice. Grilo and Jardim-Gonçalves (2009) developed a model for e-procurement in which BIM is used from the first preliminary design of a project.

In this model, after setting initial specifications through an application based on BIM, the initial program can be exported to a cloud platform. Then a generic model that will be the basis for the next stages is created in the next phase, architects can import the conceptual model and refine its details. The model can be exported thereafter again to the cloud, where a compliance test can be run between the received model and the original one. Until this point. It would not be necessary to connect to the network, but with the evolution of the project and the involvement of more professionals for specialized projects, more complex interactions occur. From then the competition for the preparation of projects may begin, and so do the flow of commercial and managerial data. After updating the model, new compliance testing must occur. This model assumes that the BIM model would be the basis for transactions throughout the project life cycle and would be enriched always when an exchange occurs. Whenever a need for a service would emerge, it would be triggered on the cloud, where transactions would occur regardless of the physical location of stakeholders.

Grilo and Jardim-Gonçalves (2011) evolved into a case study with a project called PLAGE, a partnership between the Portuguese government and companies that develop software. One of the major issues of this project was to eliminate as much as possible of unstructured information from e-procurement process. In the created platform, it is possible to incorporate objects from virtual catalogs into the file during the detailing phase of architectural design. It is possible as well to link information not *per se* model objects, such as PDF files or Internet links, but each element shall be related to a BIM model object. In their study, only the design phase has been validated on the platform, the execution was not carried out.

Ren et al. (2012) devised a basic structure of BIM and e-procurement integration and proposed tools for its implementation. In this structure, the general contractor is responsible for system operation and control. The responsible should store the initial BIM model in the system. This model is enriched then, and the quantification of the material and a cost estimate proceeds. The work schedule should also be stored and updated. With that information, contractors can release requests for material supply proposals. As tenders come, the contractor can observe the supplier performance history to choose the winner. The contracts would be managed through the system and the information would be available to those who need it.

Grilo and Jardim-Gonçalves (2013) introduced the concept of Cloud-Marketplace of Vortalway (an industrial research and development pilot project conducted by Vortal – at that time the leading e-marketplace company in Portugal and third largest in Europe in the field).

The application and submitting of tenders scenario was tested in an environment that allows the connection of multiple heterogeneous electronic platforms, which is illustrated in **Erro! Fonte de referência não encontrada.**. To make it possible, support for transactions across platforms is necessary, as well as dissemination of opportunities and data flow management, among other interoperability activities. The suppliers markets are in Vortalway community platforms (Vortalway_OFFICESUPPLY and Vortal_ECONSTROL) and in external e-marketplace platforms. In addition to the designs and specifications, this platform offers the documents necessary for the competition based on BIM-IFC/STEP standards, as well as models for responses of competitors. In this process, additional information may be added, like expected execution dates, upper acceptable price and selection criteria. However, this information is incorporated into the bidding documents through a structured procedure that also feeds the original BIM model.

When users who are in Vortalway community respond, the platform automatically sends this response to the requester. When users are out of this community, the process takes place in its corresponding platform, but Vortalway delivers the response. The authors conclude that there are still challenges of interoperability between platforms. Vortalway supports it, but other e-marketplaces do not, unless they begin to get adapted specifically to accept access.Costa and Grilo (2014) conducted another case study in PLAGE platform. A reform and expansion project of a school had design and part of its procurement process simulated. A BIM modeling software, the PLAGE platform and the management software PRIMAVERA were integrated. After the creation of the model in the modeling software, it was released in the e-procurement platform. The platform server sent the information of each component of the model to the management software, which linked activity information for each component. This information returned to the PLAGE server, and the model was updated. From then, requests for quotation were created by selecting of model components. Suppliers could answer the requests by the fulfilment of a form with price information or by attaching external files to components. The received proposals were then evaluated with a multicriteria evaluation tool provided by PLAGE platform. The authors concluded that this method should facilitate information management activities, as the BIM model would be the sole repository for project, contractual and administrative documentation. Incompatibilities should also decrease with the concentration of information in the model. However, these benefits may not justify the high costs of the additional efforts needed for the elaboration of the BIM model and consistently maintenance of the e-procurement process. This requires specialized support

for the uniform treatment of information. It is also necessary deep knowledge about the creation of models. Thus, this process was not more agile than the traditional e-procurement. Problems with the conversion of individual building objects in blocks for applications also occurred. Again, interoperability has been identified as a problem, with the need for adoption of standardized solutions among stakeholders.

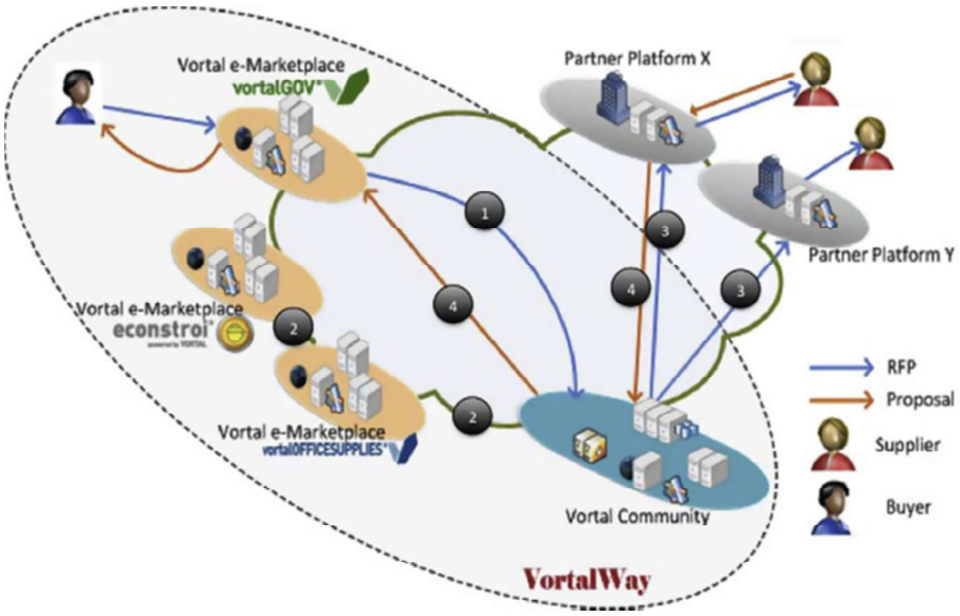

Figure 3 – Cloud-Marketplaces.
Source: Developed by the authors

5 CONCLUSION

Although being object of only few researches, integration of BIM and e-procurement can result in great benefits to the construction industry, such as improvement of the information flow and reduction of the typical fragmentation of this industry. ICT developments supported the creation of new forms of business transactions. Through cloud computing, for example, smaller organizations have access to technology services equivalent to their needs, not massively investing in infrastructure and specialized service.

The researches addressed in this SBR demonstrate the feasibility of e-procurement platforms that run based on BIM model sharing. However, few researches emphasize the barriers that need to be overcome to the extensive use of the developed prototypes. The main barriers are the fragmentation of the industry and the lack of interoperability between systems. For the effective implementation of e-procurement platforms, Tran et al. (2011) conclude that the role of government has more influence than the role of the company itself. This is verified

by the fact that the most advanced research raised in this SBR are concentrated in Portugal, where public e-procurement is required.

Further researches can address the implementation of the systems shown in this paper in order to validate their suggested workflows. Both private and public entities could benefit in different ways from BIM based e-procurement and that could be assessed too. The categorization of BIM project elements to match the usual supplier range of products is a third possibility of research.

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