An Approach to Develop Flexible Systems with Organizational-interoperability Requirements

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1 INTRODUCTION

Flexibility of information systems (IS) have been studied to improve the adaption in support of the business agility as the set of capabilities to compete more effectively and adapt to rapid changes in market conditions (Glossary of business agility terms, 2003). However, most of work on IS flexibility has been limited to systems architecture, ignoring the analysis of interoperability as a part of flexibility from the requirements.

This paper reports a PhD project, which proposes an approach to develop IS with flexibility features, considering some challenges of flexibility in small and medium enterprises (SMEs) such as the lack of interoperability and the agility of their business.

The motivation of this research are the high prices of IS in developing countries and the usefulness of organizational semiotics to support the analysis of requirements for IS. (Liu, 2005).

2 STAGE OF THE RESEARCH

This paper reports the work of an initial state of a PhD project, which is the discussion of definitions of flexibility and interoperability of IS from literature review.

Flexibility is studied from different point of views such as flexibility in enterprise, information systems and software development, analysing this lacks and applications in the IS. The literature review has revealed that flexibility of IS affect the agility of enterprise, because both case have pursued the capability to adapt to rapid changes. Additionally, the agility of enterprise is affected by the integration between internal and external process of business, so the interoperability of IS is reviewed to understand how it can affect the adaptability of the IS

After a literature review, the next step of this stage is the analysis of flexibility in software design, IS and enterprise, using a semiotic framework (Stamper, 1973) to identify the impacts of each definition between the organization and the IS.

3 OUTLINE OF OBJECTIVES

The aim of this research is to develop an approach to design flexible information systems to support the business agility.

In order to achieve this aim, the objectives of this research are:

1. To propose an assessment model, which involves the identification of the key features of a flexible system such as level of abstraction of flexibility.
2. To propose an approach to analyze and model business requirements for interoperable and flexible IS.
3. To propose an approach to analyze and design information systems with technical components to achieve flexibility.
4. To evaluate the approach to develop IS based on a case study to achieve the design of a system with flexible features.

4 RESEARCH PROBLEM

Small and Medium Enterprises (SMEs) are the majority in Latin America and Europe. They represent more than 99% of enterprises and around of 30% of GDP of them. (Economic Commission for Latin America and the Caribbean , 2013; Kushnir, et al., 2010).

SMEs of Latin America have showed some difficulties in their IS to support the expansion and globalization of their business. According to the Economic Commission for Latin America and the Caribbean (ECLAC) (2005) the obstacles related to the IS are: weakness of information management; lack access to information relating to markets, regulation and technical norms; and the high costs

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and slowness of trade-related procedures. According the ECLAC, these difficulties are related with the flexibility lack of Information systems to support the customization of processes for:

- Achieving of cooperation among SMEs: The integration of several SMEs can provide a virtual cluster to offer product or services that alone cannot satisfy the customers' demands. For instance, the cooperation needed between delivery services and retailer companies in order to offer products and delivery service in only one web page.
- Accomplishing of international regulations: Although, SMEs have to follow local regulations, each country has different norms to sell the same products.
- Integrating with large companies: Several SMEs are providers of large companies, and the lack of integration with their processes can be translated in a loss of business opportunities.

In Europe, the situation is not different. SMEs do not have much money to spend in Information and Communication Technology (ICT) and the low cost pre-package software has limited the agility for innovation or business alliances. They need ICT to support their core business, easy to upgrade and at as low cost as possible (European Commission, 2006). The SMEs should ensure flexible production environment to experiment new business models in order to respond quickly to changing markets conditions and improve the innovation support (European Commission, 2007).

In sum up, the current challenges of flexibility are:

- Improving of the customization of business processes to accomplish the requirements of partners, customers and regulations.
- Encouraging the integration among enterprises to provide a product or service.
- Reducing of time to add new functionalities or to update IS
- Improving the adoption of new technologies.

Although, the first problem is how to reach the flexibility of an information system, there are not a standard definition of its main features, then the first questions is 1) How can it be designed a flexible IS? The second question is related to the context of the system 2) is it possible to achieve flexibility in legacy systems?

Additionally, the evolution of a system as a part of an organization should be defined, because the reusability, extensibility and interoperability of a system may help the flexibility for new functionalities in order to support the organization. This context illustrate new questions 3) How can it be identified the interoperability in an information system? 4) Is it possible to achieve interoperability in legacy systems just adding new functionalities? 5) How can it be achieve the reusability? 6) How can it be achieve the extensibility? 7) Could the extensibility and reusability improve the adaptability of an information system? These questions should be responded before proposing a new approach to achieve these features.

Therefore, it is significant to define the main features for an interoperable system, focusing in the extension and reusability in order to achieve evolvable characteristics to adapt the current system to the organization and their future functionalities.

5 STATE OF THE ART

This research has been focused on the flexibility and interoperability of information systems (IS), because according with some authors presented in this study, the agility of enterprises comprises the interoperability between internal processes and the environment of the organization. In the following, overviews of these terms are presented to identify their main features.

5.1 Flexibility in Information Systems

Flexibility in information system is “the ease with which a system or component can be modified for use in applications or environments other than those for which it was specifically designed.” (Institute of Electrical and Electronics Engineers, 1990). Currently, this feature has been pursued for enterprises, because the capability to change for less time in a lower cost may bring a competitive advantage. For instance, some authors emphasise that IS should have the flexibility to integrate the external information from stakeholders (suppliers, co-operators and clients) with the inner processes, in order to provide a competitive advantage and more flexibility to the enterprises. (Qi and Luo, 2007; Steven and Alevifard, 2013). Additionally, the flexibility of IS can minimize the uncertainty from the changing customer demand, because the flexibility of IS could support the core processes of the business and help to track in real time the variety of products, warehouse space, transportation and suppliers (Li and Qi, 2008).

The lack of a standard to identify and evaluate flexibility of IS may be for its dependency from external factors such as stakeholders, business

policies and new technologies. Scherrer-Rathje (2012) summarizes the common dimensions of flexibility in IS and proposes taxonomy based on end-users studies. He defined as key factors the system connectivity, process integration, hierarchical integration, user customizability and consistency. Although, this taxonomy is useful to understand the several dimensions of flexibility, this is focused on a theoretical cost and effort to add more flexibility, but it does not explain how to achieve these dimensions or calculate the real cost of flexibility.

On the other hand, flexibility in information systems can be explained in terms of the ability to change at a minimum cost, where the cost and time to provide a new IS functionality to the organization is named the "penalty of change" (POC). This cost is inversely proportional to the flexibility of an IS and can be calculated as the probabilities sum of future change demands (Furukawa and Minami, 2013). However, the POC is subjective, because this forgets other factors such as development and end-user adaptability. For instance, if the end-user adaptability is low, it will have a delay to adopt a new functionality, even if the development team have the enough flexibility to quickly create a new functionality. Furukawa (2013) classified the risk to change in IT adoption, service area, system structure, fault tolerance and exchangeability, because he states that planning in a long-term to reduce the cost to design the system and improve of skills and experience of the IT department, can minimize the POC. However, there are not concrete methods to achieve his strategies.

In the software engineering, the flexibility is commonly seen as a result of other factors such as standardization of architecture and software process (Liu, et al., 2008). Certainly, standards may help the flexibility, albeit the flexibility should be seen as a part of the design from the beginning. For instance, SOA possess standards and composition of services that can support flexibility (Chen, et al., 2014), but the lack of consideration of flexibility from the analysis of requirement may imply a design of a limited IS (Naab, 2011).

Agile methodologies have been using concepts from agile manufacturing in the software and hardware design to customize final products (Kettunen, 2009). For example, the product-line architecting can achieve the mass customization of products with a common platform, which is used through of development of new products or versions (Díaz, et al., 2014). Although, agile methodology pursues the flexibility to change at the minimum effort possible its software components, it has based on agile manufacturing of their products, forgetting the identification of flexibility in the system and the organization.

Finally, some works have faced flexibility due to the complexity of the problem and the information system. The flexibility of user interfaces has been researched to divide the content between static and the dynamic in order to change the user's interface, without an intervention from a programmer (Bonacin, et al., 2007). An extension of this works is the management of user interactions as an array of facts, which makes an action plan to change the user's interface after of analysing the norms and the context identified (Fortuna, et al., 2010). Other research to face flexibility is the solution proposed by Li (2010), who analysed the flexibility in the clinical pathway with a semiotic approach to identify the context between the agents and their norms of negotiation. Although, these cases face flexibility by means of norm analysis, they do not identify requirements of interoperability and flexibility from the inception stage.

5.2 Interoperability in Information Systems

The definition of interoperability and their features are not clear, because there is confusion between integration and interoperability. The interoperability can be define as "the ability of two systems to understand one another and to use functionalities of one another", and the integration as "the interaction between enterprise entities necessary to achieve domain objectives", then the components cannot be separated (Chen, et al., 2008). In this context, interoperability can be seen as self-independent systems or components, which is integrated among them. However, enterprise integration may be interoperable, but it is not mandatory.

Currently, several frameworks have been proposed for integration and interoperability of information systems' architectures. However the majority of works have been on business processes or technical issues, failing to consider the organizational dimension. For instance, the framework for Level of Information System Interoperability (LISI) proposed by the Department of Defence of the United States (Architectures Working Group, 1998) defines five levels of interoperability, but its list of attributes to identify each level covers just standards and procedures. Other example is the ATHENA interoperability framework (AIF), which considers three

components: conceptual integration, application integration and technical integration (Vernadat, 2010). Although, these components include guidelines for interoperability issues, they partially cover the organizational point of view.

On the other hand, some approaches have made with organizational considerations. The European Interoperability Framework (EIF) proposed 4 levels of interoperability: technical, semantic, organizational and legal. Such as the previous framework, the first two levels are focused on the problems to interchange information among systems and how that this can be interpreted. Its top levels propose the coordination among inter-organizations, considering legal aspects to data exchange in the definition of processes, synchronizations steps and messages. Additionally, the European Commission suggests the service orientations to design and develop systems, due to their components are modular and loosely coupled (European Commission, 2010). However, the organizational aspects of the EIF has been limited to formal relationships among organizations and users, neglected the informal aspects. This lack is seen in the work of Allen (2013), who described the informational problem in the emergency service using activity theory. He concluded that the interoperability problem is the analysis focused on technological solutions, when the real problem is the organizational constrain in the interchange of information. For instance, in an emergency situation, every organization should access the police information in order to know if the emergency is in a risk area.

New approaches have proposed the interoperability from the organizational semiotic, where the pragmatic level (associated with intentions) should be identified, because this allows the coordination of work across different people. These interoperability requirements should be articulated with their context such as stakeholder, location, constraints and motivations (Liu, et al., 2014). This work proposes two dimensions to evaluate the interoperability in an organization by means the observation of abstract processes, which include 2 dimensions. The former dimension is referring to the organizational onion (technical, formal and informal) and the latter to the taxonomy of behavioural norms (substantive, communication and control).

6 METHODOLOGY

Currently, the research of software engineering has focused in the creation of new methods or objects, paying attention in artificial aspects instead of natural aspects. Then the research philosophy should consider an integrated perspective with the capacity to understand the organization aspect. Constructivism philosophy is useful to understand the subjectivism of organization without define a rigid structure of methods to research it (Lazaro and Marcos, 2005).

In order to define the flexibility, it is needed a theoretical understanding to identify their main characteristics and predict some particular cases (Hevner, et al., 2004). The next step is the identification of requirements, where the flexibility and interoperability are part of the requirement analysis. Consequently, it will propose an approach to analyse and design the requirements with software development methodologies. Finally, the results will be evaluated with a case study.

6.1 Organizational Semiotic

In spite of exists several definitions about flexibility, their meaning is related to the agility of processes in the enterprise, forgetting to analyse the signs of flexibility in the organization in order to understand the current functionality and its potential extensions. Semiotic can provide the theoretical foundation to examine the nature and properties of all kinds of signs and how they are part of the social life (Morris, 1946).

Organizational semiotic is one branch of semiotic, which observes how the organizational behaviour can be affected by the communication of signs and their interpretation. Stamper (1973) proposes a semiotic framework to study organizations, which deal with the structures, meanings and usage of signs. The levels of the semiotic framework from the lower to the upper level are: physical world, empirics, syntactics, semantics, pragmatics and social world. This framework is useful to understand the differences of the social consequences of signs, their structure and how they are transmitted. In the analysis of flexibility is significant to realize the level of flexibility in an Information System, because the formal requirement of an organization may be different of the real flexibility. For instance, it is important the understanding of the level of flexibility of an organization before proposing a design of a system, because some rigid organizations

such as government organizations has policies that can affect the flexibility of their process and the IS.

The concretes applications of this organizational semiotic to the Information Field can be seen in the Methods for Eliciting, Analysing and Specifying Users' Requirement (MEASURE) (Liu, 2000), and the Analysing and Modelling Behaviour of Legacy System (AMBOLS) for requirement recovery (Liu, 2005), which propose methods such as the Semantic Analysis Method (SEM) and Norm Analysis Method (NAM) to develop information systems. These methods are significant to analyse and design information system in the requirement stage, because they can address the identification of organizational aspects. For instance, SEM is useful to analyse the agents of the organization and their possibilities of interaction with the environment and the system. The figure 1 illustrates an overview of these methods (left) in each stag (right) of this research

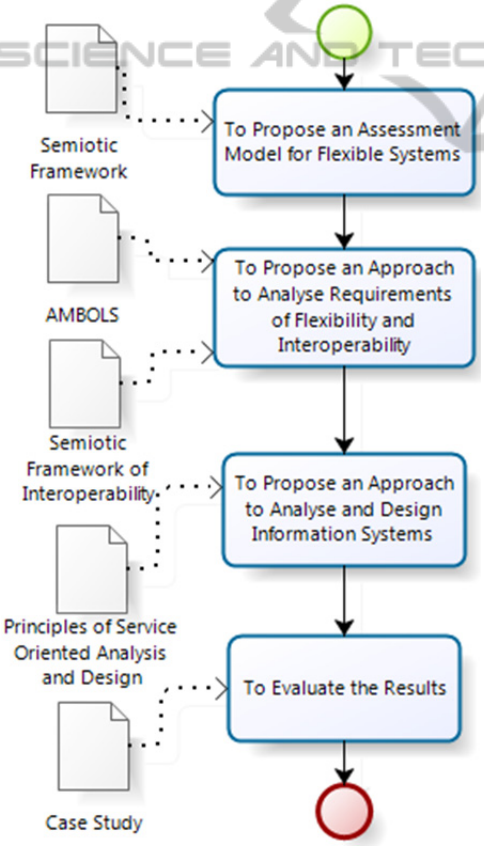

Figure 1: Methods (left) and stages (right) of this research.

6.2 Assessment Model for Flexible Systems

Flexibility for information system is a characteristic, which can be seen from different point of view. For instance, from a technical perspective, there are several patterns such as singleton or factory, to design information system with an extensible and flexibility features. For that reason, the flexibility should be defined in different levels to identify the level of flexibility needed. The semiotic framework is useful to analyse and describe every definition of flexibility.

This stage is a descriptive study based on literature review, considering the interpretation of flexibility in each part of the framework, in order to define a guideline to identify flexibility in organizations and information systems.

6.3 Requirement Analysis for Flexibility and Interoperability

The second stage is based on AMBOLS (Liu, 2005), because its three stages (Behaviour Capture, Dynamic Behaviour Modelling and Requirements Derivation) are useful to understand the pattern behaviour of organization and their dynamic conditions. However, this technique is focused on legacy systems and their impact in new functionalities, forgetting the formal analysis of flexibility, new systems and new technologies. On the other hand, although AMBOLS consider the study of IT environment and the interaction between human and machine, this does not describe the interoperability of the organizations and their possible expansions. For that reason, the semiotic framework of interoperability may help to analyse this kinds of requirements (Li, et al., 2013), because this holistic point of view considers the interoperability in each level of the semiotic framework. For instance, According to Li (*op. cit.*), the analysis of the interoperability from the syntactic level can identify the non-functional requirement to propose standard data to interchange the information in different platforms such as JAVA and .NET.

6.4 Approach to Analyse and Design Systems with Flexibility

This research considers techniques to analyse and design system, including flexibility to modify the business for future changes and new functionalities. One example is the capability of the Service Oriented Architecture (SOA) to support the flexibility and interoperable requirements, because its main features are (Hirschheim, et al., 2010):

- The functionality exposed (services) is fully encapsulated, with well-defined rules.

- Each service is adhered to a set of standards to allow interoperability.
- This architecture considers a service registry with definitions and connection points, in order to improve a transparent discovery of service and re-direction.
- The specification and invocations of services are expressed with a protocol based on XML.

The encapsulation of functionality of each service may help the flexibility of the system, because it is possible an orchestration or composition of service, in order to change or reuse the functionality of the system. Additionally, the standards may help to achieve the interoperability of the current system or legacy systems by means of their encapsulation of service.

New steps of process to achieve the flexibility of systems from the analysis and designed should be proposed in order to achieve it, where the semantic and norm analysis worked in the previous stage is crucial. The semantic analysis is useful to analyse and design the static view of the system and the norms for the dynamic part. An example of this can be seen in the research of Bonacin (2004), where he proposed a heuristic approach to translate an ontology chart (part of the semantic analysis) into a class diagram. On the other hand, steps to analysed and design services such as the proposed by Erl are considered to compose service in different layers (Erl, 2005).

6.5 Validation

The result of this research can be evaluated by means of qualitative information using a case study, identifying the requirement for legacy or new systems. Although, an enterprise with agile business is desirable, it is not mandatory to work with this methodology to identify requirements.

7 EXPECTED OUTCOMES

The expected outcome of this research is to provide an approach to design information systems with features of flexibility and interoperability in order to support the business agility, decreasing the time and cost for future developments or maintenance of their components. The expected partial outcomes are the following:

- Assessment model of flexibility: Theoretical model to identify kinds of flexibility in an information system.
- An approach to analyse and model business requirement: structured method to identify requirements, considering the organizational interoperability and flexibility.
- An approach to analyse and model information system: Steps and models to design information systems with features of flexibility and interoperability.

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REFERENCES

Allen, D. K., Karanasios, S. and Norman, A., 2013. Information sharing and interoperability: the case of major incident management. *European Journal of Information Systems*, pp. 1-15.

Architectures Working Group, 1998. Level of Information System Interoperability (LISI). [Online] Available at: *http://www.eng.auburn.edu/~hamilton/security/DODAF/LISI.pdf* [Last access: 23 June 2014].

Bonacin, R., Baranauskas, M. C. C. and Liu, K., 2004. From Ontology Charts To Class Diagrams : Semantic Analysis Aiding Systems Design. Porto, Brazil, s.n., pp. 389-395.

Bonacin, R., Baranauskas, M. C. C. and Medeiros, T., 2007. A Semiotic-Based Framework for the Development of Tailorable Web Applications. Beijing, China, Springer, pp. 859-868.

Chen, B., Peng, X., Yu, Y. and Zhao, W., 2014. Requirements-Driven Self-Optimization of Composite Services using Feedback Control. *IEEE Transactions on Services Computing*, PP(99), p. 14.

Chen, D., Doumeingts, G. and Vernadat, F., 2008. Architectures for enterprise integration and interoperability: Past, present and future. *Computers in Industry*, pp. 647-659.

Díaz, J., Pérez, J. and Garbajosa, J., 2014. Agile product-line architecting in practice: A case study in smart grids. *Information and Software Technology*, 56(7), pp. 727-748.

Economic Commission for Latin America and the Caribbean , 2013. Latin American Economic Outlook 2013, s.l.: *ECLA Press Centre*.

Economic Commission for Latin America and the Caribbean, 2005. Project documents Information Technology for Development of Small and Medium-sized Exporters in Latin America and East Asia, s.l.: *Economic Commission for Latin America and the Caribbean (ECLAC)*.

Erl, T., 2005. Service-Oriented Architecture: Concepts, Technology, and Design. s.l.:*Prentice Hall*.

European Commission, 2006. Task-Force on ICT Sector Competitiveness and ICT Uptake, s.l.: *European Commsision*.

European Commission, 2007. Follow-up of the Recommendations of the Task Force on ICT Sector Competitiveness and ICT Uptake, *Brussels: Europe Commission*.

European Commission, 2010. European Interoperability Framework (EIP) for European public services: Annex 2. [En línea] Available at: *http://ec.europa.eu/isa/documents/isa_annex_ii_eif_en.pdf* [Last access: 23 June 2014].

Fortuna, F. J., Bonacin, R. and Baranauskas, M. C., 2010. A Framework Based on Ajax and Semiotics to Build Flexible User Interfaces. Funchal-Medeira, Portugal, *Springer*, pp. 526-540.

Furukawa, M. and Minami, A., 2013. A Study on the 'Flexibility' of Information Systems (Part 1): Why Do They Need to Be Flexible?. *International Journal of Business and Management*, 8(20), pp. 48-61.

Glossary of business agility terms, 2003. *Business Agility. Financial Times*, 15 May, p. 1.

Hevner, A. R., March, S., Park, J. and Ram, S., 2004. Design Science In Information Systems Research. *MIS quarterly*, 28(1), pp. 75-105.

Hirschheim, R., Welke, R. and Schwarz, A., 2010. Service-oriented Architecture: Myths, Realities, And A Maturity Model. *MIS Quarterly Executive*, 9(1), pp. 37-48.

Institute of Electrical and Electronics Engineers, 1990. IEEE Standard Glossary of Software Engineering Terminology. New York, *IEEE*, p. 83.

Iturralde, D. y otros, 2013. A new system based on web services and RFID for tracking people in a pervasive mining environment. Santiago, *IEEE*, pp. 1-5.

Kettunen, P., 2009. Adopting key lessons from agile manufacturing to agile software product development—A comparative study. Technovation, 29(6-7), pp. 408-422.

Kushnir, K., Mirmulstein, M. L. and Ramalho, R., 2010. Micro, Small, and Medium Enterprises Around the World: How Many Are There, and What Affects the Count?. [En línea] Available at: *http://www.ifc.org/wps/wcm/connect/9ae1dd80495860d6a482b519583b6d16/MSME-CI-AnalysisNote.pdf?MOD=AJPERES* [Last access: 1 July 2014].

Kuwayama, Mikio, 2005. Project documents Information Technology for Development of Small and Medium-sized Exporters in Latin America and East Asia, s.l.: *Economic Commission for Latin America and the Caribbean (ECLAC)*.

Lazaro, M. and Marcos, E., 2005. Research in Software Engineering: Paradigms and Methods. Porto, Portugal, s.n., pp. 517-522.

Li, Q. and Qi, Y., 2008. A Framework for Assessing Supply Chain Flexibility. Taipei, *IEEE*, pp. 12-15.

Liu, J. Y.-C., Chen, V. J., Chan, C.-L. and Lie, T., 2008. The impact of software process standardization on software flexibility and project management performance: Control theory perspective. *Information and Software Technology*, 50(9-10), pp. 889-896.

Liu, K., 2000. Semiotics in information systems engineering. *Cambridge: Cambridge University Press*.

Liu, K., 2005. Requirements Reengineering from Legacy Information Systems Using Semiotic Techniques. Systems, Signs and Actions An *International Journal on Communication, Information Technology and Work*, pp. 38-61.

Liu, S., Li, W. and Liu, K., 2014. Assessing Pragmatic Interoperability of Information Systems from a Semiotic Perspective. *Heidelberg, Berlin, Springer,* pp. 32-41.

Li, W., Liu, K. and Liu, S., 2013. Semiotic Interoperability - A Critical Step towards Systems Integration. s.l., *SCITEPRESS*, pp. 508-513.

Morris, C., 1946. Signs, language and behavior. *Oxford, England: Prentice-Hall.*

Naab, M., 2011. Enhancing architecture design methods for improved flexibility in long-living information systems. In: *I. Crnkovic, V. Gruhn and M. Book, edits. Software Architecture. Essen, Germany: Springer*, pp. 194-198.

Qi, Q. and Luo, G., 2007. Constructing Enterprise Flexibility Competence on the Basis of Product Platform and Collaborative Product Commerce. Jinan, China, *IEEE*, pp. 2857-2861.

Stamper, R. K., 1973. Information in Business and Administrative Systems. *New York: John Wiley and Sons.*

Steven, M. and Alevifard, S., 2013. Management of Flexibility in IPS² - Business-Relationships. In: The Philosopher's Stone for Sustainability. *Heidelberg, Berlin: Springer*, pp. 97-102.

Vernadat, F. B., 2010. Technical, semantic and organizational issues of enterprise interoperability and networking. *Annual Reviews in Control*, pp. 139-144.