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Sustainable Customer Relationship Management for BIM Procurement in the Ornamental Stones Cluster under Industry 4.0

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Abstract

The construction industry competitive environment has been demanding buildings conforming with the dynamic customer/owner requirements put together with the procurement of adequate personalised natural materials *made to order* in integrated value networks. But, the technological push has introduced BIM procurement as a mandatory industry best practice that demands standard mass produced materials (*made to stock*) to be introduced in IFC e-libraries ahead of their selection by technical specialists, not the owner. A three experts focus group generated an innovative Cyber Physical System conceptual model (research contribution) to solve this apparent paradox arising from an in depth literature review (theoretical contribution).

Keywords: Customer Relationship Management and BIM procurement, Ornamental Stones under Industry 4.0; IFC libraries and personalised smart materials.

Introduction

This paper will focus on the relationship with the built asset customers (building owners) to define and offer adequate and conforming personalized natural materials for the buildings, such as the Ornamental Stones. The study of this relationship will provide further insights to the replacement of the traditional procurement processes in the Architecture, Engineering and Construction (AEC) sector (Marinho, 2014). So, the overall research exercise will explore new forms of generating sustainable value supported by Digital Business Platforms, under a Building Information Modeling (BIM) approach for construction, design and operations in the AEC.

A framework supported by Service Science Theory (Vargo and Lusch, 2016) that promotes a customer-centric approach (Rajah et al., 2008), will accommodate the positive impact of the I4.0 production control model in transforming the threats resulting from BIM procurement, in the AEC industry, into opportunities. However, this is possible, if materials suppliers firms have a flexible manufacturing system supporting the dynamic offer of new *customized* materials or objects, by *quickly* redesigning them and being able to *fully adjust* the supporting processes (Zawadzki and Żywicki, 2016) to sustain the *evolving* customer (owner) requirements/expectations within the scope of a co-creative participation (Rajah, et. al, 2008). On the other hand, products/materials in the emerging BIM procurement context must be expressed in a standard format (e.g. Industry Foundation Class - IFC) and so, commercially available in the BIM-web-libraries, ahead of their choice. Only then, customers can choose them, which currently occurs under a traditional push approach that makes to stock (MTS) standard products in high volumes. However, if one follows a pull approach, materials should be first customized in conformance to their specification, aligned with the building one and, only then, made electronically available for selection from e-libraries. In addition, nowadays, this spec is mostly expressed as the material being "mouldable" to the area to be clad (i.e. the built asset geometry), including a certain type of holding system and, also surface texture, everything according to the architect's (or building technical team) creativity. There is no objective link with the requirements/expectations of the building owner.

Thus, there is a conceptual conflict (paradox), because a major advantage of BIM usage concerns the standardization of the virtual objects to be part of the building, in order to bring in more stability to the construction business by a more transparent and stable procurement process itself. Therefore, the main objective of this paper concerns the introduction and operationalization of a dynamic "virtual element" designated as a [quasi-] Smart Object (Motamedi et al., 2016), co-created with the customer. This should be made available in a IFC standard (ISO16739:2013), on small enough time gap to be competitive with the standard materials, despite being personalized and made to order (MTO). So, this paper starts by establishing the type of customer relationship that should be specified, adopted and operationalized to target Sustainable networked Value Co-creation by pursuing a Service Science approach enabling a significant Strategic Business Positioning to accommodate the response of the Portuguese OS SME to the threats resulting from BIM procurement.

The chosen path to address the previously expressed paradox is, as follows: (i) firstly, by objectively recognizing that there is an increasing and unstoppable trend towards not only customization but personalization, not compatible with mass production products; (ii) secondly, by defining a role for the new digital technologies in the business change process; (iii) thirdly, by identifying new business models and processes aligned with the competitive context progress; (iv) fourthly, by proposing a much more effective support to the MTO option, supported by digital technologies and coming from an accepted internal change dynamics that might not be objectively dismissed and also, from focusing the customer relationship on the customer/owner interest.

Next sections of this paper are, as follows: 1) the Literature Review, where topics (i), (ii), (iii) are covered; 2) the Methodology, where an exploratory abductive approach based on a focus group is explained; 3) the Empirical Findings, where the topic (iv) is addressed. So, in this section it is put together a conceptual proposal for a Cyber Physical system that enables to introduce a «quasi-smart» personalized material in the IFC library to cope with the challenging initial paradox; and, 4) the conclusions.

Literature Review

The competitive context progress and new business models

World population will increase 2 billion in the next 20-30 years, most of it concentrated in urban areas. As the Construction Industry (CI) is one of the largest consumers of raw materials and energy (Perspectives and Economics, 2015), it is imperative to find new solutions and innovative products that can contribute to the construction of sustainable cities, since along with sectors such as transport, the planet's sustainability (Gao et al., 2015) will depend on the CI. Moreover, the Portuguese Ornamental Stones as a subsector of the Construction Industry also shows a significant national importance deserving to be investigated in line with the pursued record of research in the cluster (e.g. Peres and Costa, 2006; Frazão, 2016).

On the other hand, several researchers have argued that the firms' competitiveness will progress across new management models concerning the integration of their operations in value networks (Lusch et al., 2009). However, in most cases, the customer is still seen as a strange element, independent and far away from the production sites (Lusch and Nambisan, 2015). So, a strategic business operations model promoting inter-organisational collaboration is definitely a solution to be seriously taken into account (Silva et al., 2016). For instance, in the Mass Personalization Paradigm (MPP) customers are intensively integrated into the production process (Wang et al., 2017). MPP requires product fulfillment to be changeable, adaptable, and configurable. In addition to the final product, the basic design and product structure must be able to differentiate at the module and parameter level to meet individual unique needs. Thus, for I4.0 to involve customers in products' co-creation, the customer must be considered an indispensable actor (Vargo and Lusch, 2016), a situation still not very common, as several Service Science authors were considering. Nevertheless, Camarinha-Matos et al. (2017) confirm that the customers involvement in product design as well as close interaction among engineers of different nodes along the value chain require effective collaboration between manufacturers and customers, and so, it is argued that new sustainable Customer Relationship Management (CRM) models are on high demand. However, Forgues and Koskela (2009) made explicit the nature and fragmentation of procurement within the "design-bid-build" process and the client's lack of understanding of its role in a new integrated design process, in the AEC sector. So, the role of the built asset owner within the construction networks should change and become clearer, in addition to the building technical team, i.e. architects, engineers and other specialists. An opener network interaction is required, where specialised and integrated agents increase end-user interactions with users, flexibility and iterative facilities design (Grilo et al., 2013).

Naoum and Egbu (2015) still argue for the need to break the fragmented approach of the traditional route and to encourage cooperation through an integrated method of procurement, communication and ideas able to be shared. This means that the construction industry's poor performance with adversarial procurement practices causing high fragmentation, lack of quality outputs, and low productivity were still going on, as

Latham (1994) and Egan (1998) have reported 20 years earlier. In between this time gap many other researchers have considered that new procurement modes were required to transform the relationships dynamics between the client and the members of the supply chain, improving performance (e.g. Forgues and Koskela, 2009). It should be noted that any construction project involves several stakeholders like client, architects/engineers, developers, manufacturers, general contractors, subcontractors, suppliers and consultants. Moreover, construction material information systems are isolated, with no interaction between them (Kong et al., 2004). In general, it is difficult for a contractor to find all the information using one system and, even more difficult, to do a comparison of the products supplied by different suppliers based on criteria such as product specification, cost, availability, and delivery time (Empirica GmbH, 2007). According to Al-Bizri and Gray (2010), procurement approaches were not creating an organizational framework to deal with fragmentation of the building process and with the cultural issue. One of the biggest problems is the difficulty in implementing widespread team working and collaboration, primarily due to cultural barriers – something that BIM boasts as one of its main attributes (Naoum and Egbu, 2015). Some authors also pointed out specific consequences of unclear and performed ad hoc partner responsibilities, in construction networks, such as conflict of resources and coordination efforts (Legner and Wende, 2006; Magdaleno et al., 2007). Therefore, an end-to-end Supply Chain (SC) approach appears to be needed at the AEC sector. However, besides the problem of aligning business processes from different organisations there is the problem of lack of transparency. Even minimal process visibility in BIM-based projects often provides business benefits to business partners, e.g. regarding technical and managerial decision-making (Grilo et al., 2013). In addition, Forgues and Koskela (2009) have identified another gap concerning the absence of recognized code of practice or Body of Knowledge (BoK) to support the new form of collaborative work inherent to that SC streamline approach. So, the BoK related to collaborative networks should be considered in this assignment.

In addition, Bullen and Davis (2003) highlight that the use of the traditional procurement process creates a professional barrier to innovative change that is required by sustainability. Furthermore, Hamza and Greenwood (2007) added that under the traditional design and build procurement arrangements it may prove to be a very challenging task to design environmentally sensitive buildings as the iterations required are at odds with the contractor's incentive to avoid delays and extra cost.

The role of new business platforms such as Building Information Modeling

BIM can support project collaborative working environments for enabling: (i) the built asset owner to develop an accurate understanding of the nature and needs of the purpose for the project; (ii) the design, development and analysis of the project; (iii) the management of the construction of the project and (iv) the management of the operations of the project during its operation and decommissioning (Grilo et al., 2013). BIM is an extension to CAD, as regards its design dimension. New functionalities coming from CAD 4D are mentioned in the literature. For instance, the combination of 3D CAD and 4D animations, e.g. virtual building modelling or energy performance graphics, can dramatically improve communication, coordination, and planning of construction projects while reducing risks and costs (Kymmell, 2015). Other sub-dimensions of design are also found in literature, as such concerning time-programming, costing or sustainability (Redmond et al., 2012). For non-design disciplines, such as contractors and project managers, BIM is more like an intelligent Data Management System (DMS) that can quickly take off data from CAD packages directly (Singh et al., 2011). Oreni et al.

(2014) add up the following functionalities, in both previously defined categories: (i) a single repository including both graphical documents - drawings - and nongraphical documents - specification, schedules, and other data; (e.g. ArchiCAD) (ii) a modeling of both graphical and non-graphical aspect of the entire Building Life cycle in a federated database management system (e.g. Bentley); (iii) a building design and documentation methodology characterized by the creation and use of coordinated, internally consistent computable information about a building project in design and construction (e.g. AutoDesk).

Thus, BIM does impact the business performance, by a technological push resulting into: (i) functional integration along the supply chain (Papadonikolaki et al., 2016); (ii) data standardization that defines the information formats, geometry, behaviour and presentation of BIM objects to maximize consistency, efficiency and interoperability across the construction industry, e.g. IFC (NBS National BIM Library, BIM Object Standard, 2019); (iii) data interoperable usability (Lee et al., 2006); (iv) inclusion of ICT frameworks that support collaboration with stakeholders over projects life-cycle (Motawa and Carter, 2013); (v) cloud-based sharing of the lists of products and materials with Suppliers (BIM Object - BIM Supply, 2019) and, (vi) better materials conformance (NBS National BIM Library - BIM Object Certification, 2019) through adequate procurement. In fact, as more disciplines of the construction industry adopt BIM, integrated design, and delivery work processes, the need for interoperable applications grows clearer (Lipman et al., 2011). So, BIM application may help to leverage construction procurement performance, particularly by emphasizing the role of information throughout the procurement cycle and, mostly, by allowing the automation of several procurement processes, diminishing the probability of errors and processes duration (Costa and Grilo, 2015). As each building/engineering project tends to be unique, it is critical to the success of e-procurement that the BIM approach considers the use of universal interoperability standards for the various dimensions, i.e., not only on the e-Tendering, e-ordering, e-invoicing or e-Catalogues, but also on product and process models (Grilo and Jardim-Goncalves, 2011). Thus, data interoperability and standardization provide *sine qua non* technical support to the claim that fully integrated procurement methods that include Design, Build and Project Management are most appropriate and significantly contribute to the buildability of the project change (Naoum and Egbu, 2015), i.e. to save time, costs and cost of change (Ma et al., 2013). Through the use of a common standard, the integration of building and materials information and, its effective use becomes possible (NBS National BIM Library, BIM Object Standard, 2019). Electronic integration in heterogeneous, distributed environments, business interoperability research intends to determine how and to what extent the potential of these concepts can be reclaimed for realising seamlessly integrated value chains (Li et al., 2008). In addition, BIM-based e-procurement vision may extend the buying capabilities requirements for procurement, also to design and develop products, manufacturing processes, logistics, and distribution strategies (Presutti, 2003; European Commission, 2010). Enhanced collaboration needs to be developed in the AEC sector and BIM requiring changes not only in the information systems. For example, service-oriented architecture (SOA) based BIM, new business processes and employees and culture, along with new management of business relationships are other major required changes (Grilo et al., 2013).

Role of the new digital technologies in the business change process

The fourth industrial revolution is characterized by an increase in digitalization and interconnectivity of physically separated manufacturing systems (Camarinha-Matos et al., 2017). While the digitalization of the systems of machines is made through the use of Cyber-Physical Systems (CPS), the interconnectivity is enabled by the Internet of Things technology (IoT) (Hermann et al., 2015). The Cyber Physical Production System is application of CPS to traditional manufacturing system with a CPS where Internet, manufacturing and cloud computing work side by side (Singh et al., 2019). So, by integrating CPS with production, logistics and services in Ornamental Stones' suppliers today's factories would turn into an Industry 4.0 (Lee et al., 2015) generating "quasi-smart" materials able to dynamically adjust to the building specification and customer/owner requirements. IoT could then communicate data throughout the building value chain (VC) if adequate care is put on data standardization and interoperability. This is the core base to support the implementation of BIM procurement with information flowing seamlessly along the VC to feed both technical and management systems associated with the building apecification, design, construction and management.

In this way, the horizontal integration of data flow between partners, suppliers and customers, as well as the vertical integration within the organizational structure, involving factors related to the development of the final product and combining the real world with the virtual world (Abreu, 2018) would enable novel forms of personalization (Wang, et al., 2017; Abreu, 2018). This is the proposed theoretical way to overcome the paradox resulting from the introduction of BIM procurement as highlighted before. Therefore, the real world would be connected with a virtual one, ensuring more efficient use of available information (Zawadzki and Żywicki, 2016) to produce individual products at the cost of the mass production (Wang, et al., 2017) of standard materials. Thus, it is argued for the application of Industry 4.0 as a collective term for technologies and concepts to organize the value chain organization (Wang et al., 2017) by enabling real-time planning of production along with dynamic self-optimization (Abreu, 2018).

Methodology

An exploratory qualitative research was conducted by putting together a focus group of specialists that were carefully chosen and so, by asking about their perceptions, opinions, beliefs, and attitudes towards the presented ideas. Three engineers were participating. Topics were clearly and precisely defined based on the literature and there was a focus on enabling an interactive discussion between participants. The participants had common professional characteristics related to the topic being discussed and they were encouraged to discuss and share their points of view without any pressure to reach a consensus. These discussions were run for several times lasting for a total of 20h (10 sessions X 2hours), with the same participants. Questions to be considered were generated from the literature review. This exploratory assignment was expected to provide enough feedback to help to model the theoretical situation that has been previously described. Data were treated and processed according to adequate techniques that are usually used to process the focus group notes in qualitative analysis, i.e. contents analysis (Bell et al., 2018). Finally, the participants made an effort to put together a conceptual proposal for a CPS that enables to introduce a «quasi-smart» personalized material in the IFC library to cope with the challenging initial paradox. By the end this methodological choice configures the operationalization of an abductive approach.

Empirical Findings

The experts in the focus group agreed that the current trends on the competitive environment of the Construction Industry are requiring new business models for the Ornamental Stones SME to overcome traditional problems of the AEC Sector, such as: (i) disaggregation of the value network; (ii) SC fragmentation originating lack of visibility in operations, lack of transparency in procurement and lack of management of the SC as a whole entity (i.e. an end-to-end approach); (iii) favouring MTS mass production materials, which are not aligned with the competitive requirements that are asking for personalisation; (iv) exclusion of the building owner from the business processes concerning the design and construction of the built asset, excluding him/her from the interaction with the SC members, by promoting the imperative of the technocratic decision making; (v) replacement of the built asset owner by the technical specialists, such as architects and engineers among others, with no formal definition of a role for the building owner; (vi) favouring the minimisation of short term costs over costs discussed under the umbrella of a broader Life Cycle Assessment (LCA); (vii) no formal and explicit linkage to the use of local natural materials (e.g. stone), instead of global ones (e.g. glass, steel and concrete), in the category "sustainable cities and communities" of the UN sustainable development goals; (viii) lack of integrated information systems and data interchangeability.

BIM was praised by the focus group members as a powerful information platform to seamlessly and automatically exchange and share data coming from the strengthened CAD software together with other computer sources. These data might be used for several purposes, as follows: to feed Computer Aided Engineering Systems (CAE), e.g. studying the building envelope; for management and administrative purposes, e.g. the collaborative management of the project or of the SC; for better organisational arrangements, e.g. functional integration, fostering a collaborative culture; for innovative studies by putting together several sources, e.g. following the water pipes inside walls by augmented and virtual reality techniques; for supporting a different collaborative customer (owner) relationship both with the building technical team and with the other partners of the supply chain, e.g. with the help of electronic platforms for exchanging relevant information; and, of course, to foster and support a different type of materials procurement by introducing electronic means and bringing in transparency and visibility.

However, the focus group recognised I4.0 as the missing link to pursue sustainable value creation, in terms of the required updated technology to operationalise the new business processes arising from BIM procurement and a collaborative network. By associating the concept of CPS with the IoT, products and machines interconnect and communicate with each other and with the network they are part of, which also includes the final customer, i.e. the built asset owner. Digital technologies enabling the interconnections between the digital world and physical assets are made possible by sensory technologies for acquiring and exchanging data aiming to develop the "quasi-smart" object to include in the BIM IFC library to satisfy a personalized demand for a material (eventually an ornamental stone) on a MTO base. The experts agreed to fully adapt and renew the concept of Cyber Physical System of Silva (2018) to represent the required innovative CPS. The model mapped in Figure 1 is described, as follows.

Suppliers' manufacturing data such as material consumptions, workforce situations, machine statuses, and order progress are collected and automatically managed in real-time to answer quotation queries for a «quasi-smart» material defined according to its specifications coming from the material requirements expressed by CAE/engineering applications working on the building specification, the objective engineering criteria. However, a second set of criteria that are qualitative, e.g. the off-line application, maintenance and demolition issues, will act as moderators of the main engineering criteria (first set) enabling a choice among alternative rival scenarios by the BIM modeler. This is the personalized offer (MTO) to be inserted both in the IFC library and in the ERP system. However, the CPS also operates MTS materials, by directly importing their definitions and standard ordering conditions from the ERP to the IFC libraries. One final remark to say that the above mentioned building specification results from the expression of requirements/expectations for the building by its owner, which are transformed into the spec by the building technical team (engineers, architects, others) through the design process. Finally, the term «quasi-smart» material was coined after the focus group discussions, to define a material of which spec is dynamic, depending on acceptable changes from the stakeholders, i.e. the technical teams, the built asset owner and other stakeholders. Then the CPS should be able to deal with these changes.

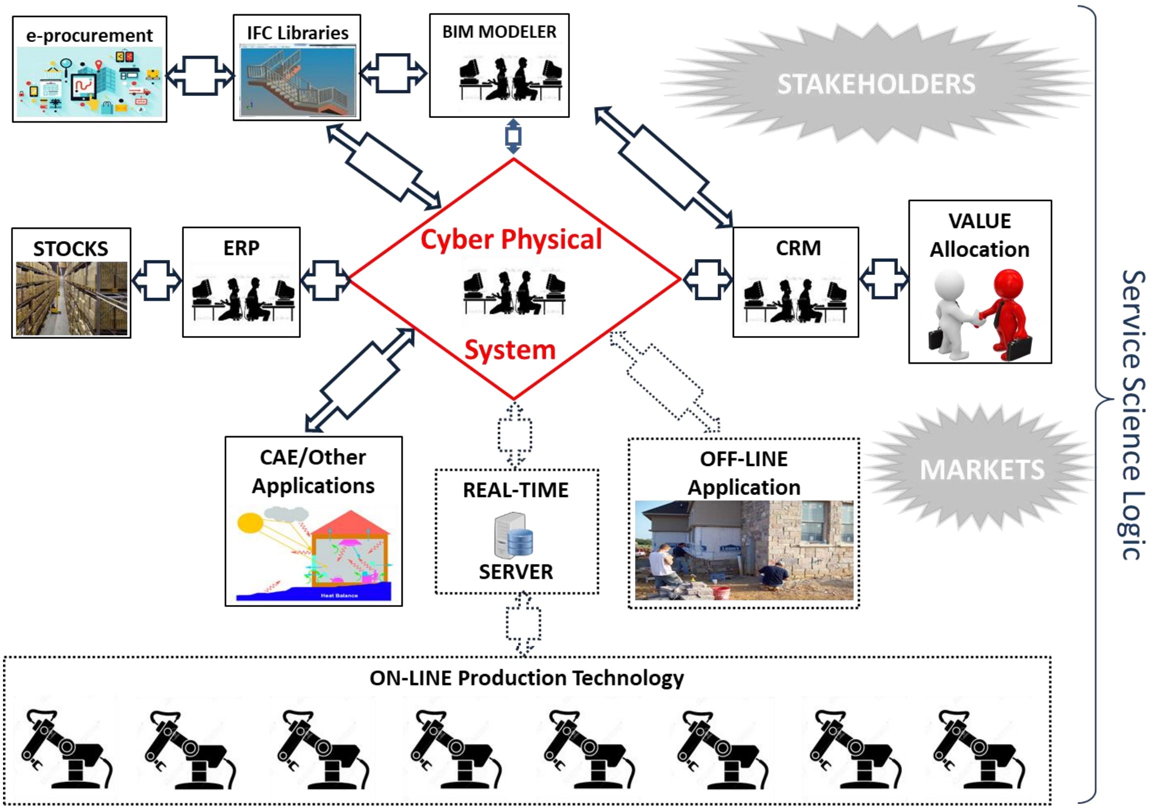

Figure 1 – Cyber Physical System (Adapted from Silva, 2018).

Conclusions

This paper introduced an innovative conceptual model of a Cyber Physical System (theoretical and research contributions). It aims at solving the conflict between the administrative requirements for the BIM-web-libraries for standard mass produced industrial materials and the electronic needs of «quasi-smart» personalized natural materials conforming with dynamic specs that connect to the requirements/expectations of the building owner. The CPS should only be a (semi-)automatic way to expedite the administrative process of inserting the personalized materials on the BIM e-library within a sufficient time gap to be competitive with the standard ones. However, it is argued that this initial question is a false question because the authors expect that the personalized material can offer other functionalities that the standard one cannot (practitioner contribution). For instance, it is expected the conformance of the personalized materials with a strict engineering criterion coming from the building specification (not only aesthetical issues), or even the ability to adjust to dynamic customer/owner requirements for the building, which impact the materials' spec. In fact, this is what the construction industry "says it needs" and, also, what is on demand after analyzing the competitive environment of the AEC sector, as well as the flaws detected on the current business models requiring to be fixed. Thus, we conclude that the standard material is not competing with the «quasi-smart» personalised material (term coined on this paper). At most they might complement each other. Anyway, the CPS can cope with both situations. As a recommendation for further work, there is a need to find an engineering criterion strong enough to promote the linkage and conformance between the material to be procured, under a BIM paradigm, the building spec and the building owner requirements.

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References

Abreu, P. (2018), "Perspectives for the management of management of knowledge in the context of the industry 4.0", *South American Development Society Journal*, 4 (10), pp.126-145.

Al-bizri, S. and Gray, C. (2010), "Management framework for technology clusters implementation", *Construction Management and Economics*, 28(7), pp.771-782.

Bell, E., Bryman, A. and Harley, B. (2018), *Business Research Methods*. Oxford university press, Oxford.

BIM Object - BIM Supply, https://www.bimobject.com/en. Accessed March 2019.

Bullen, P. and Davis, P.R. (2003), "Explorations in sustainable construction and procurement in Western Australia. *19th Annual ARCOM Conference, University of Brighton*, 2, pp.745-754.

Camarinha-Matos, L., Fornasiero, R. and Afsarmanesh, H. (2017), "Collaborative Networks as a Core Enabler of Industry 4.0", *IFIP Advances in ICT*, pp.3–17.

Costa, A. and Grilo, A. (2015). "BIM-based e-procurement: An innovative approach to construction e-procurement", *The Scientific World Journal*, Vol. 2015.

Egan, J. (1998), *Rethinking Construction: construction task force report for department of the environment, transport and the regions*. HMSO, London.

Empirica GmbH. (2007), *The European e-Business Report: A Portrait of e-Business in 10 Sectors of the EU Economy*. Technical report, European Commission.

European Commission. (2010), *Green Paper on Expanding the Use of E-Procurement in the EU*. Publications Office of the European Union.

Forgues, D. and Koskela, L. (2009). "The influence of a collaborative procurement approach using integrated design in construction on project team performance", *International Journal of Managing Projects in Business*, *2*(3), pp.370-385.

Frazao, J. (2016), *Evolução do Colaborador no Setor da Pedra*. Master's thesis – ISG, Lisbon.

Gao, G., Liu, Y.S., Wang, M., Gu, M. and Yong, J.H. (2015), "A query expansion method for retrieving online BIM resources based on IFC", *Automation in Construction*, 56, pp14-25.

Grilo, A. and Jardim-Goncalves, R. (2011), "Challenging electronic procurement in the AEC sector: A BIM-based integrated perspective", *Automation in Construction*, 20(2), pp.107-114.

Grilo, A., Zutshi, A., Jardim-Goncalves, R. and Steiger-Garcao, A. (2013), "Construction collaborative networks: the case study of a building information modelling-based office building project", *International Journal of Computer Integrated Manufacturing*, 26(1-2), pp.152-165.

Hamza, N., and Greenwood, D. (2007), "The impact of procurement methods on delivering environmentally sensitive buildings", *23rd Annual ARCOM Conference*, pp.723-732.

Hermann, M., Pentek, T., and Otto, B. (2015), "Design Principles for Industrie 4.0 Scenarios: A Literature Review" *Technische Universitat Dortmund (No. 01).*

Kong, S.C., Li, H., Hung, T.P., Shi, J.W., Castro-Lacouture, D. and Skibniewski, M. (2004), "Enabling information sharing between E-commerce systems for construction material procurement", *Automation in construction*, *13*(2), pp.261-276.

Kymmell, W. (2007), *Building Information Modeling: Planning and Managing Construction Projects with 4D CAD and Simulations: Planning and Managing Construction Projects with 4D CAD and Simulations,* McGraw Hill Professional, New York.

Latham, M. (1994), *Constructing the Team: Final Report of the Government/Industry Review of Procurement and Contractual Arrangements in the UK Construction Industry*, HMSO, London.

Lee, G., Sacks, R. and Eastman, C.M. (2006), “Specifying Parametric Building Object Behavior (BOB) for a Building Information Modeling System”, *Automation in Construction*, 15(6), 758-776.

Lee, J., Bagheri, B., and Kao, H. A. (2015), “A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems”, *Manufacturing Letters*, 3, pp.18-23.

Legner, C. and Wende, K. (2006), “Towards an excellence framework for business interoperability”, *19th Bled eConference eValues*, 29.

Li, M., Crave, S., Grilo, A. and Van den Berg, R. (2008), “Unleashing the Potential of the European Knowledge Economy–Value Proposition for Enterprise Interoperability”, *European Commission*, *Information Society and Media.*

Lipman, R., Palmer, M. and Palacios, S. (2011), “Assessment of conformance and interoperability testing methods used for CI product models”, *Automation in Construction*, 20(4), pp.418-428.

Lusch, R. and Nambisan, S. (2015), “Service Innovation: A Service-Dominant Logic perspective”, *MIS Quarterly*, 39(1), pp.155–175.

Lusch, R.F., Vargo, S.L. and Tanniru, M. (2009), “Service, value networks and learning”, *Journal of the Academy of Marketing Science*, 38(1), pp.19–31.

Ma, Z., Wei, Z. and Zhang, X. (2013), “Semi-automatic and specification-compliant cost estimation for tendering of building projects based on IFC data of design model”, *Automation in Construction*, 30, pp.126-135.

Magdaleno, A.M., Cappelli, C., Baiao, F., Santoro, F. and De Araujo, R.M. (2007), “A practical experience in designing business processes to improve collaboration”, *International Conference on Business Process Management*, pp.156-168.

Marinho, A. (2014), *Aplicação do Building Information Modeling na gestão de projetos de construção*, Master’s thesis, Universidade do Minho, Portugal.

Motamedi, A., Setayeshgar, S., Soltani, M. and Hammad, A. (2016), “Extending BIM to incorporate information of RFID tags attached to building assets”, *Adv Engineering Informatics*, 30(1), pp.39–53.

Motawa, I. and Carter, K. (2013), “Sustainable BIM-based evaluation of buildings”, *Procedia-Social and Behavioral Sciences*, 74, pp.419-428.

Naoum, S. & Egbu, C. (2015), “Critical review of procurement method research in construction journals”, *Procedia Economics and Finance*, 21, pp.6-13.

NBS National BIM Library - BIM Object Standard, https://www.nationalbimlibrary.com/en/nbs-bim-object-standard/scope-and-purpose. Accessed March 2019.

NBS National BIM Library - BIM Object Certification, https://www.nationalbimlibrary.com/en /nbs-bim-object-certification/. Accessed March 2019.

Oreni, D., Brumana, R., Banfi, F., Bertola, L., Barazzetti, L., Cuca, B., Previtali, M. and Roncoroni, F. (2014), “Beyond crude 3D models: from point clouds to historical building information modeling via NURBS”, *Euro-Mediterranean Conference*, pp.166-175.

Peres, M. and Costa, C. (2006), “Projeto AMA: Ações de Melhoria Ambiental do Setor das Pedras Naturais”, *Cevalor-Assimagra*, 98.

Perspectives, G.C. and Economics, O. (2015), *Global Construction 2030: A Forecast for the Construction Industry to 2030*, Global Construction Perspectives and Oxford Economics, London.

Presutti Jr, W.D. (2003), “Supply management and e-procurement: creating value added in the supply chain”, *Industrial marketing management*, 32(3), pp.219-226.

Rajah, E., Marshall, R and Nam, I. (2008), “Relationship glue: customers and marketers co-creating a purchase experience”, *Advances in Consumer Research*, 35, pp. 367-373.

Redmond, A., Hore, A., Alshawi, M., and West, R. (2012), “Exploring how information exchanges can be enhanced through Cloud BIM”, *Automation in construction*, 24, pp.175-183.

Silva, A. (2018), *Improving Industry 4.0 through Service Science: A Framework to improve the Portuguese Ornamental Stone Sector in BIM Procurement Context*, PhD dissertation, Universidade de Évora, Port.

Silva, A., Vilas-Boas, J., Almeida, I. (2016), "The role of digital technologies in the innovation of collaborative networks", *20th Cambridge Int. Manufacturing Symposium Univ. of Cambridge.*

Singh, V., Gu, N. and Wang, X. (2011), “A theoretical framework of a BIM-based multi-disciplinary collaboration platform”, *Automation in Construction*, 20(2), 134-144.

Singh, S., Mahanty, B. and Tiwari, M.K. (2019), “Framework and modelling of inclusive manufacturing system”, *International Journal of Computer Integrated Manufacturing*, 32(2), pp.105-123.

Vargo, S. L. and Lusch, R. F. (2016), “Institutions and Axioms: An Extension and Update of Service-Dominant Logic” *Journal of the Academy of Marketing Science*, 44(1), pp.5-23.

Wang, Y., Ma, H., Yang, J. and Wang, K. (2017), “Industry 4.0: a way from mass customization to mass personalization production”, *Advances in Manufacturing*, 5(4), pp.311–320.

Zawadzki, P., and Żywicki, K. (2016), “Smart Product Design and Production Control for Effective Mass Customization in the I4.0 Concept”, *Management and Prod. Engineering Review*, 7(3), pp.105–112.