Sensing, Smart and Sustainable S^3 Enterprises: Principles, Goals and Rules

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Abstract. Currently, traditional companies need of models, skills, processes and technologies to face the challenges imposed by the highly competitive market, which requires constant innovations. Through the concepts of detection and monitoring, intelligence and sustainability, Sensing, Smart and Sustainable (S^3) enterprises exert an important role in the digitization of strategies, decisions and operations, and are efficient to face the challenges intrinsic to the digital economy and intelligent manufacturing. Literature presents the need of development of methods and enterprise models that portray reality of the S^3 Enterprises. In this context, to facilitate the formalization of S^3 Enterprises and understand the dynamics of their operations, this paper aims to develop an enterprise model of such organizations. Through the For Enterprise Modeling method, the enterprise model documents the goals, business rules, processes and concepts of S^3 Enterprises. The contribution of this paper is the identification of guiding principles that allow companies interested in applying the S^3 concepts have a reference as base, once it has been mapped through perspectives of different domains of knowledge.

Keywords: Sensing enterprise · Smart enterprise · Sustainable enterprise
Enterprise modeling · Intelligent manufacturing

1 Introduction

Weichhart et al. [1] introduced the concept of Sensing, Smart and Sustainable (S^3) enterprise system, presenting the challenges and current developments of digital age companies. This concept its quite new, therefore, there are a lot of challenges around this novel theme. Like the Industries 4.0, Made in China 2025, Internet Industrial, Advanced Manufacturing, Internet +, Society 5.0, among other similar initiatives developed in many countries, S^3 Enterprise can be seen as one of the industrial approaches for achieving the intelligent manufacturing.

The concept of sensing enterprise was created with the advent of the Augmented Internet, representing an attempt of reconciling traditional non-native "Internet-friendly" organizations with the stupendous possibilities offered by the cyber worlds [2]. Sensing enterprise is characterized by the anticipation of future decisions through of capture of multidimensional information, and it enables that a company reaches and

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knows different scenarios. In addition, sensing enterprise develops proactivity and dynamism for quick and efficient decision-making in a short time [3]. According to Filos [4], smart enterprise is an interconnected, knowledge-driven organization. Smart enterprise is able to adapt quickly to changes and challenges of the current competitive market, and also is agile enough to create and exploit knowledge, in response to the opportunities of the digital age [4]. Sustainable enterprise concept is associated with the implementation of good manufacturing practices, reducing the use of inputs for production, optimizing plant operations and improving products in order to minimize the inherent environmental impacts arising from its use and life cycle. Thus, in addition to environmental concerns, the sustainable enterprise must include social, economic and ethical aspects [5].

S^3 enterprises aim to meet the challenges of the digital age, requiring proper formalization [1]. Enterprise modeling is fundamental to understand the connection between companies, as well as the dynamics, robustness and fragility of the activities developed [6]. So, this paper aims to model the main elements related to S^3 enterprises through For Enterprise Modeling (4EM) method. The enterprise models aim to stimulate the application of sensing, smart and sustainable concepts.

2 Guiding Principles of the Modeling

According to Weichhart et al. [1], the sensing, smart and sustainable concepts are based on eight principles: agility, transparency, empowerment, sharing, collaboration, resilience, innovation and self-organization.

Agility is a temporal concept, associated with the response time and cycle of identification of opportunity, configuration, operation/reconfiguration and dissolution [7]. Transparency ensures access to information and cloud-based processing for enabling community response [1]. Empowerment refers to the influence and control of individuals and communities on the decisions that affect them. Sharing information and knowledge encourages innovation and collaboration processes [1]. Collaboration occurs when several autonomous and geographically distributed entities with a heterogeneous operating environment, culture, goals and social capital collaborate to achieve better results and common goals. Collaboration among companies is present in several studies involving: network of collaborative companies, alliances, partnerships, cooperation, collaborative supply chain, among others [8]. Resilience is the association of 3 essential components: notion of trauma, adversity and risk to the human development; positive adaptation and overcoming adversity; and process that considers the dynamics among emotional, sociocultural and cognitive mechanisms that influence human development [9]. Innovation is the successful use of new ideas in terms of products, processes, services and business practices [10]. Self-organization is the ability of reorganization of networks into more complex structures, as well as the use of more complex processes without a detailed and centralized management guideline [11].

This paper aims to stimulate the application of S^3 systems in companies, aid its formalization and processing of large amount of information, and pursuing this purpose, the principles have been incorporated into the modeling.

3 Methodology

3.1 Research Method

For modeling S^3 enterprises, papers published in Scopus and Web of Science databases were analyzed, and specialists of companies that are targeting the sensing, smart and sustainable concepts were interviewed. The professional interviewed was part of the staff of a technology company in the field of optoelectronics (working in the medical, industrial, optical, aerospace and defense components). In 2009, the company received the FINEP Innovation Award, in the category Medium-Sized Company. The professional was responsible by the departments and processes of import, export, purchasing, planning and control of production, warehousing, receiving and shipping.

3.2 Enterprise Modeling

For Loucopoulos and Kavakli [12], enterprise modeling is a set of conceptual modeling techniques to describe the structure and business processes of a company, its missions and objectives. For Sandkuhl et al. [13], 4EM provides systematic support for analyzing, understanding, and documenting a business, its objectives, business processes, and support systems. 4EM is based on organizational modeling, in order to clarify all current corporate functions, present requirements and necessary reasons for possible and certain organizational changes, expose alternatives to those requirements, and provide criteria for the evaluation of these alternatives.

4 Results

Based on the interview conducted and the information of the literature related, the Concepts, Goals, Business Rules, and Processes models were developed.

4.1 Concepts Model

S^3 enterprise is a digital company. The learning environment is necessary for efforts to bring benefits to companies. In this learning environment, teamwork refers to the flexibility, versatility, creativity and intelligence, essential concepts to S^3 enterprises. Sensing system includes orientation towards change and smart system involves the concepts of human and technological system and virtual organization. Sustainable system covers the concepts of reuse, reduction, recycling and consumer orientation, where the first three refer to the environmental aspects and the fourth to the economic and social aspects. Architectures and languages divided in enterprise architecture and service-oriented architecture serve as support for the system sustainability. Architecture is a description of a basic arrangement and connectivity of parts of a system and usually has several meanings, depending on its use. Guiding principles of S^3 enterprises are: agility associated with dynamic configuration, transparency, empowerment, sharing,

collaboration, resilience, innovation and self-organization. Figure 1 presents the Concepts Model.

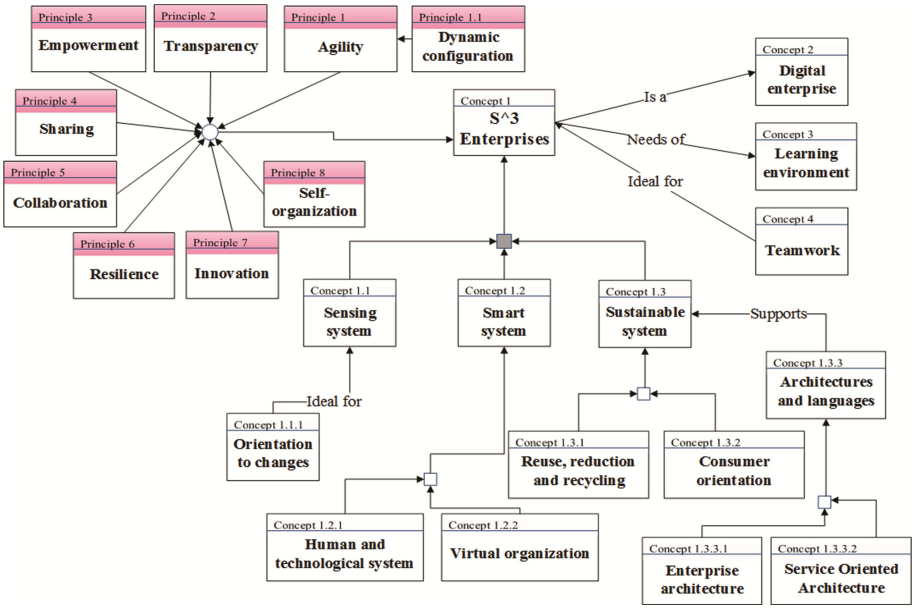

Fig. 1. Concepts model.

4.2 Goals and Business Rules Models

Figure 2 presents the Goals and Business Rules of S^3 enterprises. The main goal is to stimulate the application of S^3 systems, and it is directly supported by two goals: to strengthen competitiveness and to process large amount of information. S^3 system seeks to stimulate the sensing, smart and sustainable philosophies, create mechanisms for stimulating innovation, and to ensure collaboration, cooperation and a holistic vision. The threats related to this goal are conceptual, organizational and technological barriers. Some business opportunities are identified, such as improving digital competencies and decision-making. To strengthen the company competitiveness, it is necessary to invest periodically in intellectual assets. Processing large amounts of information requires strategic use of Information and Communication Technologies (ICTs) for real-time information gathering, integrated ICTs platforms, and adaptation to the increase in the volume of transactions. Stimulating the sensing philosophy requires the use of convergent ITs, and dynamism to meet market expectations. Stimulating smart philosophy makes continuous use of smart services. Stimulating sustainable philosophy requires the constant incorporation of elements of self-organization. Creation of mechanisms to stimulate innovation requires the continuous reappraisal of traditional paradigms and actors with complementary cognitive distances. To ensure collaboration and cooperation and a holistic view, it is essential to invest in Research and Development (R&D)

throughout the product life cycle. In addition, we can mention some rules that support this last goal, such as: stakeholder involvement throughout the product life cycle, development of an overview of the supply chain, and systematic monitoring of the product development process. Lastly, of course, there is a need to periodically audit the S^3 system, to ensure that it remains fully operational and that the main goals and all other goals are effectively achieved.

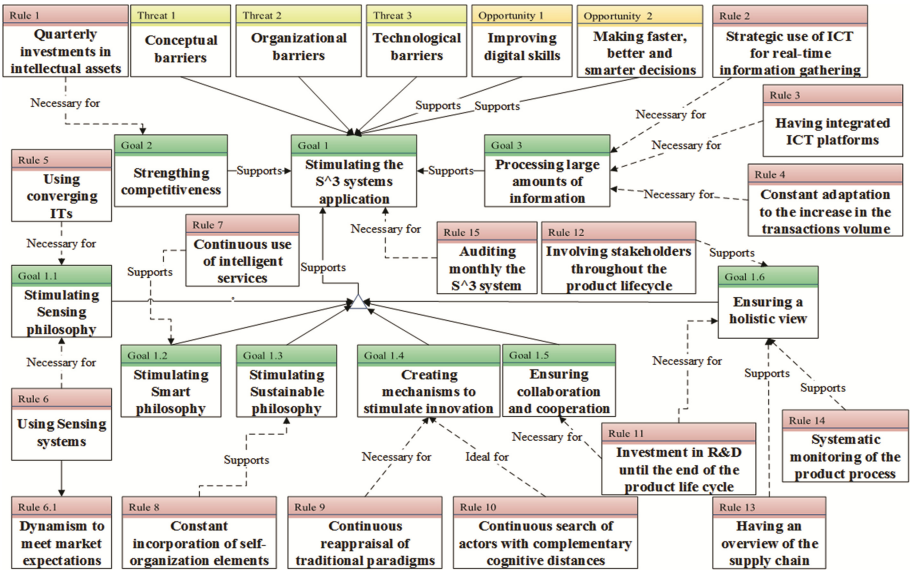

Fig. 2. Goals and business rules model.

4.3 Processes Model

The Processes Model of the 4EM interacts with Goals, Business Rules, and Technical Components and Requirements models. Figure 3 illustrates the Processes Model of S^3 enterprises. The process of sensing systems development is supported by the stimulus to this philosophy, capture of multidimensional information and proactivity and agility in decision making. Process 1 is triggered by five business rules: use of converging ITs; strategical use of ICTs to collect information in real time; establishment of collaborative links for innovation transfer; sharing of skills and resources; alignment and compatibilization of interorganizational goals. The process of smart systems development is supported by the stimulus to smart philosophy, adaptability to market needs, creation and exploitation of knowledge and responsiveness to the opportunities of the digital age. continuous use of intelligent services, integrated ICT platforms, establishment of collaborative links for innovation transfer; sharing of skills and resources; alignment and compatibilization of interorganizational goals are rules that trigger this process. The process of sustainable systems development is supported by stimulus to the sustainable philosophy and operations optimization of facility that receives support of a best

practices bank. The process of sustainable systems development has eight associated rules: constant adaptation to the increase in the volume of transactions, incorporation of elements of self-organization, periodic audit of the S^3 system, reduction of productive inputs, improvement of products to minimize environmental impacts, establishment of collaborative links for innovation transfer, sharing of competencies and resources, and alignment and compatibility of interorganizational goals. Dashed lines indicate the interface among elements of different 4EM submodels.

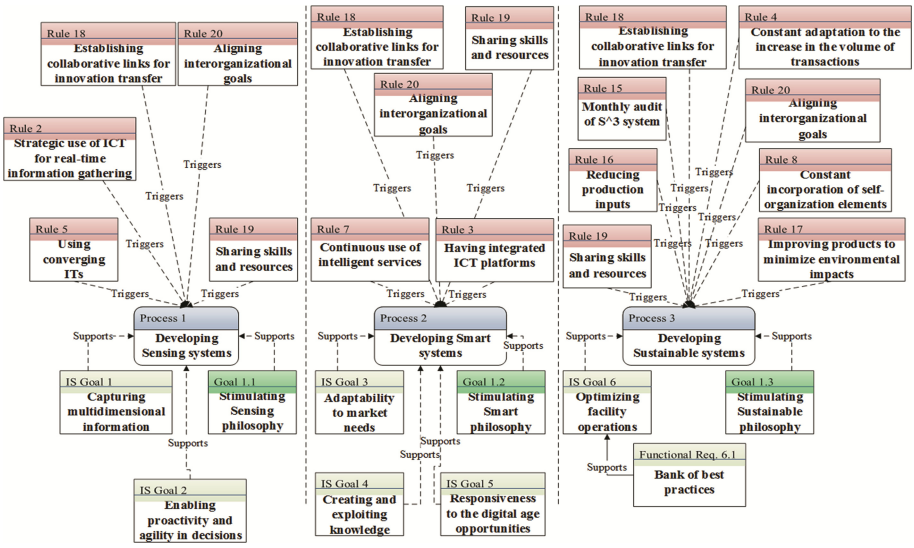

Fig. 3. Processes model.

5 Discussion of the Results

Using the 4EM methodology it was possible to obtain the following results:

- The Concepts Model presented the main definitions and principles of the S^3 enterprises, as well as some supporting concepts (architectures and languages) and its needs (orientation to change, teamwork and learning environment).
- The Goals and Business Rules Models presented the main goals of S^3 enterprises, the opportunities that can be reached with this new business paradigm, threats that hinder these opportunities, as well as the guidelines that, in addition to being closely related to the goals and processes, indicate the main considerations to be analyzed in its formalization.
- The Processes Model associates goals, rules, technical components and requirements, however, due to restriction of information, this model does not present in detail the main activities carried out for the formalization of S^3 enterprises. Even so, it is possible to observe the main rules that trigger each necessary process, as well as the information system goals and functional requirements that support certain processes.

6 Conclusions

This research presented concepts related to the S^3 enterprises, whose goals are directly related to the new trends and needs of the market. Through a literature review and consultation with specialist in the field, this study sought to provide an overview of the sensing, smart and sustainable concepts, with the purpose of developing enterprise models based on 4EM method. In this way, the models presented an initial view on the main requirements necessary for the formalization of S^3 enterprises. These models also allowed researchers, entrepreneurs and interested in the development of such organizations to analyze them from other perspectives.

6.1 Practical and Scientific Contributions of the Research

The main practical and scientific contributions of the research were:

- Provide stakeholders with an overview of S^3 enterprises, its foundations, concepts, expected goals, as well as the processes and rules necessary for its execution.
- Representation of S^3 enterprises in an enterprise model that was developed and systematized with the Concepts, Goals, Business Rules, and Processes models of the 4EM method. Such representation allows its analysis and orientation from different perspectives.
- Contributions for the literature of sensing, smart and sustainable enterprises, by filling research gaps identified in previous works, and presenting a new analytical approach for such organizations.

6.2 Critical Positioning

In our vision, collaborative networks have been identified as a major vehicle for consolidation of S^3 enterprises. Collaboration is an inherent principle to the S^3 enterprises, as the definition of its domain and use of the enterprise modeling as language allows to understand more clearly how the relationship among companies occurs. Regarding the development of the Processes Model, despite the difficulty in modeling the processes to the point of identifying specific steps, the modeling in high level allows to understand how the rules, goals and principles are correlated with the processes. Finally, the enterprise model is an initial step towards the construction of a formal and well-recognized framework of S^3 enterprises.

6.3 Limitations of the Approach and Future Research

It is important to point that not all steps defined by the 4EM method have been met. The method reinforces the need to gather a group of people to perform the enterprise modeling of the process in question, however this not occurred, as S^3 enterprises is still a future perspective, and consequently there are not many experts in the field with consolidated knowledge to provide consistent information.

Another important limiting factor to be mentioned is the fact that there are few papers applied on this subject in the literature, which complicates the collection of consolidated data and information. As S^3 enterprises are not yet properly formalized, the models of Actors and Resources, and Technical Components and Requirements of the 4EM method were not developed. Thus, future research can thoroughly examine the main agents and supporting information systems of these organizations, to incorporate them into the abovementioned enterprise submodels of the 4EM and join them to the other models presented in this paper. Another suggestion for future works is the execution of a case study to apply the models developed in this work, as according to Voss et al. [14], this is the most appropriate research method to conduct investigations in which experience is rare and contextual conditions are unknown, and for Runfola et al. [15], case study offers the opportunity of understanding a phenomenon that is particularly important in the field of management.

References

1. Weichhart, G., Molina, A., Chen, D., Whitman, L.E., Vernadat, F.: Challenges and current developments for sensing, smart and sustainable enterprise systems. Comput. Ind. **79**, 34–46 (2016)
2. Agostinho, C., Jardim-Gonçalves, R.: Sustaining interoperability of networked liquid-sensing enterprises: a complex systems perspective. Annu. Rev. Control **39**, 128–143 (2015)
3. Ferro-Beca, M., Sarraipa, J., Agostinho, C., Gigante, F., Jose-Nunez, M., Jardim-Gonçalves, R.: A framework for enterprise context analysis based on semantic principles. Comput. Sci. Inf. Syst. **12**(3), 931–960 (2015)
4. Filos, E.: Smart organizations in the digital age. In: Mezgar, I. (ed.) Integration of ICT in Smart Organizations. Idea Group Publishing, London (2006)
5. Mauricio-Moreno, H., Miranda, J., Chavarría, D., Ramírez-Cadena, M., Molina, A.: Design S3-RF (Sustainable x Smart x Sensing - Reference Framework) for the future manufacturing enterprise. IFAC-PapersOnLine **48**(3), 58–63 (2015)
6. Braha, D., Stacey, B., Bar-Yam, Y.: Corporate competition: a self-organized network. Soc. Net. **33**(3), 219–230 (2011)
7. Goranson, H.T.: The Agile Virtual Enterprise: Cases, Metrics and Tools. Quorum Books, Westport (1992)
8. Camarinha-Matos, L.M., Afsarmanesh, H.: On reference models for collaborative networked organizations. Int. J. Prod. Res. **46**(9), 2453–2469 (2008)
9. Luthar, S.S., Cicchetti, D., Becker, B.: The construct of resilience: a critical evaluation and guidelines for future work. Child Dev. **71**(3), 543–558 (2000)
10. Christopherson, S., Kitson, M.: Innovation, networks and knowledge exchange. Camb. J. Reg. Econ. Soc. **1**(2), 165–173 (2008)
11. Kash, D., Rycroft, R.: Emerging patterns of complex technological innovation. Technol. Forecast Soc. Change **69**(6), 581–606 (2002)
12. Loucopoulos, P., Kavakli, V.: Enterprise knowledge management and conceptual modelling. In: Goos, G., Hartmanis, J., van Leeuwen, J., Chen, P.P., Akoka, J., Kangassalu, H., Thalheim, B. (eds.) Conceptual Modeling. LNCS, vol. 1565, pp. 123–143. Springer, Heidelberg (1999). https://doi.org/10.1007/3-540-48854-5_11
13. Sandkuhl, K., Stirna, J., Persson, A., Wißotzki, M.: Enterprise Modeling: Tackling Business Challenges with 4EM Method. Springer, Heidelberg (2014)

14. Voss, C., Tsikriktsis, N., Frohlich, M.: Case research in operations management. Int. J. Oper. Prod. Manag. **22**(2), 195–219 (2002)
15. Runfola, A., Perna, A., Baraldi, E., Gregori, G.L.: The use of qualitative case studies in top business and management journals: a quantitative analysis of recent patterns. Eur. Mang. J. **35**(1), 116–127 (2017)