The role of digital technologies in the innovation of collaborative networks: the case of the ornamental stones in Portugal

Agostinho M. Antunes da Silva[1,2], J. M. Vilas-Boas da Silva[1,2], Isabel Duarte de Almeida[1,3]

[1]Instituto Universitário de Lisboa (ISCTE-IUL), [2]BRU-UNIDE,
Avª das Forças Armadas, 1649-026 Lisboa, Portugal
Fax: +351 217 964 710; E-mails: amasa11@iscte.pt; jmvbs@iscte.pt; icspd@iscte.pt

[3]Universidade Lusíada, (CLISSIS-UL),
Rua da Junqueira 188-198 1349-001 Lisboa, Portugal
Fax: +351 213 638 307; E-mail: isabel.dalmeida@edu.ulusiada.pt

Abstract
This exploratory research outlines an innovative business model for the ornamental stones, in Portugal, targeting World Class Manufacturing. Research questions arise from an inductive approach empirically based on a participant-observer that participated in JETSTONE and INOVSTONE, two important Mobilising Projects for the cluster. A collaborative network pursuing a Service Systems view, leveraged by digital technologies was proposed based on a 3-stage development facilitated by the ARCON framework (ECOLEAD project), as follows: development of a general VBE/VO model completed by knowledge coming from BIM, Industry 4.0, IoT and Service Science backgrounds, in order to build up a specific model to the ornamental stones Industry. Finally, the specific model should be verified by case studies as demonstrating instances. While the generic VBE/VO might be customized to other domains, the specific model generates a representation of the Industry and the case studies serve as instances to verify it.

Keywords: Value Networks, Collaborative Networks; Virtual Organizations, Virtual Breeding Environments; Industry 4.0, Internet of Things (IoT); Building Information Modelling (BIM); Service-Dominant (S-D) Logic, Service Science.

1. Introduction

This article reports an inductive study with an exploratory purpose that is based on the extensive empirical knowledge of one of the authors. In fact, he has been part of the change process of the industrial cluster that has re-invented the ornamental stones sector, acting as a key participant-observer. This investigation aims at discussing the adequateness of a set of research questions that should establish relevant guidelines to orientate the development and confirmation of a conceptual business model addressing sustainable operations within the ornamental stones cluster. This should be able to leverage the competitive advantage both in Portugal and in the international arena according to the demographic characteristics of the sector and of its business agents.

This innovative organizational model is expected to follow a collaborative networked approach, to be sustainable, to consider the Service Science view and to incorporate the state-of-the-art of the digital technologies, as regards concepts such as the Building Information Modelling (BIM), the Industry 4.0 and the Internet of Things. Therefore, it should be developed and presented a preliminary outline of the features for an updated Information and Communication Technology (ICT) interface to support the network business processes that enable each organization to magnify its core competencies, resources and skills with complementary ones from the virtual community. Moreover, the ICT should be coordinated on the three levels of the Value System interaction - intra-/inter-partner and integration, in order to reduce the complexity of the design and implementation (Fuchs, 1997) of a system to realise and capture the value of a business opportunity (Katzy and Obozinski, 1998).

This is a significant topic since that the *Global Construction 2025 Report* (*in* HM Government, 2013) estimates a 70% growth for the construction sector, until 2025, at a global level. In the launching year of the BIM, i.e. 2013, the UK saved £840 M because of its use in two public projects (UK Government, 2013). Moreover, the United Kingdom is a major player, holding a top ten global market position and being part of a World Class Construction industry (Global Built Asset Performance Index, 2014).

Motivated by these results, the UK Government started a strategy towards the implementation of BIM in the Architecture, Engineering and Construction (AEC) industry, the Digital Built Britain (DBB). It aimed at increasing the annual profit in £10 Bn/year, in the domestic marketplace, by reducing waste and increasing competitiveness through the general use of BIM after 2016. These performance indicators anticipate the size of the potential savings in the international market, in the industry where the ornamental stones belong, as well as of the importance of this economic sector.

Therefore, the section 2 of this paper shows the economic importance of the ornamental stones, in Portugal, that goes far beyond €1000 M/year, acting as a cornerstone of the regional development by supporting a traditional cluster of the national industry. In addition, the leading purpose of the of the natural stone industry supported by a strong technological interface is disclosed. The aim is to assure the survival by pursuing a recognized world class excellence. Finally, the two earlier successful mobilizing projects were revisited, i.e. JETSTONE and INOVSTONE, as the context to frame the forthcoming organizational and technological steps. These developments should fit the industry nature, related to small dispersed SME, but simultaneously part of a hostile international environment of strong competition. Then, using a collaborative network for organizational modelling appears as an attractive path to proactive creation of value. From this point onwards research questions are set. Their interest and mechanics will be discussed in a subsequent section by considering the knowledge areas proposed as significant through empirical induction by the participant-observer taking into consideration not only his accumulated experience but also the progress of the competitive context.

However, before the discussion of the Research Questions taking place, the research methodology, i.e. the expected path to link the RQ to the expected outcomes is addressed (section 3). Several leading authors in collaborative networks were considered to inspire and support the choice of a reference model to operationalize the value system of the ornamental stones cluster. This model is part of the ARCON framework which includes both the endogenous and exogenous elements of a collaborative organization operationalized in a network. It also enables three levels of representation, as follows: general, specific to the ornamental stones cluster and case study instances.

Section 4 promotes the discussion of the empirical assumptions that were preliminarily considered by the participant-observer, by performing a literature review based on scientific journals. Not only the contents of the choices was checked, but also their relationships in the definition and operationalization of the key dimensions of a new model that should be adequate to the business, organization and current operations demands in the ornamental stones industry. Firstly, the role of the collaborative networks and virtual organisations is found as a relevant alternative, after the strategic context being set. Secondly, the impact of the new trends of the technological infrastructure in the collaborative model proposed for the ornamental stones is discussed. The potential contribution of the digital technologies to the sustainability of the collaborative model is approached under a Triple Bottom Line view. Finally, the strategic requirements of a Service-Dominant Logic are analysed in their proposal, value network relationships and progress needs. A significant gap was found out and a solution was proposed based on the Service Science domain.

Section 5 provides a summary of the core aspects of the article and revisits the research questions. It also explicits the expected innovative contributions to theory, research and practice.

2. Competitive environment of ornamental stones

Importance of the ornamental stones cluster in Portugal

Portugal does produce a broad range of ornamental stones, playing a major role in the exportation of these materials as the 8th world producer (ASSIMAGRA, 2014). The industrial cluster includes 17.000 of direct jobs, in 2.700 companies, acting on several activities, such as extraction, manufacturing, advanced machinery and tooling. The cluster turnover is around €1 Bn/year and the coverage rate of total imports by exports is 768%.
These data are completed by EUROSTAT and *Direção Geral de Geologia e Energia* (DGGE), as follows. In the early 2000s, exportations of ornamental stones were about €207 M€/year in 2004, i.e. 50% of the cluster activity. Moreover, these figures also represented more than 50% of the Portuguese exportations of mineral substances, in 2004. Marble and Limestone were the most exported (≈63%), followed by Granite and similar stones (≈19%), Stone to Sidewalk (≈15%) and Slate (≈3%) (Schists).
The excellence of raw material, the robustness of the industry cluster despite being a traditional sector, the flexibility and adaptability to new market demands are the critical success factors that support the ranking of Portugal amongst the tem major world players. This is a significant economic activity for the national economy and also for rural development that is among the top industry sectors as regards Gross Added Value (GAV).

Main purpose of the natural stones cluster in Portugal

The natural stones cluster aims at continuing to increase exports in a sustainable way. The main cluster drivers were identified, as follows:

- To continue to develop a leading industry, as regards both technology and organization, under a World Class Manufacturing paradigm;

- To leverage the competitive advantage with state-of-the-art technology, developed in Portugal, aiming at its transference/trading to other significant world players;
- To improve the «supply chain» operations performance by broadening variety; developing customization; reducing time-to-market; decreasing cost; improving quality and business sustainability becoming more environmental friendly;
- To create the appropriate conditions to reinforce the credibility of Portuguese players in the international arena, e.g. as regards the satisfaction of both higher volumes and higher variety levels;
- To improve the image of the natural stone products of Portugal and so, adding value to the industry;
- To develop a more demanding collective behaviour in the cluster, as regards environmental friendly operations.

The industry has been recognizing the co-creation of value both internal and externally to the «supply chain» as the path to increase competitiveness and so, the long term sustainability of its operations towards survival assurance. However, the pursued sustainability is a broad approach that also concerns the well-being of the stakeholders, the concern with the depletion of non-renewable and renewable resources, the removal, treatment and disposal of waste, the survival of the members of the industry and the economic problems of target market communities. This view is aligned with the principles of sustainable development proposed by Elkington (1997), Hawken et al. (1999), Porritt (2001) and, Dyllick & Hockerts (2002).

Anticipated future of the ornamental stones in Portugal and research questions

The ornamental stones cluster has suffered the positive impact of a few Development Mobilising Projects targeting the development and application of a new generation of technologies, concepts and practices, as follows: (i) adding flexibility to manufacturing and promoting agility of customized projects; (ii) reducing the raw material waste; (iii) improve energy efficiency; (iv) upstream integration in the supply chain; (v) increasing productivity; (vi) promoting new product development; (vii) improving the working conditions; (viii) improving product and service quality; and, (ix) being more environment friendly.

The JETSTONE Mobilising Project operationalized the first stage of this path, by setting up a consortium of 10 companies and organisations from the National Scientific and Technological System (SCTN). 15 innovative prototypes of advanced machining centres used by tenths of firms were the main visible outcome, in 2008. The INOVSTONE Mobilising Project (2013) resulted from a consortium of 16 organisations and generated more 8 prototypes, their integration in modern layouts and addressed new production concepts. These projects contributed to the creation of 2.000 jobs and a positive input of €180 to 240 M for the Portugal's trade balance. Thus, the wealth created by these projects, in a 5 years' period, was 34 times bigger than the investment. The lesson to be learnt from practice is that these projects created a leverage effect across the cluster that would be impossible to achieve from non-coordinated action of individual companies.

Lately, different concepts about creating value from «*Collaborative Networks* (CN)» (Camarinha-Matos & Afsarmanesh, 2007) have been proposed. However, they require a research effort towards their operationalization. In fact, several projects concerning «*Collaborative Networks* (CN)», «*Virtual Breeding Environment* (VBE)» e «*Virtual Organizations / Virtual Enterprises* (VO)» have been financed, since the European Union's fourth research and technological development (RTD) framework programme (1994-98). One of these was the ECOLEAD project developed under the FP6.

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) aiming at collecting synergies from these collaborative trends. These models include ICT interfaces (e.g. Fuchs, 1997 and Katzy, 1999) that have to be updated with the outcome from digital technologies, either in general, or coming from a AEC background, such as the Building Information Modelling (Kim et al., 2015) or the CAD 3D (Björk & Laakso, 2010). In this way, the advanced manufacturing technologies coming from the JETSTONE and INOVSTONE projects are a critical requirement to assure the internal integration of the partners, a cornerstone for the inter-partner coordination and control required for the external integration in a value network.

Despite organisational and technological development follow the direction pursued by the classical collaborative models of Bernhard Katzy and Luís Camarinha Matos (*e.g.* Silva & Almeida, 2016), there is new knowledge to be considered and integrated. Thus, a new reference model (*vide* Romero & Molina, 2010) for the ornamental stones should be developed. The Digital Economy and the Internet of Things are examples of new concepts and technologies that further power models such as the Industry 4.0. On the other hand, some authors have been arguing for a change from a product-dominant to a service-dominant logic (Edvardsson & Tronvoll, 2013), where stakeholders are considered as resources of the value chain.

This is the background, both from practice and theory that accommodates the following preliminary research questions derived in an inductive way

- RQ1 – How may a collaborative typology fit the requirements of the ornamental stones cluster made up of familiar SME?
- RQ2 – What is the specification that a collaborative network for the ornamental stones cluster should meet, in order to be built an effective framework, as regards:
    i. Common organizational structuring;
    ii. New business models;
    iii. Shared ICT infrastructure;
    iv. Manufacturing technologies.
- RQ3 – Why should both individual organisations and also the cluster of the ornamental stones pursue the implementation of a collaborative environment?
- RQ4 - Which methodological path is adequate to the design, development, implementation and operation of a collaborative environment in the ornamental stones cluster, in Portugal?

3. Outline of the methodological path to be pursued

The ECOLEAD Reference Model (e.g. Romero et al., 2008; Romero & Molina, 2010), comes from the ARCON framework, which covers both endogenous and exogenous elements of a collaborative organization arranged in a network (e.g. Silva & Almeida, 2016). This model appears to be a good starting point for the operationalization of the *Value System Lifecycle* (VSL) of Fuchs (1997) and Katzy (1999). The VSL is a framework to support the design of

Virtual Organisations by covering all the stages of their lifecycle based on a collaborative network of competences that are made available by the partners. This is what would later be called a *source network* or a *breeding environment* (Silva & Almeida, 2016). On the other hand, this model should be completed by knowledge coming from such domains as BIM, Industry 4.0 and S-D logic.

This is how the future developments of the ornamental stones is anticipated, within the context of the 4th Industrial Revolution. The current knowledge of the computer science is applied to the development of a value system based on a collaborative network that emulates and focus on relationships, interfaces and partnerships. These three dimensions are the core part of (i) the collaborative processes that overcome the focus on the physical resources; (ii) the co-created service value that overcome the (physical) product specifications; (iii) the implementation of a *Virtual Organization Breeding Environment*.

Within this context, the *instantiation* methodology looks adequate as a good fit (Romero et al., 2008), enabling the following four main steps:

i. To critically appreciate the usefulness of the *Reference Model* from ECOLEAD, to consolidate it and to develop it into a general model leveraged by the current ICT potential, leveraged by the S-D logic;

ii. To further develop the general into a specific model adequate to the ornamental stones cluster;

iii. To empirically test the resulting specific model in a case study from the ornamental stones, implementing it or detailing recommendations for its implementation;

iv. To analyse the external validity of the general model specification through an analytical approach.

4. Discussion of the proposal obtained through an inductive approach

Strategic positioning of the ornamental stones industry

Procurement is a relevant function, specially when a focus-company is outsourcing operations. However, the e-procurement is still residual in the ornamental stones (Silva, 2013) because the required information is neither structured, nor in a digital format in the AEC sector (Grilo & Jardim-Goncalves, 2012). Moreover, the use of BIM at a global level (Liu et al., 2015) that is being imposed by governments such as the UK one (HM Government, 2013), places new challenges to the AEC stakeholders, as regards procurement (Grilo & Jardim-Goncalves, 2012). The consequences of these demands are still unpredictable (Merschbrock & Munkvold, 2015). Nevertheless, the Digital Built Britain (DBB) strategy aims at making the UK a world leader in BIM, with expected outcomes of £10 Bn/year profit, coming from more competitiveness and bigger exports.

The virtual building design in BIM is obtained by adding up elements in digital format IFC (Won et al., 2013). Objects are specified in an open format of eight dimensions (ISO 16739:2013), from where the BIM modeler, now the customer, might appreciate materials diversity, geometric adaptability, originality, price, lead time, ecological footprint, maintenance cost during the whole lifecycle, safety (Jung & Joo, 2011), i.e. their fingerprint.

The next step is the project approval by the adequate authorities and, then, parts will be allocated to suppliers according to the planning outcome of BIM. The construction stage will, then, start (Hamil et al., 2014). Despite the building owner might buy the parts freely, the elements' fingerprint has to strictly follow the project approval requirements (Eadie, Browne, Odeyinka, McKeown, & McNiff, 2013). Thus, choices during design might very well constrain vendor's selection, unless a new formal approval is obtained (Malsane, Matthews, Lockley, Love, & Greenwood, 2014). In this way, the BIM modeller, typically an architect, will assume the role of decision making customer. Moreover, it is mandatory that the building is constructed according to the plans, in order to be obtained the expected result.

As the very first consequence of this new procurement model, the supply chain stakeholders must make public all the commercial and technical information concerning their products in open format IFC (Hamil et al., 2015). Being the prices public, the chosen option should have a more effective value structure, where reducing waste through continuous improvement will perform a relevant role (Yang et al., 2011) in competitiveness.

In the specific case of ornamental stones there will be an additional determinant for the BIM modellers to prescribe this type of solution. If the objects in the libraries do exhibit a rigid spacial geometry the IFC objects will not adapt to building irregular shapes and, so, material differentiation that characterizes Portuguese ornamental stones will be lost. Therefore, the stone objects have to be dynamic at the moment when they are inserted in the BIM platform (Heidari et al., 2013), in order to be adaptable to the building, during the design stage (Soediono, 2003). This challenge is even bigger, because these elements are manufactured from natural raw materials, where every block is unique (Galetakis & Soultana, 2016). Thus, there is a conflict 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 visibility to the business and to the procurement process itself (UK Government, 2011). On the other hand, making available ornamental stones' objects adaptable to the building and to the BIM modeller/prescriber requirements might become a competitive advantage, if information interoperability is assured.

Beyond taxes becoming easier to update in real time, other expected advantages of BIM are, as follows: 33% reduction in the costs of construction and maintenance during the whole lifecycle; 50% reduction in construction time for both new buildings and refurbishing; 50% reduction in total CO_2 emissions in the construction industry (HM Government, 2013). The assumption of these objectives will put pressure on all the stakeholders of the AEC supply chain. As regards the ornamental stones, these targets together with the adaptability requirements of the virtual object do impact the way operations are currently organized in the supply chain and also, the existing organisational model. If no action is taken, the survival of the ornamental stones industry is seriously threatened. Therefore, an operations model that assures the sustainability of companies within a BIM context has to be addressed. In fact, several researchers have tried to address the advantages of collaboration in sustainable competitiveness, when facing more hostile environments, with more complex products, more dynamic ones with more changing requirements and also, more demanding contexts, as regards quality and accountability (Feller et al., 2013). Therefore, the collaborative network model appears to fit well within these dimensions of the competitive context of the ornamental stones.

Expected role of collaborative networks and virtual organisations

According to Kropotkin (1903) cooperation and mutual aid are determinants of the evolution and survival of the species. The collaborative work in organisations helps to overcome individual limitations, specially in SME where skills and resources are very limited (Camarinha-Matos & Afsarmanesh, 2007).

The ornamental stones cluster both in Portugal and in the World is mainly made up of familiar SME (UK Government, 2011). Therefore, the lack of both economies of scale and scope might be a serious drawback of sustainability within a BIM context. For this reason, an operations model promoting inter-organisational collaboration is definitely a solution to be seriously taken into account. In fact, the BIM modeller will share information concerning the progress of the virtual building with other professionals, which might result into shared innovation leading to value creation (Edvardsson & Tronvoll, 2013).

Several types of collaborative organisations have been introduced such as *Industrial Clusters*, *Industrial Districts*, *Business Ecosystems* (Akaka et al., 2015). Usually, they put together organisations sharing common interests within a certain region that build up a coordinated response to business opportunities that would not be individually affordable (Romero et al., 2008). In addition, the quick progress of the ICT put together with globalization, but including requirements for increased customization has led to the conceptualization of new types of long term strategic alliances such as the *Virtual Breeding Environments* (VBE) (Afsarmanesh et al., 2009).

A VBE is a long term consortium of organisations (Camarinha-Matos & Afsarmanesh, 2007), committed to adopt common operations principles and to share infrastructures pursuing the goal of being prepared to work together in a collaborative network at any moment (Afsarmanesh et al., 2009), generating Virtual Organisations (VO) that might be able to operationalise value co-creation. Therefore, a VO is a model of collaborative operations in the short term, designed within a VBE to respond to an emergent business opportunity by integrating knowledge, skills and other resources (Romero, 2009).

The VBE concept applied to the ornamental stones appears to be an effective way to overcome some weaknesses of the sector. VO might overcome the consequences derived from the small size of the cluster firms, e.g. the lack of knowledge and skills of individual organisations, the diversity of raw materials, the high customization requirements, the shorter lead times being asked, the high costs of promotion and market entry, and the high structure costs. However, developing a shared ICT infrastructure by all the VBE members is a *sine qua non* condition (Afsarmanesh et al., 2009).

In the last 15 years, the ornamental stones industry has incorporated both ICT and advanced manufacturing technologies, as previously mentioned (JETSTONE and INOVSTONE Mobilising Projects). Thus, these companies make use of the state-of-the-art production technologies in their internal operations. However, to work within a VBE/VO paradigm there is a need to develop inter-organisational systems that respect common interoperability protocols. So, the development of the requirements for this interface is a relevant part of the technological ICT infrastructure to be implemented.

Trends of the technological infrastructure and impact on the collaborative model

Many researchers consider that the 4th Industrial Revolution already started. Some call it Industry 4.0 (Kagermann et al., 2013), where real and virtual worlds meet in the Cyber-Physical Systems (CPS) (Fair et al., 2012). Industry 4.0 was coined by the German Government in 2011 (Produktionsprozess & Prozesskontrolle, 2014) to describe a leadership strategy from the German Industry (Mosterman & Zander, 2015). The idea was to use digital technologies to facilitate the interaction between machines and products (Fair et al., 2012) to reverse the industrial decline in Europe (Kagermann et al., 2013). Moreover, the potential to improve collaborative innovation (incremental and radical) within the AEC supply chain might be magnified by digital technologies (Eppler, 2008). Therefore, a 20% increase in value creation until 2020 is expected (Davies, 2015).

Within the ornamental stones Industry, it is expected that machines' communication might be promoted inside CPS, without being dependent on the geography of each one (Ivanov et al., 2016). Therefore, machines, devices, sensors, and people should be able to connect and communicate with each other via the Internet of Things (IoT) or the Internet of People (IoP). This is the expected meaning of interoperability (Karan & Irizarry, 2015), when applied to the AEC sector. Moreover, there is a strong synergy between these requirements and the technological infrastructure for a VBE (Afsarmanesh et al., 2009), in such a way that this platform might arise almost naturally, if production follows an Industry 4.0 approach (Ivanov et al., 2016).

Trends of the technological infrastructure and impact on sustainability

Industry development, despite important in economic terms, has originated growing problems, such as depletion of natural resources, negative impacts of waste and social damage. Industry uses 37% of the total amount of energy consumed in the world (EEA, 2010; IEA, 2013), which stresses the need to avoid waste during the total product lifecycle. There is an opportunity to increase energy efficiency and to improve the effectiveness of monitoring and management of energy (Wong & Zhou, 2015).

The ornamental stones cluster is very sensitive to the problem having promoted studies to refurbish machinery in order to reduce the consumptions of water and energy, at the same time that the production performance ratios are increasing. Reducing dust, waste and noise have also been recurrent concerns (Silva, 2014).

Industry 4.0 enables an opportunity for more sustainable value creation (Mosterman & Zander, 2015) since the resource allocation, i.e. raw materials, energy and water might be more efficient (Kagermann et al., 2013), contributing to the three dimensions of sustainability, i.e. economic, social and environmental (Veludo, 2015).

On the other hand, the real time approach to phenomenon of the Internet of Things (IoT) (Albert, 2015) facilitates object (inter)communication, i.e. information exchange about location, functionalities and problems enabling a strong connection with the virtual world by powerful sensing of the real world (Motamedi et al., 2016). The ability to monitor and control in real time the production of ornamental stones is essential to generate a positive impact on the environment. In this way, one may speak about closing the planning loop previously opened with the definition of the ecological footprint of the BIM objects with this ability to control the events in real time in the construction elements and, also, within the building itself (Wong & Zhou, 2015).

Moreover, as an "intelligent connection of people, processes, data and things" (Hoske, 2015), the IoT can improve the sustainability performance of the companies, since it magnifies the potential of the analysis in real time of several business processes and enables the visualization of resource inefficiencies (Benkhelifa et al., 2014). On top of that the growing availability of data through the IoT will bring a massive amount of information about the contexts where sensors are. Thus, by combining big data analysis, companies may identify with more accuracy environmental risks and even avoid resources to be fully depleted (Bojanova et al., 2015).

Evolution of purpose and relationships in value networks: a Service-Dominant Logic

The Service-Dominant Logic (Lusch et al., 2009) has developed by focusing its analysis on partnerships, relationships and value created, in alternative to production and product transactions. All the economic activity is understood as a service, and this, as a resource or competence of the value chain that exist and is available to benefit another entity (Lusch et al., 2009). So, services are the fundamental processes of the economic activity. As regards demand and supply of services stakeholders are understood as resources from the value chain of which the customer is part as a co-creator, always not fully satisfied (Payne et al., 2007; Lusch et al., 2009).

In the context of this assignment the targeted collaborative operations model is aiming at diversity, originality, differentiation, competitive price, short lead time, sustainability, safety and low maintenance costs, features that appear to be compatible with the value approach promoted by the S-D logic (Lusch et al., 2009). Moreover, the Service-Dominant logic is in line with BIM, as regards considering the customer as a co-creator, which is the architect role (Yalcinkaya & Singh, 2015). However, Ivanov et al. (2016) state that in smart factories it is not enough that IT just give support to services to distribute information within the value network as Lusch et al. (2009) put it. In fact, products should communicate with the machines inside the CPS, during the production process, independently of the plant location (Lasi et al., 2014; Davies, 2015). Therefore, the S-D logic fits a VBE because Innovation and Production supported by CPS might be seen as a service, since the architect (BIM modeller) might co-create innovation (Edvardsson & Tronvoll, 2013) and, then, send the final fingerprint to the plants' CPS exactly in the same way one sends a file to a 3D printer. On the other hand, the S-D logic does not consider communication processes between machines and customers, which is a drawback that limits the concept of Industry 4.0.

Considering the customer as part of the value chain within the VBE might be an advantage to the application of the VBE model (Romero & Molina 2010) to the ornamental stones cluster. In fact, the customer plays a significant role as value co-creator within the supply chain (Eppler, 2008) by performing the modeller job in BIM. Moreover, this solution might even be stronger by considering the *lean thinking* (Fullerton et al., 2014) and digital processes coming from the 4th Industrial Revolution (Mosterman & Zander, 2015). In summary, these concepts and theories are common to the AEC stakeholders and, therefore, they are identified as critical determinants of the mandatory objectives for BIM projects (HM Government, 2015).

Conceptual outline of the organisational model under development

In digital production there is a need for a perfect communication in real time between machines and customers, where lacking a *bit* might stop a full production line. Thus, some authors that have started from the S-D logic suggested a computer science approach, creating the service system concept, as configurations of co-creation of value by sharing information and, internal and external linkages of people, technology and organisations (e.g. Maglio & Spohrer, 2008; Edvardsson & Tronvoll, 2013). In the extreme, the global economy is the biggest service system, including cities, countries, governments and economic agents, such as companies and consumers (Maglio et al., 2009). The Service Science is the study of the service systems that are simultaneously supplier and customer of the same chain of services and, also, of co-creation of both value and innovation (Maglio & Spohrer, 2008). In *Service Science*, resource typologies of the value chain are identified according to their nature, i.e. resources with rights (people and organisations), resources with property (technologies and shared information) and, social resources (organisations and shared information) (Maglio & Spohrer 2008). These four categories are simultaneously centred on value creation by the S-D logic, where the customer is a co-creating resource in the supply chain and, in line with the principle of utilization of the BIM collaborative platforms (Yalcinkaya & Singh, 2015).

As regards the VBE model applied to the ornamental stones, advantages might arise from the service logic, i.e. from the interaction of the customer (BIM modeller) with the suppliers of objects within the AEC supply chain, which also is a source for collaborative innovation, both incremental and radical. By taking the Service Science view, the existing separation between products and services in the VBE models (e.g. Romero & Molina, 2010) might have to be reformulated under the grounds of the 4th Industrial Revolution (Constantinescu et al., 2014). Moreover, the customer might have to be considered as an internal resource able to co-create value and innovation within the VBE. In addition to the Service Science, the conceptual VBE model for the ornamental stones should be part of the current paradigm and include emerging ideas such as the *Internet of Things* and the *Industry 4.0*. This is a strong modern despite arguable view to converge over the mandatory objectives set to drive the BIM approach (HM Government, 2013).

In summary, it is proposed that the suppliers of products in stone (plants) might be considered as an interactive resource of the customer (BIM modeller). Thus, he or she will co-create innovation when integrating the value chain. This innovation will be sent as a final fingerprint, in IFC format, to the plants CPS. Thus, the BIM modeller and the supplier interact to optimize the final product. This simplifies the ICT typology essential to a VBE (Afsarmanesh et al., 2009).

5. Conclusions

This research made an attempt to outline the main guidelines for an innovative business model adequate to the ornamental stones Industry that targets excellence in the global market. The exploratory research questions were established inductively, based on the cluster observation put in the competitive context. They anticipated the Industry purpose and so, a proposal for a collaborative network model with two critical dimensions, i.e. the organizational and the ICT infrastructure. The *ex-post* discussion helped to theoretically assess the interest and adequateness of the proposal and to characterize the guideline requirements of this model by following the Service Science logic leveraged by state-of-the-art digital technologies such as

BIM, Internet-of-Things and Industry 4.0. This was the chosen path to operationalize a value system based on a collaborative network attempting to match the requirements for the cluster strategic positioning.

Revisiting the research questions

As regards collaborative typologies (RQ1), the VBE/VO operations model appears to fit well within the "mandatory" dimensions of the competitive context of the ornamental stones, by assuring the sustainability of Portuguese familiar SME within the environment of the AEC sector. In fact, the co-creative collaborative interaction between the BIM modeller (customer) and the resources (suppliers) was understood as a cornerstone in value creation centered on a service dominant logic.

As concerns the specification outline of a collaborative network (RQ2) inter-organisational systems that respect common interoperability protocols should be outlined for the AEC sector by considering a strong synergy between organisational requirements and the technological infrastructure for a VBE. Digital technologies, such as Industry 4.0 and Internet of Things should support the creation of Cyber-Physical Systems where real and virtual worlds meet to operationalize a competitive and sustainable Service System.

These concepts and theories, which are already available to the AEC stakeholders, are identified as critical determinants of the mandatory objectives for BIM projects as follows: reduction in the costs of construction, in the costs of maintenance, in the construction time and in the total CO_2 emissions, in the construction industry. The Portuguese ornamental stones cluster aims at developing a leading industry, under a World Class Manufacturing paradigm (RQ3).

As regards the methodological options (RQ4), the ECOLEAD Reference Model was chosen to represent a collaborative network. The approach should start by a general VBE/VO model completed by knowledge coming from BIM, Industry 4.0 and Service Science backgrounds, in order to build up a specific model to the ornamental stones Industry. Finally, the specific model should be verified by a case study as a demonstrating instance.

Expected innovative contributions

This research assignment should contribute to an innovative approach to the (re)organization of an important sector to the country – the ornamental stones Industry. This approach is closely related to the development of organizational environments to incubate and source virtual organisations. The scope of the investigation concerns both the organizational and the digital (ex-ICT) dimensions of the model. The following contributions are expected:

1. To theory, as regards the development of the stage I of the reference model, which focus on the broad business needs; this model is enough general to be customized to other domains, if its usability and applicability requirements are fulfilled;

2. To research in the Operations Management domain, as concerns the positioning of operations as the thrust of value co-creation and as supporting the achievement of competitive advantage (stage IV of Hayes & Wheelwright); the stage II of the reference

model is expected to generate a model specific to operations in the domain of ornamental stones, in Portugal;

3. To practice, because the research should drive the modernization of the ornamental stones Industry, assuring its survival even in global hostile competitive environments; the development of organizational models enabling economies of scale and scope should be facilitated and verified through case studies (stage III of the reference model).

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