Enhancing the Flexibility of Information Systems

A Thesis Submitted in Partial Fulfilment of the Requirements of the University of Reading for the Degree of Doctor of Philosophy

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Declaration

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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Abstract

Information systems (IS) flexibility has been studied as a key capability to adapt and change organisations. Several definitions have covered technical and human factors to assess the IS flexibility. Technical factors have measured Information Technology (IT) infrastructure, its efficiency, standards and designs (modular or monolithic). Human factors have assessed the skills of the team, its commitment and the leadership's skills. Indeed, these factors affect the capability to change an organisation, but it is not clear how information systems should support the capability of organisations to change, maintaining their functions and dynamic.

This research proposes a methodology named Information Systems Flexibility by Organisational Semiotics and Autopoiesis (ISFOSA), which uses a metaphor from living systems and the process to maintain the life (autopoiesis). This metaphor states the significance of the boundary to keep a living system alive, so this method uses organisational semiotics to identify the boundary of the human organisation and how this boundary can affect the focal Information system. ISFOSA consist of fives phases: Problem and context identification, boundary analysis, focal system analysis, identification of flexibility, and design and implementation. The phase one identifies the context of the problem, proposing stakeholders that can affect the human organisation. The second phase develops ontology charts and norm analysis to identify the affordances that can affect the boundary. The third phase analyses a focal information system, which is the information system to enhance the IS flexibility. This phase uses semantic and norm analysis, but their focus is on the dynamic inside the human organisation. Phase four proposes requirements of flexibility by identifying norms of the organisation that can affect the norms in the focal system. This comparison leads to a scenario analysis that can repeat semantic and norms analysis under a possible situation of change. The scenario analysis uses the previous phases and the strategies of IS flexibility to propose requirements.

Design science research and case study research guide the process to develop the method. Firstly, a gap in the identification of requirements is identified as a research problem to address the propositions of previous researches about IS flexibility. Then a theoretical proposition uses a metaphor of autopoiesis to propose a focus on the boundary of the organisation to analyse the flexibility. A retrospective case study is conducted to refine the first two phases of the method, using the change from a good-dominant (GD) logic to a service-dominant (SD) logic of Rolls-Royce. An evaluative case study is conducted to illustrate ISFOSA's methodology to propose a system to track people in underground mines. Also, the method is enhanced with the feedback obtained from interviews from IS professionals. This feedback validates the overall result obtained from the second case study.

This research postulates contributions from the theoretical, methodological and practical perspective. The theoretical proposition asserts that organisations behave as living systems from organisational semiotics. From the methodological perspective, this research can guide the application of retrospective case studies with design science. In practice, this model can provide guidelines to identify socio-technical requirements of organisations. Therefore, information professionals can integrate this model with existing methods for IT projects, identifying requirements and defining elements that the design of information systems should cover to enhance the IS flexibility.

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List of abbreviations (or symbols)

AOB	any other business
KPI	key performance indicator
UoR	University of Reading
IT	Information Technology
VLC	Visible Light Communication
IS	Information Systems
ECLAC	Economic Commission for Latin America and the Caribbean
ICT	Information, and Communication Technology
SME	Small and Medium-Sized Enterprises
SOA	Service Oriented Architecture
DSRIS	Design science research in IS
COBIT	Co-designs of business and IT
PAM	Problem articulation method
SAM	Semantic analysis method
NAM	Norm analysis method
AMBOLS	Analysing and modelling the behaviour of legacy systems
ISFOSA	IS flexibility by organisational semiotics and autopoiesis
IoT	The Internet of Things

Chapter 1

Introduction

This chapter introduces the research domain of Information Systems (IS) flexibility. Firstly, the motivation and significance of this research are summarised. Secondly, the research problems and related research questions are discussed from a theoretical and empirical viewpoint. Then, the research scope, aims and objectives are outlined. Finally, the thesis structure is explained.

1.1 Motivation and Background

According to the Economic Commission for Latin America and the Caribbean (ECLAC), small and medium-sized enterprises (SMEs) of Latin America have struggled with barriers to cooperate and export products. This report blames the lack of flexibility of Information systems to support the customisation of processes for the regulation of each country, the cooperation with partners and the price involved in this adaptation.

The report of Kuwayama, Tsuji, and Ueki (2005) suggests the improvement of the cooperation with virtual clusters and the improvement of the use of IT systems with the concept of "capacity building". Virtual clusters are the cooperation of businesses, using the internet in a network-type form (Kuwayama et al., 2005). The cooperation of the supply chain of partners can provide a flexible environment to create new business opportunities, promoting innovation. On the other hand, the concept of "capacity building" is how the IT as a tool can promote international trade of SMEs (Kuwayama et al., 2005). The study of ECLAC found a positive effect of IT in the streamline of administrative work, but they also found that SMEs do not understand the potential of IT to improve operations such as trade and export. This situation is similar in Europe, because SMEs do not have much money to spend on Information, and Communication Technology (ICT) and the low-cost of pre-packaged software does not encourage virtual clusters or the capacity building (EU ICT Task Force, 2006). According to the European Commission, SMEs need an environment to experiment with new business models under changes in the market's conditions and innovations.

Although the formation of virtual clusters can seem a technical issue, the cooperation of businesses for international trade can involve human factors such as a lack of standards and regulations. An example is South America, where there are no standard regulations among countries, putting difficulties in the exportation of good or services. These difficulties affect their

information systems because an SME of a country needs to adapt its IS to the regulations of another country.

These reports mentioned the word flexibility in different contexts such as products, production environment, partnership and business. In the report of European Commission (2007), they said “flexible products” as software products with the capability to change (page 3), “flexible production environment” as an environment with enterprises working together with low barriers to entry and exit, and with adaptable workforce (page 13). In the case of the report of Kuwayama, Tsuji and Ueki (2005), the word “flexible” is mentioned in the context of the capability of enterprises in Virtual Clusters (page 21); as flexible partnership of IT platforms as a platform to share IT resources (page 74), and “flexible for adaptation” as a capability to adapt the businesses to new circumstances (page 222). A few features in common are in these definitions. Firstly, flexibility seems an enabler of change in concrete or abstract objects. Secondly, this potential change modifies the original object, but this object is identified as something “adapted” and not as a new object. Thirdly, this potential change seems a possible change, and it seems easy or low-costly. Finally, the flexible object can show this capability, when an event or change in the environment affects it.

Flexibility as a capability seems a “holy grail” for businesses because it promises a capability to adapt the IS to organisational changes (Palanisamy and Sushil, 2003). Although there are studies about IS flexibility, the IS literature has focused on the impact of IS flexibility in the organization (Agarwal, 2004; Cheng & Bi, 2008; Gebauer & Lee, 2008; Savanevičienė, 2006; Verdú & Gómez-Gras, 2009; Wadhwa, Mishra and Chan, 2009), and the evaluation of factors that can provide flexibility (Allen and Boynton, 1991; Anwar and Masrek, 2013; Duncan, 1995; Fitzgerald, 1990; Jacome et al., 2011; Palanisamy, 2012; Palanisamy et al., 2009). As such, there is a blurred line in the development of IS, because the current studies propose the development of flexible features in the IS (Burkhart et al., 2012; Fleischmann et al., 2013; Nunes et al., 2012; Tan and Zhao, 2005; Yagüe et al., 2003; Zhao et al., 2012), without consideration where these features may be needed.

For this reason, this research will explore where the IS flexibility needs to be applied in an organisation to connect the proposed approaches by previous studies.

1.2 Research Problems and Questions

This thesis considers theoretical, methodological and practical research problems, which affected the development of research to enhance the flexibility of information systems.

1.2.1 Theoretical Research Problems

The following list summarises the research problems that motivate this research.

- Lack of agreement of the concept of IS flexibility: The literature has proposed definitions of IS flexibility related to the support of organisational changes. However, there is no agreement about the size or extent of a change in the IS to be considered as a change or an adaptation, showing a problem in the current definitions of IS flexibility (Gebauer and Schober, 2005; Palanisamy and Sushil, 2003).
- Lack of connection between the flexibility of IS and organisations: The literature has shown a connection between the flexibility of IT and the responsiveness of the organisation (Verdú and Gómez-Gras, 2009). However, there is no connection between IS flexibility and changes in the organisation. In general, the current studies have identified a lack of awareness of sources of changes (Fitzgerald et al., 1999; Gebauer and Lee, 2008).
- Lack of address between technical solutions of IS flexibility and organisations: The current research related to IS flexibility are focused on technical solutions, providing layers of abstractions for minimising changes (Zhao et al., 2012) and the use of standards or patterns from the industry (Mannaert et al., 2012). However, an application of these methods or techniques in the wrong context can imply issues for the organisation. For example, the concept of “Anti-Patterns” (Long, 2017) states several problems in the use of patterns such as the application of generalisations without knowing the business domain.

1.2.2 Methodological Research Problem

Although, the theoretical research problems have shown a lack of connection among the propositions that promise IS flexibility, the current studies attempt to develop the IS flexibility in the form of frameworks (Anwar and Masrek, 2013), architectures (Zhao et al., 2012), software components (Bonacin et al., 2007), workflow in health (Yang et al., 2010) and so on. According to Hevner et al. (2004), these propositions are artefacts, but they do not use any method or protocol to assess the design of the artefact. The paradigm of design science can provide a platform to develop artefacts, using the concept of utility as part of the evaluation and also an iterative process to improve the artefact through time. Design science has focused on the evaluation of designs problems that can be found in the present (Venable et al., 2014), so this paradigm may not suit in the study of IS flexibility.

IS flexibility can be seen when an IS needs to change, putting a temporal constraint on the research and the iterations to improve the artefact. However, design science is a research

paradigm that provides guidelines instead of strict steps (Baskerville, 2008). Thus, if the researcher can follow the main steps of design science, this paradigm can work with other methods. For this reason, this research needs to adapt design science to test and validate the artefact, using a case from the past and a case from the present.

1.2.3 Practical Research Problems

At a practical level, the generalisation of results is problematic because each enterprise or organisation possess their form of interaction and their practices. Additionally, the evaluation of flexibility can be made with partial or hypothetical changes, because the final judgement about flexibility is the historical changes in the organisation that affect the IS. In this context, the historical changes imply an observation's period that cannot show any change.

1.2.4 Research Questions

The research problems highlighted above are investigated with the following research questions:

1. What are the current studies related to the flexibility of IS?
2. Which principles of IS flexibility can support changes from external drives of the organisation?
3. How to enhance the IS flexibility to support the organisational changes?
4. How can the information systems support the survival of organisations?
5. How to develop IS with flexible capabilities?

1.3 Research Scope, Aims and Objective

This research aims to develop an approach to enhance the flexibility of information systems to support potential changes induced by external and internal drives. The following objectives can guide the study to achieve the aim:

- To explore the notion of information systems flexibility, using the current literature. Firstly, this study synthesises the current literature of flexibility of IS and related concepts such as organisational changes and organisational structures.
- To define principles of IS flexibility and the identification of external drives that can cause changes. This study defines a concept of flexibility of IS, main features and potential agents or causes of changes in the organisation.
- To propose a methodology to enhance the IS flexibility. This objective leads to a methodology to identify where the flexibility of information systems is needed. Then,

the principles of IS flexibility can help to the identification of requirements to covers how in the methodology.

- To test the methodology in case studies. This research uses two case studies to validate the methodology. The first case tests a part of the methodology, looking for patterns in a case from the past to understand the IS flexibility from the observation of the boundary. Then, the methodology is applied in a second case to validate the whole methodology as an artefact.

1.4 Thesis Structure

This thesis consists of seven chapters, which follows an approach based on design science and case study. Chapter 1 explains the research problems and motivation. Chapter 2 reviews the literature on the flexibility of information systems. Chapter 3 proposes a methodology to identify where the IS flexibility is needed in organisations, using a metaphor of living systems to explain why is needed. Chapter 4 explains the research methodology, analysing the current philosophical trends and proposing the methodology for this PhD research. Two iterations assess the artefact. The first iteration uses part of the methodology in chapter 5 to identify the boundary of Rolls-Royce, during the servitisation process. Chapter 6 improves the method used in chapter 5, adding steps to identify IS flexibility requirements, proposing strategies (represented as requirements) in the construction of an IS to locate people in underground mines. Chapter 7 concludes this research proposing future works. Figure 1.1 shows a diagram of these chapters and their connections.

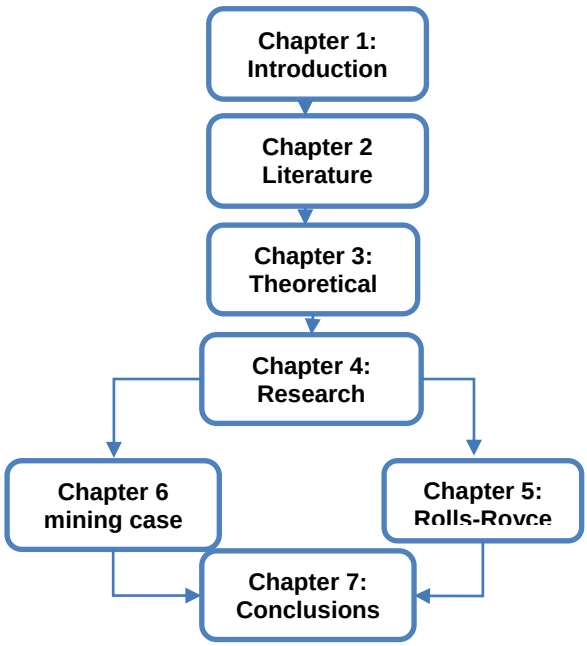

Figure 1.1 Thesis Structure

Chapter 2

Literature Review

This chapter reviews current trends of IS flexibility, analysing its definitions to understand what it is and which factors can enable it. Additionally, it is reviewed several propositions which state to provide features linked to IS flexibility. Several problems in these propositions are discussed in this chapter to point out what issues should cover the development or enhancement of IS flexibility.

2.1 Definitions of Information Systems Flexibility

The concept of IS flexibility has been developed through the years, updating its meaning due to changes in the technology and the development of information systems as a research field. The following sections review and discuss the definitions of IS flexibility as a generic feature and as heuristic capability.

2.1.1 IS Flexibility as a Generic Capability

This trend about IS flexibility claims that the IS can adapt or change the IS according to the need of an organisation. Although this trend recognises that the IS flexibility as a capability should support changes from the environment with a low cost, there is no agreement about how to measure, implement or enhance it.

The concept of IS flexibility as a feature can be seen from the earlies 90s in the work of Allen and Boynton (1991) named “Issues and Opinions information Architecture: in Search of Efficient Flexibility”. In this work, they defined a “high-road approach”, which are centralised IS with independent applications to share through the company. These authors pointed out that the application of standards to core IS infrastructure can provide better support to unanticipated demands, giving some “flexibility” to the company. In contrast, the “low-road approach” are the IS owned by user’s divisions and departments, and they restrict the access and application of standards. In this case, the concept of IS flexibility is linked with the potential use of IS for other purposes different to the original construction, enabling the IS of the company to support new conditions or requirements.

In the following decade, the IS flexibility has been seen as a capacity or capability of IS to change according to the conditions of the environment. Palanisamy and Sushil (2003) defined this capability in connection with the organisation, and how it can "predict changes", facilitating the organisational change. However, this research stated that an outline is needed to achieve the flexibility, because "Flexibility without any intent will lose its identity", raising the question about, which outlines should be defined. Ramaraj (2010) extended the work of Palanisamy and Sushil, proposing a conceptual model that analyses the flexibility from several perspectives such as users, technical and processes. However, Ramaraj suggests that several dimensions should analyse the environment, but he did not propose them. Some authors added a time frame to this definition, including how quick an enterprise can respond to the changes (Li and Qiu, 2008), or how fast an organisation can adapt the IS to the user's needs (Palanisamy, 2012). However, the problem in the definition of IS flexibility as a capability is how the IS flexibility is measured. The added time frame can give some hints about what should be measured, but there is no consensus about the main factors.

Some authors have proposed forms of measurement for this trend, using the penalty of change (POC) to say how flexible is an information system. This POC quantifies the changes or potential changes of an IS to determine how flexible is the IS (Furukawa and Minami, 2013). POC has been used to assess IS under potential risks that can trigger a change (Furukawa, 2013), which may define if a system is more flexible than other. Although the concept of POC includes several dimensions to assess IS flexibility, it remains the lack of methods to analyse and enhance it.

Therefore, the IS flexibility as a generic capability is useful as a concept to understand that it depends on the factors of assessment, the context and the environment of the system. It is needed to adjust this definition to formal methods of analysis, which can help the comparison. In general, the IS flexibility as a capability relies on the organisation as an enabler of the agility (Drnevich and Croson, 2013), assuming that the organisation is ready to change, blaming to the alignment with IT as the main problem. For this reason, formal methods, diagrams of the organisation and its capabilities, may help to the enhancement of flexibility, putting pressure on the potential changes perceived by the organisation.

2.1.2 IS Flexibility as a Heuristic Capability

In contrast with the previous section, this capability can emerge when the design and implementation are purposeful. The purpose can provide a heuristic address to develop the flexibility such as visibility of the change, user's requirements and IT infrastructure. However, several problems related to the election of the purpose and the metrics of analysis can put difficulties during the analysis of the IS.

The visibility of the change means that there are foreseen and unforeseen changes to consider in the development of the IS. Gebauer and Schober (2005) have called them “flexibility to use” and “flexibility to change” respectively. The first kind of changes usually affect small components of the IS such as business rules or interfaces (Jacome et al., 2011), and its meaning is similar to the concept of customisation. The second kind of changes are unforeseen changes, they need significant disruptions to implement the changes, and they are close to the concept of adaptation (Jacome et al., 2011). Customisation and adaptation differ for the cost of money and time to implement the changes, but there is no clear definition of the changes’ size and how to assess them. Current implementations of this kind of flexibility align business strategies with IS strategies, developing parametric and modular systems (Jacome et al., 2011), but they do not provide any guidance to develop systems with parameters or/and modules.

The IS flexibility for user’s requirements uses an initial set of requirements to test if the system can absorb new changes. This definition of IS flexibility is “the quality to adapt changes” from the environment (Lu et al., 2007), recognising changes from the market and the technology. Naab (2012) added attributes such as easy, cheap and fast as part of the quality, which can enable the analysis of potential scenarios to decide if the system is flexible or not. However, the scenario analysis depends on the knowledge of the designer to identify potential changes and also how complete are captured the user’s requirements.

The IS Flexibility by IT Infrastructure recognises that the flexibility is a capability of an information system, but this only can emerge when a set of properties are implemented in the IS, and they are aligned with the strategy of the organisation. This definition is a legacy of the IT flexibility, which is focused on factors such as modularity, connectivity and compatibility of IT infrastructure to enable changes (Duncan, 1995). After the year 2000, the trend was to include skills of the IT team to provide flexibility to the IS (Golden and Powell, 2000). These factors are usually aligned with the strategy of the organisation to provide agility to the firm, improving the capability to respond to the market (Tallon and Pinsonneault, 2011). This trend recognises that some changes cannot be foreseen, proposing some methods such as process flexibility or modularisation to enable future changes (Dorsch, 2015; Kumar and Stylianou, 2014). The problem of this definition of flexibility is the lack of methodologies to analyse and implement them.

The idea of heuristic analysis of the IS Flexibility seems an available form of analysis and implementation, but there is a lack of connection between the organisational needs and the software components. This approach seems to go in the right way, but it is needed to add an analysis to decide possible contexts and an agreement on the metrics to assess these decisions.

2.2 Factors of IS Flexibility

Section 2.1 revised several definitions of IS flexibility as a capability that can emerge or can be addressed by a purpose. This section review several factors proposed to achieve the IS flexibility, using three sections: factors from the IT Infrastructure Flexibility, factors dependant on the size of change and factors from holistic approaches.

2.2.1 Factors from IT Infrastructure

These factors come from the definition of IT infrastructure flexibility, but they are technical factor mainly. This focus on technical factors shows a lack between the organisation and the IS, losing potential applications of them in the analysis and design of IS.

Chanopas, Krairit, and Khang (2006) summarises several trends of these factors, and they found that the following factors from IT infrastructure flexibility are the predominant in the field of IS.

- **Connectivity**: How easy or difficult is the generation (or destruction) of connections from one component in the system to other outside the system.
- **Compatibility**: How easy or difficult is the sharing of information across different platforms.
- **Modularity**: How easy or difficult is to add, modify and remove a component in the IS. This component can be hardware, software or data.
- **IT personnel competency**: This factor referrer to the skills of IT personnel to perform IT tasks effectively.
- **Scalability**: How challenging is the upgrade or scaling of hardware/software components.
- **Continuity**: This factor is the capability to avoid a disruption when a component in the IS change.
- **Rapidity**: How fast a hardware/software can deliver a piece of information when it is needed.
- **Facility**: How easy the users can handle hardware/software components.
- **Modernity**: How new is the hardware/software in comparison with the current technological trends.

Scherrer-Rathje and Boyle (2012) extended these factors to IS flexibility to assess the flexibility of Enterprise Systems (ES), using the end user's perspective. They suggest these factors as an assessment and method to achieve the flexibility of ES, but they recognise the lack of analysis of organisational factors to compare potential links with the IS. Consequently, Anwar and Masrek (2013) have tried to link the strategy of organisations with the IT flexibility, but

these factors do not cover the integration of the IT system with the organisation. Thus, these factors do not recognise some issues in the measurement of IS flexibility such as the perception of users and participants of the organisation (Ramaraj, 2010).

Byrd and Turner (2000) extended the IT personnel competency into business, management and technical knowledge. Additionally, they divided the factors on technical and human. The technical factors IT connectivity, application functionalities and IT compatibility are similar to connectivity, modularity and compatibility respectively. Furthermore, they proposed data transparency as a factor to control the access of data. The human factors are:

- **Technology management:** The organisation can deploy the technology most effectively if they can support business strategies.
- **Business knowledge:** It is the degree of understanding of business from the IT personnel to support and apply the best technical solution to a problem.
- **Management knowledge:** It is the skills and knowledge of the IT personnel for non-technical tasks such as project management and business process support.
- **Technical knowledge:** Technical skills and knowledge of the IT personnel such as programming and operative system.

Although the framework of Byrd and Turner (2000) has been used to assess the IS flexibility, it shows the same problem of connection between changes in the organisation and IS. For instance, there is no analysis of the capabilities of the organisation covered by the IS, and where it is needed one of these factors.

2.2.2 Factors from the Size of Change

These factors follow the definition of flexibility to use or flexibility to change proposed by Gebauer and Schober (2005) or the foreseen and unforeseen changes proposed by Jacome et al. (2011). In this case, the kind of change can address a set of factors, which should be aligned by the strategy of the organisation.

The flexibility to use represents changes that do not need a substantial investment to change because they are seen beforehand, and the organisation can implement strategies in advance. This kind of changes affect operators of IS (Data, models, parameters, responses and visual representations), rules, adaptors (components that allow creating and modifying operators) and Navigational Aids. The main elements of this kind of flexibility are:

- **Functionality:** Degree of procedures covered by an electronic resource.
- **The scope of Database:** Large of database or the extent of the catalogue, including many reports and analyses contained in a data warehouse.

- **User Interface:** Features and method that information system provides to the user interaction.
- **Processing capacity:** Number of users, transactions and user's request that the IS can process without significant losses of performance.

The flexibility to change addresses unforeseen changes and these changes are more in the line of adaptation of IS. In this case, the IS needs major adjustments that require new system setup, including re-installation and re-testing, causing significant disruptions. There are three main elements:

- **Personnel:** Skills and attitudes of the IT staff.
- **Integration of data and functionality:** It is the access to platforms and applications, and the compatibility with several applications across platforms. This integration considers the interfaces and the level of access to each platform.
- **Modularity of systems components:** Use of reusable software modules, vendor-independent database connectivity and object-oriented development tools.

These definitions of IS flexibility have a similar problem of the framework proposed by Byrd and Turner (2000) because they are focused on technical capabilities instead of the organisation and its integration with the technology. The classification of the changes as customisation and adaptation can help to restrict them, but their size or strategies to achieve them are not precise.

2.2.3 Factors from Holistic Approaches

These factors consider the organisation and how they interact with technology as a holistic approach to flexibility. There are two main cited works in this line, the framework proposed by Byrd et al. (2010) and the conceptual model proposed by Palanisamy et al. (2009).

The framework Byrd et al. (2010) proposes the study of four dimensions to observe how the IT projects interact with their environment, and how the organisation's participant perceive the IS. This framework proposes the following dimensions.

- **People:** This dimension is extended to the people of the organisation instead of only people from IT. The authors emphasise that the IS flexibility needs dynamic teams, skills, good communication between people, and skilful managers.
- **IT:** This dimension is the IT infrastructure and its ability to support a wide variety of components. Additionally, this infrastructure should achieve other properties such as efficient maintenance, modern, updatability based on standards, no monolithic, and low dependency on hardware connections.

- **Process:** The process' dimension analyses how modular are the processes in the organisation, and how well understood they are.
- **Data:** How the data is managed in the organisation. This dimension includes the use of standards, how independent are the data and the integration.

A set of interviews were conducted to validate these dimensions, but this framework is in an early stage because there are no practical contributions, which can show its usefulness.

On the other hand, the conceptual model proposed by Palanisamy et al. (2009) looks for business needs in the external and internal environment of the organisation, proposing factors in the IS that can affect them. For instance, this model recognises product and services from the environment that should be implemented in the organisation by the capabilities of IS. This model is divided in sources of changes, enablers of changes and results of changes, putting the IS flexibility as result of the change, which can enhance the degree of fit between the organisation and the IS.

Although these propositions consider the organisation and the environment for potential research using organisational theories, they have not suggested a precise method to connect organisations and IT systems.

2.3 Methodologies to Enhance IS Flexibility

The IS flexibility has been addressed from the theory instead of the praxis, leaving a gap in the form to enhance the IS flexibility. On the other hand, several studies with practical applications claim to provide flexibility to the IS without assessing it. This section reviews methodologies that claim to provide flexibility to information systems from the field of information systems and organisational studies. These two fields can cover several aspects of the IS flexibility such as the implementation of IS and the management of change of IS.

2.3.1 Methodologies from the Field of Information Systems

The field of information systems has proposed several forms to provide flexibility to the system. This review classified them into two trends, the implementation of IS flexibility by abstraction and the alignment between IT and business.

IS Flexibility by Layer of Abstraction

Several studies have claimed to provide flexibility to the IS, developing layers of abstractions and functional divisions. The model of three layers is the prominent functional division, which can restrict the flexibility to the system according to the problem to resolve into data, business and interfaces.

The developments of flexibility for data integration has been studied to provide customised access to information, using several systems like data sources. This kind of integration uses abstracts layers of data according to the source of data, and its composition (Zhao et al., 2012). This composition may use a degree of intelligence such as agent systems to compose queries, processing the data by recursion (Lu and Sterling, 2000). The level of abstraction in the layer of data is useful to integrate several sources of data and legacy systems, and also the application of a degree of intelligence can avoid potential change if a source of data changes. However, this layer is usually challenging to integrate, because there is needed the same standards and protocols to manage them.

The layer of process proposes the development of IS with the capability to link process with context. This links can face the uncertainty of the business processes, which can change according to the circumstances of the environment (Nunes et al., 2012). One of the prominent work in this trend is the Process-aware information systems (PAIS), which considers the deviation of tasks under specific context during the execution of a process (Burkhart et al., 2012). The implementation of a PAIS involves several layers of infrastructure such as databases, object management systems and languages for modelling processes (Tan and Zhao, 2005). However, this variety of task and process can present some conflicts with the execution of restricted workflows (Santos et al., 2013). Thus, the division of layers can face the uncertainty of processes, but they need a context to derive processes. This analysis of context and the processes of the organisation have not been developed in the proposition of PAIS.

The flexibility of user interfaces has been researched to divide the content between static and dynamic to change the user's interface, without 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’s plan to change the user’s interface after the analysis of a set of norms and a context (Fortuna et al., 2010). This approach proposes the flexibility of user’s interfaces by the division of content, norms and context, but it is not focused on the analysis of the IS flexibility in the organisational context, proposing forms of analysis to identify where the interfaces need to change.

The concept of software evolvability involves these three aspects, using patterns and good practices (Mannaert et al., 2006). According to Mannaert et al. (2011), the following guidelines should be followed to promote the software evolvability:

- Separation of concerns: An action entity can only contain a single task, and separable modules should contain the change drivers.

- Data version transparency: Data entities must be passed to action in a hidden format, creating several version of data elements without affecting the action elements. It should have an additional action layer for persistent objects.
- Action Version Transparency: Actions should represent task version, dividing their real and abstract representations. Additionally, each action should have their representation of remote access.
- Separation of States: The calling of action among action entities must exhibit the state of the workflow.

These researches identified the context as an enabler or constrained of flexibility because the context can resolve the purpose of the change and the system. However, no one of these research proposed a form to identify context, showing a lack of connection between the organisation and the IS.

IS Flexibility by the Alignment of Business and IT

Another method or form to provide flexibility to the information system is the alignment between IT and business, or its the extension the co-design. Business and IT alignment is the degree of fit and integration of factors such as structure and strategy of the business and IT (Ullah and Lai, 2013). The co-design is a form of alignment that proposes concrete actions or steps, resolving the lack of methods of the alignment. However,

The alignment usually assesses communication, competency/value, governance, partnership, architecture's scope, and skills (Luftman, 2003). These factors assess the perception of the IT area in the business area and vice versa. However, these factors can be difficult to assess in big organisations with several departments.

For this reason, some authors divide this assessment into layers or levels of alignment into two branches:

- **Functional Division and Context**: Chan and Reich (2007), and Ullah and Lai (2013) have suggested four levels: individual, project, system and organisational. Individual-level is the translation of a business goal to personal goals. Project level relates to the IT project's deliverables with the strategy and objectives of the organisation. System level is alignment with some sub-functional systems such as finance or human's resources (HR). Organisation level is related to the culture of the organisation.
- **Division on organisational learning**: Balhareth, Liu, and Manwani (2012) define the levels of alignment from the perspective of the organisational learning to increase the knowledge of the organisation, improving the process of creation and implementation of the strategy. They propose that the creation of strategy starts from the individual

level, which is interpreted from the group level that shares the knowledge to the organisation level. Finally, if this knowledge is accepted, it is utilised by the organisation.

The concept of alignment and its application can be understood as a form to measure the capability of the organisation and the coverage of IS, but it does not mean flexibility. When the misalignment is found, the effort needed to align again can determine how flexible an information system is. Thus, the focus of IS flexibility on IT infrastructure may not be wrong, but it is needed a connection between the organisation and IT systems.

This problem attempts to resolve the co-design of business and IT, because the co-design analyses and implement changes in business and IT at the same time, identifying components in both “worlds” to reflect these changes. Current co-design approaches have analyses components that interact among knowledge domains and rules of behaviour in the organisation. Gasson (2008) uses the principle of a boundary-spanning framework that represents objects that intersect between two knowledge domains. Examples of this kind of objects are prescriptions given by a doctor and received by a pharmacist, or a purchase order given by a supplier and received by the buyer. This alignment considers models such as business knowledge, business processes and IT diagrams to clarify the context of the change and its impact on the organisation and the IT systems. However, this framework does not provide enough methods or tools to analyse and transfer the organisational components to IT systems. There is no connection between the organisation and the environment to identify their interaction and potential changes of them.

The co-design proposed by Liu and Li (2014) and Navid Karimi Sani (2011) uses organisational semiotics as a method of analysis for the alignment. Liu and Li (2014) propose three dimensions of co-design: Infrastructural, organisational and operational co-design. These dimensions divide the complexity of the organisation to manage several kinds of architectures such as service-oriented, socio-technical and enterprise architecture. This approach considers the application of the problem articulation method (PAM) to identify the strategy and objectives of the infrastructure, the Semantic Analysis Method (SAM) to identify organisational components such as services and capabilities, and the process modelling to connect the process and functions with the business rules and norms. Figure 2.1 shows another example of co-design with organisational semiotics proposed by Navid Karimi Sani (2011), who developed the application of this approach in a process with six steps. The co-design of business and IT (COBIT) emphasise the identification of the current context, using PAM, SAM and Norm Analysis Method (NAM). Then, phase 3 and 4 propose a solution based on an ideal situation and the current capabilities of the IS. Phase 5 perform a gap analysis to identify the processes and activities that are currently supported by the IS, the process and activities.

Finally, phase 6 is the implementation of the alignment, where it is possible to come back to other phases like the problem identification.

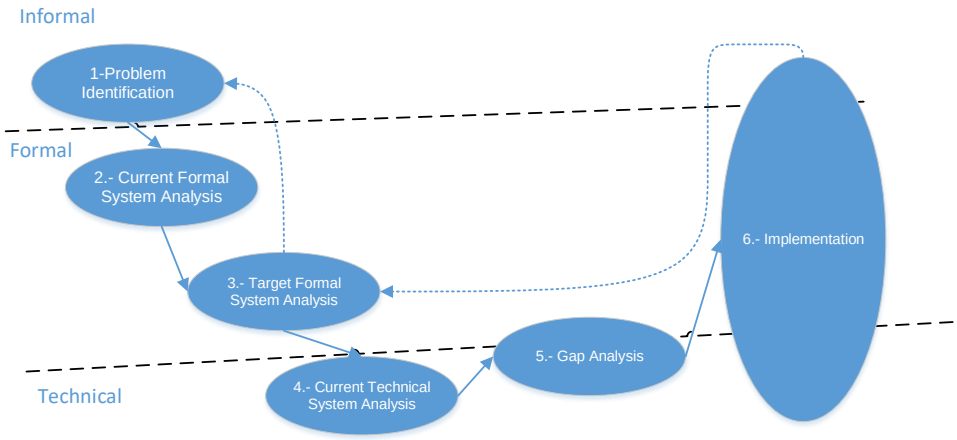

Figure 2.1 Co-designs of Business and IT (COBIT)

Source: Navid Karimi Sani (2011)

The co-design can address where the analysis of capabilities needs the IS flexibility, but the analysis of a target system does not define the potential changes or why the IS flexibility is needed. It is needed to propose an approach that includes methods or steps to identify potential changes in the organisation and then the information system.

2.3.2 Methodologies or Models from the Field of Organisational Studies

Methodologies to develop IS flexibility in organisations can be found as methods to manage changes. However, there are a few models or methodologies that includes information systems as part of the change management. These models or trends are open system model, Viable System Model (VSM), Model of organisational performance and change (OPC) and Organisations as Autopoietic Systems.

Organisations as Open Systems

The open system theory recognises that organisations can be affected for external factors because open systems need the energy such as raw material or people in order to transform into outputs such as product, services and ideas (Burke, 2011).

The components of an open system are:

- Inputs or resources: Raw material, money, people, information and knowledge, which contributes to the creation of outputs.
- Outputs: Products, services and ideas.
- Technology: Transformation methods and processes of input resources into outputs. These methods can be mental, physical and mechanical.

- Environment: All organisations and conditions that can affect the operations and technology of the organisation directly. General environment includes economy, the government, the technical knowledge, human population and the national culture.
- Purpose: Strategies, goals, objectives, plans and interest of the organisation.
- Behaviour and processes: Pattern of behaviour, interactions and relationship between groups and individuals.
- Culture: Shared norms, beliefs, values, symbols and rituals related to the organisation.
- Structure: Roles and duties of individuals, groups and large units.

The primary approaches of open system theory are the social science and economy (J. Boonstra, 2004), but there are applications in other fields like thermodynamics (Steele, 2005). The critical problems of this theory are

- The causalities between the factors of the environment their consequences on internal sub-systems are not apparent.
- Open systems do not provide a structure to analyse changes, putting a blurred line when they are analysed (Mearman, 2006).
- There is the possibility that two (or more) external forces act inside the system, cancelling them mutually (Mearman, 2006).
- A tendency to think by analogy.

Finally, technology includes information systems, but there are no details about the link between technology and other parts of the open-system (Harrison, 1987).

Viable System Model

The Viable System Model (VSM) was proposed by Beer (1984) as viable recursive systems, containing other viable systems. This approach is derived from the architecture of the brain and nervous system in the following systems.

- System 1: a set of activities that cover the core competencies of the organisation. These activities are viable systems itself due to their recursive nature.
- System 2: Communication channels that interchange information and the schedule of resources. The system three monitor and coordinate these activities.
- System 3: A set of activities that control responsibilities and establish rules of system 1. It provides interfaces with the system 4 and 5.
- System 4: Represent the activities that are observing the environment to identify needs that adapt the current organisation for future changes.
- System 5: Represents the decision making which balances the internal demands with the needs of adaptation.

The system one follows the recursive system theorem, which states that in a recursive organisational structure, every viable system contains, and is contained in a viable system. The main interchanges of the VSM with the environment are their operational activities and the constant search of the system four for future changes. These interchanges directly affect the variety of the system, because the adaptation for future changes can prepare the system to survive.

VSM has been used in social science by means the study of organisations like politics and management (Beer, 1984; Yolles, 2004). The critical problems of this theory are:

- The main applications have been on large companies (Burgess and Wake, 2013).
- This model has shown problems to define the primary purpose of the organisation and each unit, depicting a blurred line between environment and organisation (Burgess and Wake, 2013).
- There are not functional or structural details to propose an ideal organisation in details (Nechansky, 2013).
- VSM has shown some lack to manage the initial goal setting, evolution of organisations, independent top-down control, independent bottom-up corrections, the balance of power and goal changing (Nechansky, 2013)

Due to the lack of a formal definition of IS in the VSM, it is possible to use IS in each sub-system, for instance, Badillo, Tejeida, & Morales (2008) state the application of Enterprise Resource Planning (ERP) in the sub-systems from one to four. In this case, the IS can be seen like a resource that can support each system.

Model of Organisational Performance and Change

This model was developed by Burke & Litwin (1992), and it is based on the concepts of open systems. The external environment is the input of the system, and the organisational performance (product and services) is the output of the system. This model uses feedback loops between the external environment and the organisational performance to demonstrate that they can be affected mutually. The components of this model are:

- External Environment: Variables, forces or factors outside the organisation that can influence the organisational performance.
- Mission and strategy: Purpose, aim and address of the organisation.
- Leadership: It provides the direction to the organisation through persuasion and influence.
- Culture: Norms, values and codes of conduct.
- Structure: Arrangement of organisational functions and operational units.

- Management practices: A set of practices that managers carry out the organisations' strategy.
- Systems: planning, controlling, budgeting, and information systems that serve to meet organisational goals
- Climate: Collective perceptions of members within the same work unit.
- Task requirements and Individual Skills/Abilities: Profile of a job position in the organisation, which include role, responsibilities, knowledge, skills and abilities.
- Individual needs and values: personal needs and values of the organisation's members, which can be met on the job.
- Motivation: The need and satisfaction to achieve individual and organisational goals.
- Individual and Organisational performance: Outcome and results of every activity.

This model has been used in the fields of social science and management (Siegal et al., 1996). However, the following problems can be found in its application.

- The causal model lacks a more in-depth application on each level of the organisation (Lawrie and Cobbold, 2004).
- The number of factors can complicate its use, understanding and visualisation (Lok and Crawford, 2000).
- The causal path and the ordering of the proposed factors are in contradiction with other studies (Brewer and Selden, 2000)
- The model does not explain the level of effect among the factors. For instance, how much can affect one factor directly related with other? (Fedor et al., 2006).

Although, the component systems include IS and technology such as Management Information Systems (MIS), organisation's reward systems and control systems (Burke, 2011), this model does not provide methods or guidelines for applying it. Additionally, information systems are part of the component systems in this framework, so the analysis of potential interaction with other components categorised as systems may not be explicit with this framework.

Organisations as Autopoietic Systems

Autopoietic systems come from the definition of Autopoieses proposed by Maturana and Varela (1991), which define living systems as a network of processes that produce each component. In the field of social science, Luhmann (2006) proposed that social systems are autopoietic if the observed social systems can be assessed by a binary code that rules the system. This concept has been used to analyse organisations, because one of the main features of autopoiesis is the self-maintenance of the system, analysing the dynamics that can enable changes (Goldspink and Kay, 2009).

Current propositions of autopoiesis on IS have stated that IT systems are autopoietic. Huysman, Blonk and Spoor (2009) define autopoiesis like the maintenance of identity after several changes. They discuss three issues about information systems to maintain its identity that are how the system can constitute its border, how the organisation of the system determines the conditions for its functions and how to deal with changes, maintaining the system continuity. They state that IS are autopoietic if they can maintain the image of the organisation because the organisation defines the structure of IT systems and its identity. Every feasible interaction of IT systems is pre-defined by the organisation, shaping the border and the conditions of its functions. In the case of changes, the organisation updates its image (the representation of itself) into IS to maintain the continuity. However, the maintenance of the organisational image can bring new challenges, because the organisation can reflect its conflicts between components (departments or groups) to the system, even if they are autopoietic (Kay and Cecez-kecmanovic, 2002). Thus, the IS is usually a reflection of the organisation, including their drawbacks such as lack of participation in the design.

Another research about autopoiesis studies the participation's dynamics of open-source projects. Bača, Schatten, and Deranja (2007) define autopoiesis as the capacity to adapt to the needs of its current users continuasly and also to preserve all the characteristics that make it unique and recognisable as an information system. In their work, the components of autopoiesis in open-source projects are the structure for specific decisions, the collaboration systems, and creative problem-solving techniques. Thus, IS has been seen as systems with autopoietic properties, because the structure of IS defines its border and functions. However, these definitions have explained some properties of the autopoietic system that can be applied to IT systems, avoiding a concrete analysis of the concept of self-production, and the boundary of IS with the organisation. For instance, it is not clear how autopoietic systems deal with changes, or what is the boundary that should be kept.

Reichel (2011) proposes that technology is a self-referencing system distinct from society and individual humans, using the binary code work/fail to assess the technology. However, these works only analyse the generation of a binary code to define the system, being useless for the analysis and design of information systems.

The work of Abou-Zeid (2000) is one of the practical work that attempts to propose a method or form to analyse the autopoiesis of information systems. Abou-Zeid uses the topology of Luhmann to define an organisation as autopoietic by the realisation of life and meaning. The analysis of physical and communicative activities can identify the set of meanings that the organisation know, putting the information systems as a system that should cover this set of meanings. Abou-Zeid (2000) proposes the analysis of actors, their activities and the situations or events that involve these activities. This analysis can raise a set of norms, which can define

the autopoietic system. However, the analysis of the current situation in the focal system may be not enough to identify the flexibility of the system, but the current capabilities. The flexibility of the system should consider potential situations to change, which can allow designing the system with capabilities for the near future.

Comparison Between Models

The comparison of the methodologies or models is shown in table 2.1, showing the main feature of each model and the critical problems to use them.

Table 2.1 Comparison of organisational models and change

Theory	**Open System**	**Viable System Model (VSM)**	**Model of OPC**	**Org. as Autopoietic System**
Main Feature	Considers external factors Needs external resources Possess negative entropy	Five components: Core competences, communication, control, observation and decision. Recursive	Representation of the environment and the impact of inner-factors	Based on signs, their impact and their meaning for the organisation. The analysis of events can identify the current capabilities of the organisation.
Key Problems	No direct representation of R&D, quality and external sources of change Mainly theoretical approaches. No causalities of the impact of the environment on inner-changes. External forces can be cancelled among them.	No direct representations of the impact of change Main applications in large companies. No clear definition of borders of each component. Self-regulation is not autonomy. No proposition of ideal organisation. Problems with the initial goal setting and organisation	No direct representation of R&D, quality and external sources of change The impact is complicated to measure Contradiction with other studies The model does not explain the level of effect among the factors	It is needed other models or diagrams to describe the procedural aspect Does not describe a causal model of the organisation The event does not describe responsibilities and how they are interrelated

However, the following assumptions were considered to build the table.

1) Organisations possess an IT system: This assumption is made in the context that the analysis of the impact of an IS should count with an IS in the organisation.
2) The change in the organisation is the result of an external source of change: This assumption response to the fact that organisations (especially business organisations) are part of competitive environments. Every variation of customer needs or demand can affect internal factors such as workforce or processes (Oakland and Tanner, 2007).

3) The information system has achieved their initial requirements successfully: This assumption discards any change in the information system because of lacks of its initial requirement, but due to external changes in the organisation.

The result of this comparison is the lack of formal models and theories to evaluate the impact of several sources of change into the organisation, and consequently the IS. The identification of misalignments between IT and the organisation could address the study of IS flexibility, and these factors can provide valuable insight into the identification of the environment of the organisation and IS.

2.4 Summary of Challenges and Issues of IS Flexibility

This chapter has reviewed several types of research about IS flexibility, its factors and methodologies to develop, but the main problem is the lack of analysis of organisational factors that can trigger a change, linking their potential impact in the information system. Several kinds of research have claimed to provide flexibility to the IS, and also several proposed factors attempt to provide guidelines to assess the flexibility. However, the main question “why” the system needs flexibility is not answered, and its answer can address the enhancement of the IS flexibility. The following sections summarise this review, discussing the main issues of IS flexibility.

2.4.1 Summary and Issues of Definition of IS Flexibility

An agreement about this topic is that the IS flexibility is a capability to support or enable changes. This review classified the definitions of IS flexibility in two trends; IS flexibility as a generic capability and as Heuristic capability. The IS as a general capability emphasis that the IS can have a feature that can enable changes in the organisation. This definition is useful to explain what IS Flexibility is, or to measure changes in general, but it is useless when if the aim is to enable or enhance it. The IS as a heuristic capability can address the analysis or design of IS flexibility because the definition of a purpose can restrict the set of potential changes. However, the election of the purpose is transformed into the new problem of IS flexibility, because it depends on the knowledge of the managers or the people in the organisation.

However, the main problem of the IS flexibility is the subjectivity of the observer, because the current definitions rely on the knowledge of the observer about the observed IS, the organisation and the current works in this field. For instance, the definitions of “flexibility to use”

and the "flexibility to change" proposed by Gebauer and Schober (2005) are similar to customisation and adaptation, making new concepts instead of the standardisation from the researcher community. Another example can be found in the research of Byrd and Turner (2000) when the workers of the organisation responded to the statement "Flexible electronic links exist between our organisation and external entities". This statement assumes that the contestant understands the complexity of the whole organisation such as the stakeholders and their means of communication, putting the responsibility into the perception of the organisation's participant.

Additionally, the flexibility of IS depends on the observed period, which can show a high (or low) frequency of changes, adding an extra challenge to the study of the flexibility of IS. Kelly (2006) proposed the stability of the software, using the lines of codes and its modules when a software change. The system is stable when two versions of the software only have small changes, similar to the concept of "flexibility to use" proposed by Gebauer and Schober (2005). However, there is no studies or concrete reasons to define how much are small changes. For instance, a threshold of 20% between versions are small enough (Farias et al., 2014; Kelly, 2006). This percentage can make the difference between the "flexibility to use" versus "the flexibility to change", putting a challenge of agreements about the flexibility of IS in the branch of software development. This percentage can make the difference between the "flexibility to use" versus "the flexibility to change", putting a challenge of agreements about the flexibility of IS in the branch of software development. Human systems extend this challenge, because the definition of organisations may not be clear and measurable as lines of codes in software development.

In summary, the IS flexibility is a capability of IS that relies on how the knowledge of the participants of the organisation can be included in the design of the IS, to support the changes inside and outside the organisation. Thus, the IS flexibility should be purposeful and depends on the awareness of the organisation's participants.

2.4.2 Summary and Issues of the Factors

The review of the factors of IS flexibility found three branches: the factors from the IT infrastructure, the factors divided by the size of change and the factors from the holistic approaches. Table 2.2 summarises these factors and their sources.

Table 2.2 Summary of factors of IS flexibility

Focus	Source	Factors
IT infrastructure flexibility	(Anwar & Masrek, 2013) (Scherrer-Rathje & Boyle, 2012)	Compatibility, modularity, connectivity, IT personal competency, scalability, continuity, rapidity, facility and modernity.
	(T a Byrd and Turner, 2000)	**Technical Factors:** IT connectivity, applications functionalities and IT compatibility. **Human Factors:** Technology management, business knowledge, management knowledge, and technical knowledge.
Size of change	Gebauer and Schober (2005) (Jacome et al., 2011).	**Flexibility to use:** Functionality, the scope of the database, user interface and processing capacity. **Flexibility to change:** personnel, integration of data and functionality, and modularity of system components
IS flexibility from holistic approaches	(Byrd, et al., 2010)	**People:** Manager Commitment, dynamic capabilities, adaptive capacities, multiple capacities, multifunctional teams, few hierarchical levels, communication of plans. **IT:** Infrastructure ability to support a wide variety of components, efficient maintenance, systems easy to modernity, the possibility of an incremental update, standards, no monolithic applications, no hardware connections. **Process:** No tightly integrated, monolithic, decomposed, well understood. **Data:** Standards, independent data, sharing data, ID federation and data integration.
	(Palanisamy, 2012)	Proportion of business and IT changes incorporated (Extent of response), option for business-decision scenarios, ease (ability to do something with ease other than that which was originally intended), speed of change of IS, freedom of choice to the main actors to build flexibility in the IS, time / cost, effort, variety, range and balance of ISs.

The lack of connection between the IS and the organisation is the prominent problem of IS flexibility. Indeed, the factors from the IT infrastructure as a starting point to analyse the IS flexibility, because they are based on good practices from the industry, but they are not always the best solution (Long, 2017). This lack of connection was addressed by the inclusion of human factors of the IT personnel, but these approaches are still focused on technical features. This problem is also found on the factors from the size of the change, which are technical factors mainly. On the other hand, the holistic approaches can fill this gap, but a lack of connection remains. For instance, the factors proposed by Palanisamy (2012) consider the speed of change of IS, but this speed depends on a proposition of scenarios that should be important for the organisation. There are no criteria for the selection of scenarios to change from the organisation.

2.4.3 Summary and Issues of Methodologies to Enhance the IS Flexibility

This review analysed several approaches that claimed to provide flexibility to IS from the field of IS and organisational studies. The field of IS has two main trends: the layer of abstraction and alignment. The former proposed the abstraction in layers but divided in the three layers' model: data, business/process and interfaces. Several of these proposition seems to provide a degree of flexibility to the system because they minimise potential changes when the system needs to change. However, there is a lack of address of these propositions, because the implementation of all of them at the same time can add cost to implement them. On the other hand, the alignment between business and IT can provide an address to enhance the IS flexibility, but they do not identify potential sources of change from the environment.

The researches from the field of organisational studies can articulate the analysis of the environment, providing tools to address the analysis of potential changes. However, they are not practical, and the IS are not well defined. The enhancement of IS flexibility needs to provide several tools to identify potential sources of changes and how they can affect the IS.

Figure 2.2 shows a graphical representation of the context and the visibility of the change. The IS need to support changes from either the organisation (internal environment of the IS) or the environment of the organisation (external environment). Every organisation has different information systems, covering several aspects such as logistic, accounting or sales of the organisation, and part of these aspects can interact with people or systems from the environment. Thus, the flexibility of the IS depends on the organisation and its environment.

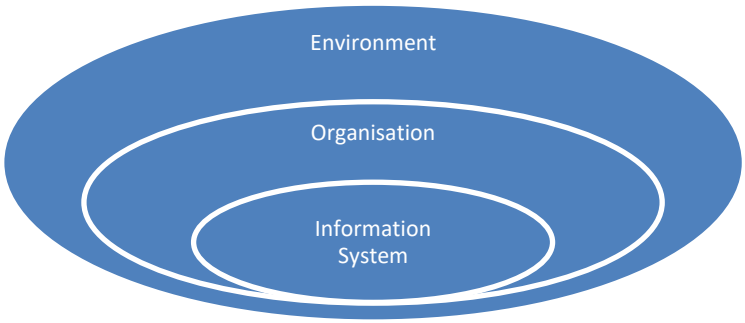

Figure 2.2 Context of the IS flexibility

This contextual representation of the IS flexibility can show the following issues showed in the reviewed methodologies:

- This representation of the context shows that an observer can assess the IS flexibility in the context triggered by the change. The changes in an organisation and the knowledge of the observer to perceive them can demonstrate if the IS is flexible or not. The kind of organisation and its environment can trigger changes in a short or long period, leaving a potential gap in the assessment of flexibility for changes with a low

probability to happen. Examples of this kind of changes can found in the change from a manufactory enterprise to a service enterprise because they change the form to get profit.

- A change can only be considered as a change when the implementation means a cost. Indeed, the customisation of the IS allows changes after the implementation of the systems, but these changes do not mean any cost. They mean less cost in money or transfer part of the cost (evaluated in time) to the users. How big this cost is in the implementation, will define If the system is “flexible to use” or “flexible to change”, so the structure of the IS can impact the perception of flexibility. New technologies such as cloud computing and the use of standards may affect the cost in the long term. Thus, the implementation of IS flexibility should cover the features of flexible to use and change at the same time.
- The human factor of the IS flexibility is the knowledge of the people involved in the assessment and implementation. The knowledge in the assessment referrers to the people in contact with the IS, and how they perceive its functionality in the organisation and its environment. It is not right to assume that only the users of the system can assess the IS flexibility because managers or partners in the organisation can assess the system without any use of it. The knowledge involved in the implementation is the knowledge needed for the construction of the system or the implementation of new changes. This knowledge is not only the official requirements of the system, but it can include the knowledge of potential changes. An example of these potential changes was found in the research of Fitzgerald, Philippides, and Probert (1999) because someone in the organisation identified several changes before happening. This example shows that the knowledge about the organisation and their potential changes are connected with the IS flexibility.

The factors from the IT infrastructure proposed by Chanopas et al., (2006) can provide a set of attributes to enhance the IS flexibility, using the layers of abstraction reviewed in section 2.3.1 such as composition of queries (Lu and Sterling, 2000) and a version of tasks (Tan and Zhao, 2005). A proposition of these attributes is summarised by layers in table 2.3, proposing forms to achieve flexibility in each layer and attributes. These attributes are useful to achieve in an IS, but they also can address a list of purpose for an analysis. For instance, the purpose for the compatibility is the capability to share a platform. This list of attributes or purposes can address the need of flexibility.

Table 2.3 Metrics of IS flexibility

IT attribute	**Layers**		
	Data	**Process**	**Interface**
Compatibility (Share platform)	Share standards of data	Share standards of data and processes	Present information
Modularity (Change of functionality)	Abstraction of entities or data objects	Division of process in tasks	Definition of contexts such as users' profiles and the functionality
Connectivity (Communicate)	Abstraction of the source of data without losing autonomy	Abstract representation of external processes	The proposition of elements that control the logical flow of interfaces
Scalability (Growth)	The composition of data queries (several sources)	Composition of Tasks	Expansion or construction of interfaces depending on user's profile
Continuity (Affordance Continuity)	Definition of a version of data with concrete implementation	Definition of a version of tasks with concrete implementation	Definition of a version of interfaces and changes in the context
Rapidity (Fast delivery of Information)	Technological dependant	Technological dependant	Technological dependant
Facility (Easy to use)	Construction standards (documentation and organisation)	Construction standards (documentation and organisation)	User Manual (documentation)
Modernity (Disposable Technology)	Technological dependant	Technological dependant	Technological dependant

Based on IT infrastructure flexibility (Chanopas et al., 2006) and the strategies of (Bonacin et al., 2007; Burkhart et al., 2012; Fortuna et al., 2010; Lu and Sterling, 2000; Mannaert et al., 2006, 2011; Nunes et al., 2012; Tan and Zhao, 2005; Zhao et al., 2012)

However, these attributes are useless without the analysis of the context to identify potential sources of changes, needing a form of analysis that includes potential changes from the organisation that can affect the IS. This form of analysis should have the following features:

- It should consider the analysis of the organisation to identify potential sources of changes.
- It should analyse the focal information system to identify the requirements.

- It should compare if the focal information system addresses the potential source of changes. The attributes and purposes proposed in table 2.3 can help to provide guidelines in the development.
- It should be compatible with the current methodologies of software development.

The analysis of the organisation and their potential sources of changes involves the analysis of the components and links of the organisation, showing what can change and what cannot change. Organisational studies have faced this problem because it involves philosophical concepts such as the identity of the organisation. However, the definition of an organisation as an autopoietic system or a living system may show what cannot change, avoiding the risk to destroy the organisation, showing which changes can be made.

Chapter 3

Information Systems as Living Systems from an Autopoietic Perspective

Chapter 2 reviews several studies related to the IS flexibility, showing that the main problem of them is the lack of analysis of potential changes of the organisation to include in the analysis and design of IS. The IS flexibility is restricted to the capability of the organisation to answer to the environment without being destroyed. This capability is similar to the survival of living systems, which should maintain the core process to produce the life. These processes and its network is named “autopoiesis” (Maturana and Varela, 1980) and have been studied to provide the capabilities of living systems such as self-production, adaptation and evolution to a focal system. For this reason, this chapter explores the application of the concept of autopoiesis into IS, because living systems are flexible systems, and its application to IT systems can provide a deep understanding of the current problems of adaptation to address the enhancement of IS flexibility.

3.1 Organisations and Living Systems

The family has been the primary form of organisation from ancient times, where the initial settings of communities started with the organisation of groups of families to survive from external risks. The need to survive also present in organisations creates the perception of the property of people’s time and goods to the organisation instead of personal property (Scott and Gerald, 2007). This need for survival could mean a natural conception of organisations and the interpretation of property could explain a structure that organisations should maintain from inner or external sources of changes. For this reason, the explanation about why living systems want to survive could help to define the changes of organisations and then the IS flexibility. The definition of life can be explained by the definition of “autopoiesis” or living systems.

The concept of autopoiesis was defined by Maturana & Varela (1980) in the explanation of a minimum unity of organisation (in the meaning of configuration) to produce life. This definition says that an autopoietic machine is organised as a system of concatenated processes of production of components, which integrate the transformation networks that created them. These net of processes are connected by continues interactions and transformations, creating

a principle of organisation and unity that define a living system (Varela, Maturana and Uribe, 1974).

Living systems poses an identity defined by their autopoiesis (their network of process and self-production), which must be invariant through the constant perturbations from the environment, and the interactions with the environment must consider this maintenance of identity.

3.1.1 Key Notions of Autopoiesis

The proposition of Maturana and Varela (1980) allows written some main features of autopoietic systems to determine the basic properties of a theory of Information Systems based on autopoiesis. The first property of the autopoietic system is the self-production of elements of the systems, which can be categorised as autonomous systems. This autonomy implies a distinction between the elements and processes that participate in the autopoiesis and their environment. This distinction is the separation between life and dead of the living system, creating its unity as a result of the non-separation of their components, where the spatial configuration is the border. The second property of autopoietic systems is their **organisation**, which is composed of elements and their interactions in the net of processes that self-produce the system. In this context, the **structure** is the current components that satisfy the relations of the organisation. The third property is the **structural determinism**, which states that its structure determines any change in the information system. The system can change only if the structure allows it to do it, maintaining the autopoiesis of the system. The fourth property is the **organisational closure**, which is the generation of activities in self as a result of a perturbation of the environment. Thus, every state´s change of the system generates an activity itself. However, this does not mean that the system cannot interact with the environment. The fifth property is the **structural coupling**, which is the ability to interact with the environment, maintaining the inner-organisation of the system.

3.1.2 Interactions and Structural Coupling

The interaction between autopoietic systems and the environment is determined by the concept of perturbations from the environment to the system. Every change can be made if the autopoiesis remains after the change, so their domain of interaction is determined by its inner-organisation or inner-configuration (Maturana and Varela, 1991).

A structural coupling occurs when an interaction between the system and the environment is recurrent. Nevertheless, this structural coupling is not only the interaction with another autopoietic system, but they can define the environment of living systems and how well adapted it is (Maturana and Varela, 1992). An autopoietic system can react to an interaction

only if the system can perceive that interaction from the environment (Maturana, 2002), so the flexibility of the system depends on its structure and the capability to perceive and react. On the other hand, when the perturbations from the environment are not repetitive, it is called ontogenic structural drift (Maturana and Varela, 1992), and it also depends on the structural determinism of the system.

The structural coupling can derive in two kinds of relationships symbiosis and meta-cellular systems (Maturana and Varela, 1992). The former was important in the creation of life because it seems that the symbiosis allowed complex cells (eukaryotes), but this kind of behaviour means a loss in the identity of the organism. The last relationship creates other types of autopoietic systems, which conserve the identity of each system, but they should maintain the autopoiesis of the whole system together. The internal elements of a high order autopoietic system behave in an allopoietic form, which means that they behave in a functional form to allow the autopoiesis of the whole (Maturana, 2002). This behaviour may simplify the analysis of the internal components of autopoietic systems because the relationship between the elements is functional.

3.1.3 Types of Autopoietic Systems

The domain of interaction of an autopoietic system can couple their behaviour when the environment or other autopoietic systems have regular interaction with the observed system. If the regular interactions among autopoietic systems are a source of perturbations and compensations, and the systems do not lose their identity, then the interaction can create a new unit named a second order autopoietic systems. In this case, the autopoiesis of each system is dependent on the autopoiesis of the superior order, and the interaction with the environment can change the structure of the autopoietic units according to the specific function in the superior-order autopoiesis. The kind of interaction of autopoietic systems can be in two forms:

- Co-dependency of behaviour: The regular interactions between unities make a dependency in both behaviours because the behaviour of one unit depends on the following behaviour of the other in a sequence.
- The dependency of an independent outcome: The interaction does not depend on a specific sequence, because the interaction can occur at any time. In this case, the interaction can be named communication. For instance, the communication of the endocrine system using hormones.

Multi-cellar and living systems with the nervous system are autopoietic systems of the second order, where the latter can bring a new form of interactions due to their abstract interactions and new inner-states as a result of their self-conscious. Additionally, the communicative

interactions can generate a kind of language, because a set of communicative interactions means a set of perturbations in the point of view of other systems, and if they are coupling systems, they have a set of compensation to response to those perturbations. Thus, in the case of a living system with nervous systems, the use of language does not imply physical interactions among them, but they can make their language based on a set of abstract representation to coordinate their activities or functions, generating a third order coupling or societies.

According to Maturana and Varela (1992), this kind of coupling is needed for at least two reasons, the former is a reproduction, and the latter is raising's children. However, the interaction among living beings can be more complicated, because they can adopt several roles to superimpose the survival of the group. In the conservation of the mutual coupling, each is replaceable if another individual can accomplish with the same communicative relations. These kinds of relations can be described as an intentional act for an observer, so it is possible to define the set of these conducts in a third order coupling as a linguistic domain. For this reason, the abstract interactions are made by descriptions and their relations with other descriptions, creating a domain of interactions based on the self-observation, where the linguistic domain can operate as a semantic domain of the interactions of individuals in the group.

The society as a group of living systems is organised with inner-regular interactions, where the communication makes the coupling of the society by linguistic perturbations and compensations among individuals. Culture or cultural conducts are a background of trans-generational configurations of conducts, to coordinate the society. Therefore, society possesses trans-generational conducts based on linguistic domain, which can describe the organisation of each part of the society, assuming the possibility of autopoietic organisation for inheritance in some sub-group such as governs and enterprise.

3.1.4 Cognitive Domain

The cognitive domain of an autopoietic system is all perturbations that the system can interact without losing its autopoiesis. Thus, every interaction that makes a new form of interaction and an internal change is named cognitive interaction. In the case of living systems with nervous systems, it is possible to change the state of a system without creating cognition, because they possess the capacity of self-observation, creating interactions between abstract representations. For instance, a person will not learn to use a pen again if the pen is different. Therefore, the cognitive domain of autopoietic systems with nervous systems is defined with a set of abstract interactions.

It is possible to say that an autopoietic system has acquired new knowledge when an observer can notice effective conduct in a specific context. The conduct can be defined as movements or actions within an environment. These conducts are the result of the domain of cognition, the autopoietic system and the environment. Some parts of these conducts are inherited (innate conducts) from years of evolution of specific species. Thus, the learning process of an autopoietic system can be seen as a long-term process that started before the conception of the living system, because if a living system alive means a domain of interaction which allows the autopoiesis of the living system.

3.1.5 Social and Organisational Autopoiesis

Section 3.1.3 stated that in social systems the interactions are not only physical, allowing interactions in a symbolic domain by the language. Niklas Luhmann proposed that social systems use communications to make distinctions and then its autopoiesis (Luhmann, 1996). This distinction separates the system to the environment as a nonphysical boundary, making the communication as the element that can create new communications (Luhmann, 2006). The act of communication is divided into three components: utterance, information and understanding. The utterance is the form of and reason of communication, information is what the speaker wants to say and understanding as the interpretation of the listener (Seidl, 2004). However, the interpretation is open to the listener, who can link the physical and social world of autopoiesis.

The distinction as a boundary of social systems can identify several sub-systems in the society such as political and legal (Roth, 2014). They are ruled by a binary code to define if the communication act makes sense or not in this subsystem. For instance, in the case of legal systems, every communication act can be assessed as lawful or not, simplifying the understanding and interpretation in that sub-system. Social subsystems can have structural coupling by the act of communication that can be understood in two systems. For instance, a sales contract structurally couples the legal and economic systems, because it involves an act of communication for a legal system (duties and responsibilities) and the economic system as the distribution of payments (Seidl, 2004). Thus, the autopoiesis of societies is the production of communication, where special kind of communication can define functional sub-systems in society.

A particular form of autopoiesis is the autopoiesis of organisations that is based on the organisational structures created as the result of a set of decisions premises (Seidl, 2006).

These premises are there in the moment of taking a new decision, constraining the set of decision (elements) that can be produced. Luhmann's theory explains how organisations work instead of explaining what organisations are (Achterbergh and Vriens, 2009), proposing the following structure:

1. Membership: This decision premise provides a status to the current member into the organisation, making a distinction between who is part of the organisation and who is not. If a person is a member of the organisation has to follow the organisational premises.
2. Communication Pathways: It is the route that the decision must follow to be considered an organisational decision.
3. Decision Programs: These are a regulatory decision that can define if a decision or behaviour is right or not. There two kinds of decision programs:
    a. Goal Programs: This kind of structure defines a desirable effect that should be pursued, which can be independent of the means unless another decision premise rules the means.
    b. Conditional Programs: These structure rules behaviours of the organisation, defining the consequences or action if a condition is achieved, under the pattern "if condition, then consequence or action".
4. Personnel: This is the decision of the right person to take the right decisions in a specific position, according to his/her training, indoctrination, professional competencies, and experience.
5. Position: A position is the conjunction of the previous decision premises because a member of the organisation's personnel must follow a set of goals and conditions programs to perform several tasks, located in the network of communication pathways.
6. Planning: This premise is the coordination of multiple decision premises to avoid chaos.
7. Organisational Culture: These are undecided decision programs that affect the decision-making of the organisation.
8. Cognitive Routines: There are undecided decision programs that appear as a result of the interaction of the organisation and its environment such as presumption about normal parameters.
9. Self-description: Represents an integrative description of the decision premises, which make a distinction of the organisation with the environment.

These decision premises define the new decisions of the organisations, which can absorb the uncertainty to distinct the organisation from the environment.

3.1.6 Minimal Autopoietic Structure

The definition of autopoiesis does not say anything about the components, or minimum components that should perform the network of productions, because autopoiesis emphasises the organisation over the structure (Maturana, 1975). However, it is possible to describe a basic structure of cells based on the concept of minimal cells (Fleischaker, 1988; Stano and Luisi, 2013). The minimal cell model defines the DNA, RNA, enzymes, ribosome, membrane and cytoplasm as the essential components to assemble a cell. This approach showed the behaviour of autopoietic systems as the self-production of its boundaries and autonomy of the environment as a result of the structural coupling (Luisi and Varela, 1989).

Additionally, Maturana and Varela (1980) have proposed relations of productions that can constitute some basic structure. They proposed the following relations:

1. Production of constitutive relations: some components maintain the topology or physical space. The net of production of these elements constitutes the topology of the autopoietic system.
2. Production of specificity relations: Some components specify the creation of other components. The net of production of these elements determines the identity of the components of the autopoietic organisations.
3. Production of relations of Order: Some components regulate the points of meeting among processes. The net of production of these elements determines the relations of order among the other processes of production of relations.

These relations describe the following components:

1. Topological Components: Components which the primary function is the topological deployment of other components. Although, the membrane is an example of these components, there are active sites in enzymes that fit with this description.
2. Creational Components: There are components such as DNA, RNA and enzymes with the capability to produce other components.
3. Control Components: There are components such as metabolites and enzymes with the capability to control the speed in the production of elements.

Thus, there are components like enzymes with more than one function. Table 3.1 classifies the components of the minimal cell with the components described from the autopoietic relations.

Table 3.1 Relation between the component and their classification

Component	Function	Kind of Component	Specification Relation
DNA	Replication	Creational	Specification
RNA	Protein Synthesis	Creational	Specification
Enzymes	Catalysis	Creational and Control	Specification and Order
Ribosome	Protein Synthesis (translation of RNA into protein)	Creational	Specification
Membrane	Maintenance of cellular environment	Topological	Constitutive
Cytoplasm	Provide a Solver System and help the movement of food	Topological	Constitutive

Therefore, it is possible to define components that constitute an autopoietic system based on three main functions, which are the creation of components, controlling process and provide a controlled environment. The creation of components in an autopoietic system conjugates these three functions because it is created a specific component in a specific physical space controlled by components produced by the cell.

3.2 An Organisational Model of Autopoiesis for Information Systems

The current approaches of autopoiesis of organisations and information systems pointed out that they can be seen as autopoietic systems, which means that it is feasible to find a network of processes that maintain the organisation. If this network of processes stops, the organisation will be destroyed, then the changes in the organisation depend on its autopoiesis. Although these approaches are impractical for the analysis of IS flexibility, the concept of autopoiesis by the creation of communication and interpretation can open the possibility to propose new forms of autopoiesis where the IS and the organisation work together. This section proposes a metaphor of autopoiesis that connects organisations and information systems through the analysis of signs of organisations. Organisational semiotics can provide the conceptual framework to analyse the IS flexibility, explaining how the IS can be linked with organisations.

3.2.1 Organisational Semiotics

Organisational semiotic studies signs in the organisation, using a semiotic framework that defines structures, meanings and usage of signs (Stamper, 1973). This framework distinguishes six layers of the problem. This framework distinguishes six layers of the problem.

1. Physical: Hardware and human agents, their performance and economics (signal, speed and components).
2. Empiric: Properties of repeated signals (i.e. patterns, codes and channel).
3. Syntactic: Formal structures of signs (i.e. language, logic and data).
4. Semantic: Relationship between signs and actions (i.e. meanings, propositions and truth).
5. Pragmatic: Speech acts and intentional communication of messages (i.e. Intentions, conversations and negotiations)
6. Social: Norms of the organisation and its environment (i.e. Law, culture and beliefs)

The semiotic approach sees the organisation like the coordination of agents and their actions through the norms they share. The analysis of organisations considers a static and dynamic component. The static component is the semantic analysis of the agents and their affordances, and the dynamic analysis is the analysis of the norms such as substantive, communication and control norms (Stamper et al., 1994). These analyses consider the division of layers to complement the whole picture of the organisation, where the communication acts are essential to the understanding of the formal and informal acts of communication. For instance, the organisational culture can be a part of informal behaviours with an agreement, but without a formal policy in the enterprise.

Additionally, the semiotic approach sees the organisation as Information systems, where agents use signs to perform actions, some of the rules are formalised as bureaucracy, and a part of the repetitive functions can be automated in computer-based systems (Liu, 2000). This assumption can provide reference dimensions in the execution of norms, where a part of the norms can be incorporated in a computer program. These dimensions are named the organisational onion, and they are

- Informal: Norms that are part of the culture of the organisation.
- Formal: Explicit norms like bureaucratic rules, which can be applied by people mechanical.
- Technical: Norms in computer programs, which can be executed automatically.

These dimensions are composed among them in the following form.

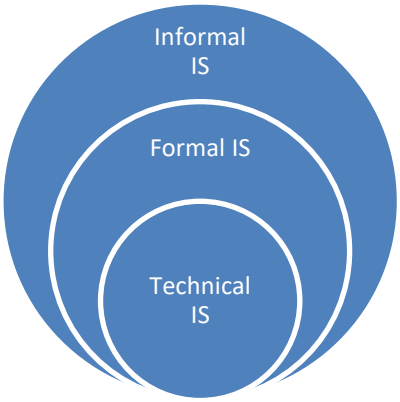

Figure 3.1 Organisational Onion (Stamper, 1973)

Organisational semiotic can be useful to understand technical and organisational capabilities because the organisational onion can divide the organisational architecture between the technological layer, application layer, business layer and organisational context (Liu and Li, 2014). Table 3.2 shows these layers and how they fit with components of the organisation, in the form of enterprise structure.

Table 3.2 Enterprise structure based on semiotics and organisational elements

Horizontal Axe	**Components**
Organisational Context	Organisational culture (informal norms) and cognitive routines (expectations)
Business Layer	Formal Norms, Mission, vision, strategy, hierarchical structure, Personnel Profile, goals
Application Layer	Tasks and IT
Technological IS	IT

Source: Based on Liu and Li (2014)

Additionally, the vertical axe represents the morphology of the organisation divided into agent, substantive, communication and control activities. Substantive activities are related to the productivity and the achievement of objectives. Communication activities are related to the use or exchange of information, and the control area includes the reinforcement of activities. It is possible to link the concept of the agent with the concept of position because a position possesses task, goals, norms, a hierarchy and a personal profile.

3.2.2 Organisations as Information Systems

Society and organisation can be seen as natural processes coordinated by communication-based on language (Maturana and Varela, 1992). Communication acts or speech act coordinate the behaviour of agents, using several commitments and responsibilities, which finally represent the norms of organisations. According to Liu (2000, p. 109), organisations are "social systems in which people behave in an organised manner by conforming to a certain

system of norms". These set of norms governs the behaviour of organisations, representing organisational signs in different forms such as a document, and oral communication or behaviour of people. Every norm can be represented in the basic form "if **condition** then **consequence**", where **condition** defines what information an agent needs to obey. The **consequence** generates information for others, sending messages or influencing the actions of other agents through the application of norms (Stamper et al., 2000). The organisational onion divides the information system into technical, formal and informal. This classification links the informal and formal components with technical IS, because the norms in technical systems and its information depend on the bureaucracy and informal structures, reflecting the real phenomenon of the organisation. Then, the data stored in a technical system is the result of the human interactions of the external layers (formal and informal).

The relationship amongst these three layers means that organisations can be seen as information systems because norms are signs of commitment that in its basic form carry information about conditions, context and agents. The application of norms can create a new sign that carries new information. For instance, if the consequence of smoking inside a building is a fine to the smoker, the fine represents the consequence of a law (a kind of norm). This fine creates a new sign that carries information about the condition to pay the fine or a new consequence for the smoker in case that he / she does not pay the fine.

The distinction among technical, formal and informal layers of organisations from the definition of norms may suggest a new definition in the interaction among the user, computer and organisation. Firstly, the understanding of information, data and interpreter can be made with the division of Peirce among interpreter, sign and object (Liu, 2000). Signs from the perspective of semiotics can be anything determined by something else (an object that is external to the person), and they can determine an effect upon a person (interpreter). This division defines an object with the independence of the observer, where a chain of signs can achieve the full understanding of an object, so there are immediate objects as partial or incomplete representations of signs (Atkin, 2013). Under the semiotic perspective, the object and their signs are external of the interpreter, and the interpretation from a person is subjective because it depends on their embodied cognition or the knowledge of the interpreter. This semiotic perspective can allow seeing information as a sign or a representation of an object, which in nature is objective, despite being interpreted by a person or an observer. Mingers and Willcocks (2014) have stated the intrinsic relation between information, events and signs. Events like objects are independent of the observer, and it can be stored and transmitted by the environment, artefacts and people. Data of an event can be seen as a collection of signs, which can be stored or transmitted as information. Thus, the data that is stored in a technical

information system is the abstraction of objects or events, and the information is the result of data and the interpretation of the person or the embodied cognition.

On the other hand, the word “Information” has several meanings, which depend on the level of analysis of the organisation. Stamper (1996) explained some definitions of information with the semiotic framework, which can be shown in the following table.

Table 3.3 Meaning of the word "information" in the organisational framework

Semiotic Layer	**Meaning of Information**
Physical World	Collection of tokens
Empirics	The entropy of the source or probability of each token, and collection of tokens that make sense a message
Syntactics	A measure of maximal combinations that a set of symbols can express meaning without contradictions
Semantics	Interpretation of an utterance or message
Pragmatics	Shared assumptions and intentions
Social World	The process of imparting form to a social situation

Based on Stamper (1996)

Table 3.3 presents how the word “information” can have several meanings, where information in the physical, empirics and syntactic levels can make sense in the context of hardware, communication and software (Stamper, 1996), so information as interpreted data is a human process of sense-making related to semantics, pragmatics and social world. Beynon-Davies (2009) states that information systems possess a technical part related to data and social part related to the interpreter. This division clarifies the double dependency of technical information systems and organisations because the technical part is created as an information system based on the data that should be stored as a representation of objects and events of the organisation. Information in the context of the social part is the interpretation of the data as a sign of the technical information system, which in a former stage was codified as a symbolic representation of reality, so information connects the social world as an abstract representation of the reality and the organisation.

The process of making sense from a user is the result of the interaction between the user and the technical IS. The user as a member of the organisation possesses its own body of knowledge composed of semantic, pragmatic and social information. Figure 3.2 shows this relation, where the technical IS is usually divided into three layers: data, business, and interface layers.

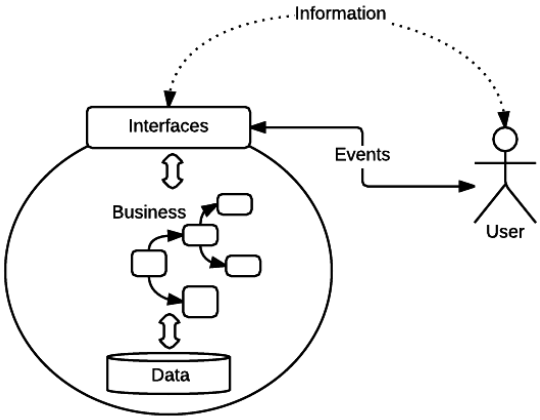

Figure 3.2 Information and Information Systems

Every interaction between the user and the technical IS can be defined as an event into the system, where the dynamic between the user and the technical IS is the interaction of the user with a specific interface. Under the condition that the user knows how to access specific data, he/she will access pre-conditioned interfaces that in a dynamic form will construct the information as a result of this interaction. This means that the data from the data layer will be shown after the validation or transformation from the business layer to the interface layer. For instance, if an interface needs the student ID to display his / her information, the student ID provided from the user using the interface will interact with the business layer, which may validate security issues and then ask to the data layer for the data of the student. The results of this process will be the data of the student displayed into the interface or an error message. This process indicates that the data displayed in an interface is dynamic because it depends on the interaction of the user. Thus, it is possible to say that the interaction of technical IS with the user shows data, which creates information with every interpretation.

3.2.3 Information Systems as First Order Autopoietic Systems

Fuentealba, Liu, and Li (2016) pointed out the similarities between organisations with living systems, describing the semiosis of organisations as a form of autopoiesis. The autopoietic test proposed by Varela et al. (1974) should provide more insights about this similarity, assessing the relationship between the boundary and the unity to maintain the autopoiesis.

The observation of boundary, environment and components of human organisation is a challenging task that depends on the understanding and identification of these components from the observer. The division of informal, formal and technical layers of the organisational onion can simplify this test, assessing the capability to produce information only in the technical layer or the IT system of human organisations. The semiotic framework proposed by Stamper (1973) can explain that users interact among them in the formal and informal layer, and the interactions with the technical layer are through events that create or provide information. The

analysis of six points proposed by Varela et al. (1974) can assess this capability to receive and provide data to an interpretant (the user) of IS. This analysis determines if the unity (an observed system) is an autopoietic system, starting with the analysis of the border and finishing with the analysis of interaction in the network of interactions.

1. **Determine, through interaction if the unity has identifiable boundaries:** The border is the information produced by the technical IS. Although the interface can be seen as the border, the real border is the production of data to be interpreted by a user. The result of this process is the production of information.
2. **Determine if there are constitutive elements of the unity, that is, components of the unity:** This step identifies components the observed unity. In the case of technical IS, the components are identifiable, because it is possible to distinguish the data that is shown to the user and the software components of the technical IS that can display a piece of data such as the interface. Additionally, software components that define the inner-structure of the technical IS can be identified and divided in a logical form such as data and business layers.
3. **Determine if the unity is a mechanistic system, that is, the component properties are capable of satisfying certain relations that determine in the unity the interactions and transformation of these components:** It is possible to explain the data displayed in an interface as a result of deterministic interactions and transformation among inner-components.
4. **Determine if the components that constitute the boundaries of the unity constitute these boundaries through preferential neighbourhood relations and interactions between themselves, as determined by their properties in the space of their interactions:** The data of the information system are commonly grouped with contexts that can generate a set of information limited by a set of pre-defined data, business rules and interfaces. For instance, the interface that is built to display the data of the student will interact with the user under the information of the student context, showing and asking data about the student. Thus, the neighbourhood is the possible interactions between system and user in a specific context (for instance the student information interface), which main consequence is the interchange of information about the student.
5. **Determine if the components of the boundaries of the unity are produced by the interactions of the components of the unity, either by transformation of previously produced components, or by transformation and/or coupling of non-component element that enter the unity through its boundaries:** The interaction

from the data to the interface layers are related, and the information is produced as a result of the inner interactions to show certain kind of data for the user.

6. **If the interactions of its components also produce all the other components of the unity as in 5, and if those who are not produced by the interactions of the other components participate as necessary permanent constitute components in the production of other components:** There are no components in the technical IS, which does not participate in the generation of information as a result of the interaction with the user. Although there are no self-produced components in the IS, all of them lead the process that generates information. Similarly, specific chemical components in the cell are not self-produced (Mingers, 1995).

This autopoietic test identifies the border or boundary mainly, how to maintain it, and the primary aim of the system (the maintenance of the boundary and its network of processes). Although technical IS accomplish the autopoietic test, this test assumes ideal conditions. For instance, this test assumes a theoretical division in layers of technical IS, providing a sense of context to the observer. Another example of the same problem is the poor design of interfaces. As it states in section 3.2.1, the creation of information as a result of interpreted data is an extension of the boundary from IT systems to human interactions. The data as the boundary of the system and its relationship achieve the autopoietic test, but the information as the boundary of an organisation can mean an autopoiesis of second-order. The implication of living systems under this point of view means the following features:

- **Self-produced:** Information systems produce information continually according to the need of the user, where the data, business and interfaces of technical IS interact with the user, resulting in the production of information.
- **Organised:** The organisation is the relation of components that create information in interaction with the user. This organisation which is independent of the individual features of the components is part of the autopoiesis of IS. For instance, the relation of the layers (interface, business and data) defines the organisation, and the individual aspect of each component defines the structure.
- **Structural determined:** The structure of the system determines the set of possible interactions with the environment and potential changes in the system. This feature can explain why the current approaches of IS flexibility propose solutions based on the structure. However, an IS with components that can enable new forms of changes, but without any connection with the production of information may not achieve the autopoietic test (and also the budget of an IT project). Thus, the current components determine the possible interaction with the user, potential changes (updates or upgrades) and the available data to show.

- **Organisational closure:** This capability means that the autopoietic system works as open systems (in interaction with the environment), but its self-production work inside a boundary. Information systems can interact with the environment through interfaces and sensors, providing different forms of interaction. However, these forms of interactions are just ways to perceive events from the environment. For instance, currently, a user can "give" information to the IS through a keyboard, mouse and voice (using Siri or Cortana). The user cannot "give" data to the IS without available components to perceive it as a form of interaction. Thus, the input and output of data/information is a consequence of the interaction with the IS. The user is not giving the data, but it is interacting through different means.
- **Structural coupled:** The system can interact with the environment (other system and users) without losing the system's organisation. The IS provides points of accesses that allow the interaction with the environment, using protocols to ensure the continuity of the system.

Therefore, IS seem autopoietic systems, but they are not living systems. The autopoietic system can behave as a kind of system, where its elements are (re)-produced by the elements of the system (Seidl, 2004). In general terms, this means that the main purpose of the system is the continuity of its life or existence, and in the case of technical IS, the continuity depends on the adaptation of the IS with potential organisational changes. This adaptation means an adjustment of the structural coupling with the environment, putting the human organisation as the IS' environment. Additionally, parts of the structure of technical IS, which participate in the production of information are not self-adapted, and they need the intervention of the human organisation to adapt its structure to the environment. This lack of self-adaptation from the environment of IS may mean that they are not well-adapted systems, no resilient to change. For this reason, Maturana and Varela (1991) have made a distinction between the ontogeny as changes into the living system without changing its identity, and evolution as a result of reproduction of living systems, with the possibility to change the identity. This assumption means that the process of change of autopoietic systems is accepted, but there is no consensus about how much and how long can take a change.

3.2.4 Information Systems as Second-Order Autopoietic Systems

The autopoietic test applied to technical IS suggest that technical IS can be seen as autopoietic systems with the capability to produce information as a result of the interaction with the user. The perspective of organisations as information systems can extend this metaphor to human organisations, but the awareness of a self-image and the reflection are properties of autopoietic systems of second-order.

Section 3.2.2 explained that information starts from the semantic layer, where the human understanding of the data plays a significant role in the creation of sign, data and information. The understanding of the events that happen in the organisation depends on the observer and his/her knowledge, so every self-description of the organisation in the form of policies, norms or software design depend on his/her point of view. This self-description and the agreements about the formalities of the organisation shape the boundary of the technical IS and its structure. This translation of a part of the organisation creates an "image", restricting the data that is displayed and then the information that can be created. Figure 3.3 shows the dependency of technical IS on the organisation, where the translation of the signs or data of the organisation defines the structure of technical IS, shaping the interfaces, business rules and data. On the other hand, the structure of the technical IS restricts the data and information that IS can create for the organisation.

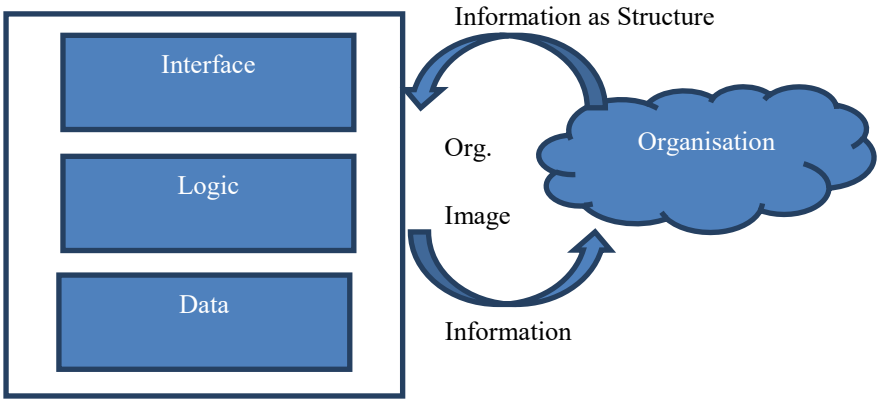

Figure 3.3 Dependency of technical IS on the Organisation

It is possible to use the same example which was considered in section 3.2.2, for instance, the generation of information from a piece of data. If a person needs information about a student, he / she will need the student number to look for the student's profile. It is possible to speak about the business layer as the set of rules or norms to find the student's information, and a data layer as the physical form where the student's data is saved. The result of this process is the data of the student displayed on a physical desk. In this case, the interactions with the user define the boundary of the technical IS, but the interactions of that user (i.e. a lecturer) with the student to ask the student number can define boundaries inside the organisation (among departments) or with the organisation's environment. If the user of the IT system is a customer or another IT system of a supplier, then the boundary of the technical IS can be extended to the boundary of the organisation. Thus, the generation of information will be based on the possible interaction between the organisation and their substantive activities.

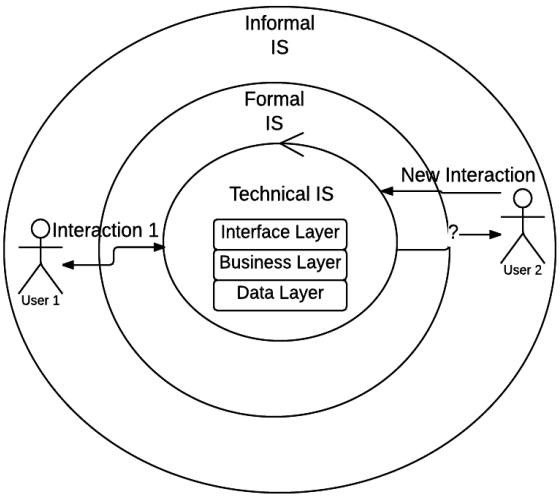

Figure 3.4 Relation between the interactions of technical IS and users

Figure 3.4 shows the structural coupling between the technical IS and the user inside the organisation, where the definition of IS an autopoietic system opens the possibility to define the organisation as a second order autopoietic system. These kinds of systems are a composition of autopoietic systems such as multi-cellar systems and human beings. In this context, technical IS, and users are autopoietic systems, which interactions are dependent interactions with independent outcome based on the communicative act that creates events, carrying information between them. Under this perspective, if the technical information systems achieve the autopoietic test, the organisation as an extension with inner structural coupling can be seen as an autopoietic system either, where the border of the organisation with other organisation is the interactions using events that interchange or generate information. From the semiotic perspective, the technical information system is a part of the description of the organisation (the automated part), so it is possible to say that the organisation possesses a reflection of itself, resulting in the conscious of the organisation. Therefore, this self-conscious and the structural coupling between the technical IS and user achieve the definition of second-order autopoietic systems despite not possessing a formal nervous system.

Although the second-order autopoietic system subjugates first-order systems, the interactions between autopoietic systems should maintain their individuality. Maturana and Varela (1992) defined the forms of interaction of living systems as the domain of interactions and the sub-set of interactions that maintain the autopoiesis as the cognitive domain. In the case of human organisations, every change in its cognitive domain can affect the cognitive domain of IS. Consequently, potential new events can carry new signs that are not in the domain of interaction of IS, because technical IS does not possess the capability to change by-self. Thus, the technical IS seems an autopoietic system at a lower level than the human organisation

such as the autopoiesis of the nervous system in contrast to the autopoiesis of the living being (Maturana and Varela, 1980).

This tension among IT systems, bureaucracy (formal) and culture (informal) shows the real problem of adaptation of IS. Informal systems are usually more adaptable (and flexible) than formal and technical layers (Stamper et al., 2000), Thus, technical information systems may extend its limits from the technical part, using the conscious or self-description of the organisation to identify the current cognitive domain (interactions with the environment), creating a sensation of flexibility.

3.2.5 Organisational Structure and Information Systems

As it is stated from Luhmann´s theory, and as a proposition of the current work, organisations are autopoietic systems; so a metaphor from the minimal cell structure could suggest an organisational structure. This work uses the creation of information from the human organisation instead of decisions as the main idea of autopoiesis, and it is accepted the idea that the human organisation creates product or service. However, for each product or service created, there are events attached to this fact that generate information. Therefore, it is possible to analyse the organisation from a semiotic point of view. The following list compares the elements of the minimal cell with the element of the organisation.

- The membrane is the component that represents the border of the cell. This structure can represent the interface of the organisation as the contact points among the enterprise, customers and suppliers.
- The DNA of the cell is the creational component that specifies the components, which can be created. In the organisational context, the DNA is the chains of activities to maintain the components that interact in the border.
- RNA of the cell is the messenger that carries the information specified for the DNA to create a new component such as proteins. In the organisation, the message is related to the communication between the organisation and the communication activities.
- Enzymes of the cells are components with the capability to create new components and the capability to control the speed of the reaction (catalyser). So, the enzyme is a creational component and a control component. From the organisational perspective, enzymes can be considered as a control activity in the organisation based on the organisation’s norms and at the same an enabler such as innovative activities.
- Ribosomes are components that translate the message from the RNA and assemble the new product. The ribosome is related with the organisational capabilities to create a product or service in the organisation. So, it is related to productivity and the physical transformation in products or services.

- Cytoplasm is the fluid inside the cell that store food, the separate nucleus from cells and aids in cell movement. In the organisational case, cytoplasm can be related to the inner structure of the organisation.

The main idea of the minimal cell is the proposition of a minimum set of components to maintain the membrane (or border) and its network of processes. For this reason, a metaphor based on the function of each component may propose a structure of organisations, which can maintain the "membrane" or border of the organisation, its network of processes, and then the autopoiesis. The description of the IS components are:

External Border Components: These components are the interactions that the IS must consider with the external environment. The sources of interaction are customers, suppliers and other stakeholders such as government (i.e. custom and revenues) and partners. Initially, the border of the organisation is the decision about the purpose of the organisation. When a group of people agree on a purpose, the new borders are the activities that interact with the environment with physical and social consequences. Examples of border activities can be the activities to obtain energy from the environment to the organisation such as sells and acquisitions. It is essential to define which sources of energies need the organisation and which the wastes are. In some cases, a border activity obtains energy and dispose of waste at the same time. For instance, in the case of a manufacturing enterprise, a final product is not useful for the organisation, for this reason, a selling activity can mean a dynamic with the environment to dispose this waste and obtain money. The components of the organisation that participate in the border activity are agents, substantive activity, control and communication.

Creation Components: These components define the address of the organisation, they should not be related to the productivity of the organisation, because that is the task of Ribosomes, but the definition of which product or service is produced, which raw material or organisational product/activity is needed to interact with other stakeholders, are part of the creation components. In the case of large organisations, they have a mission, vision or strategy, but in the case of small organisations, the definition of main purposes or activities is enough. It is important to highlight that DNA or creation components control the specification of each component of the organisation, which internal coherence can be seen as the definition of meta-norms (Stamper et al., 2000). In this case, meta-norms govern the dynamics of the border of the organisation performed by an agent such as substantive, control and message activities. Luhmann's theory proposes another kind of meta-norms as the position that defines the agent. A position is defined as a combination of membership, personnel profile, goal programs, conditional programs and a hierarchy of communication. This description of an agent can help the understanding of the origins of these components. Meta-norms govern the

generation of each component of the organisation such as the position, messages, controls and substantive activities:

- Message Meta-norms: These norms are related to the creation of a hierarchy of messages, which is a concrete form can be a decision of the hierarchy of the organisation.
- Control Meta-norms: They are related to the political aspects that control the control norms. For instance, the definition of key productivity index of substantive activities that should be controlled by control activities.
- Substantive Meta-norms: These meta-norms are the norms that restrict the main activities of the organisation to transform physical components into the final product or services. They are related to the form that the organisation is working to produce a product or service such as government laws, regulations of product and services, and the definition of the aim of the organisation.
- Personnel Meta-norms: They are the definition of profiles for a specific position or agent such as his/her training, indoctrination, professional competencies, and experience.
- Membership Meta-norms: They are the definition of political aspects of the organisation to accept members and assign specific positions.

Inner Structure Components: The inner structure in a broad sense could include more components, in this case, is focused on the hierarchy of communication, the division on departments and the assignation of the agents in certain positions. This inner structure is mainly static and defines who the boss of whom is.

Communication Component: These components define the structure of communication of the organisation. The fundamental component is the hierarchy of communication that defines who communicate to whom, but in a complex organisation, there are workflows. They are a composition of communication power and tasks because a workflow defines who communicate to whom, and who can approve a specific document or task. The inner structure defines the possibility of interaction among departments using the communication.

Production Components: These components are the substantive tasks involved in the creation of the product / service of the organisation. Other tasks are named coordination tasks because they are not involved directly in the production of product/services, but they are also significant to the organisation. For instance, the (re) definition of the strategy is a task that is not directly involved in the production, but it would affect the productivity task.

Control Components: These components regulate task and behaviour of the members. There are several classifications of norms, for instance, it is possible to classify according to

the control of human behaviour, the effect of execution and the object that is applied (Liu and Li, 2015). Thus, norms are capable of controlling every aspect of the organisation from their informal conception to their technical application.

Figure 3.5 shows a summary of the components described above, where the border is divided in customer, supplier and stakeholder interfaces. The main question that can address the analysis and identification of autopoiesis is “how each component can support the maintenance of the boundary?”. This boundary has been explained from the perspective of information systems and the generation of information, whose self-description in components is the image of the organisation. The relationship of the whole system can define a new form of autopoiesis from a theoretical perspective. For instance, goals are related to tasks, and the strategy can define new goals. These cycle that generates new organisational signs and new information can be seen as a new perspective of autopoiesis.

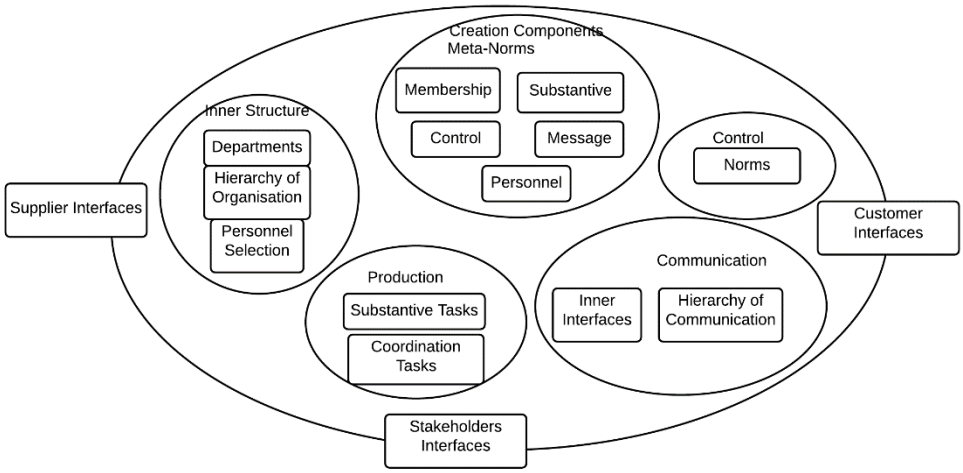

Figure 3.5 An Autopoietic Model of Organisation

3.2.6 Relationship Amongst Components

The proposition of relationships among the component assumes similar relationships of a cell model. These relationships are functional, and the concept of structural coupling is left aside to simplify this initial approach. An initial proposition of these relationships considers that creation components can affect all the components. Inner-structure can affect almost all the components except for creation components because in an isomorphism from the cell the DNA cannot be changed by other components. The interfaces are gates among the environment and the organisation. The initial proposition defines the relationship with the environment only by this component, while it can only change the production components, every component can affect it. The control component cannot affect the strategy and the inner-structure, because

this control is mainly in the activities of the organisation. Communication activities can affect the other components that contain activities directly involved with the interface. Table 3.4 provides more details on the relationships among the components shown.

Table 3.4 Proposition of Initial Relationships

	Interfaces	**Production**	**Control**	**Communication**	**Inner-structure**	**Creation**
Interfaces	N/A	Interfaces send requests to production				
Production	Production needs to deliver matter, energy or information	N/A				
Control	Control of Inputs or interactions with another component	Control of production activities or interaction with another component	N/A	Control in the communication among components		
Communication	Coordination among components	Coordination among components	Coordination among components	N/A		
Inner-structure	Definition of power and responsibilities among components	Definition of power and responsibilities among components	Definition of power and responsibilities among components	Definition of power and responsibilities among components	N/A	
Creation	Meta-norms	Meta-norms	Meta-norms	Meta-norms	Meta-norms	N/A

However, the autopoiesis of the organisation can be analysed in a further step with the relationships proposed by Maturana and Varela (1992).

- Constitutive Relations: The model proposed two topological components. The first components are the interfaces, which define a border between the organisation and the environment. The second kind of component is the inner-structure, which defines power in the organisation. The network of the process that defines these kinds of components are the constitutive relations.
- Specificity Relations: The components that defined other components can define these relations. In this case, creation components defined other components, but it is needed to identify a network of processes that defines creation components.

- Relations of Order: Order can be linked with control. Another component can control each component (even control). Once the components are identified, it is needed to identify a network of the process that maintains the identified components.

Figure 3.6 shows the direct relationship proposed in table 3.4 as an arrow between components, explaining that a component can affect another. This model is challenging to test and work, because a change in a component can trigger a change in another, creating potential loops.

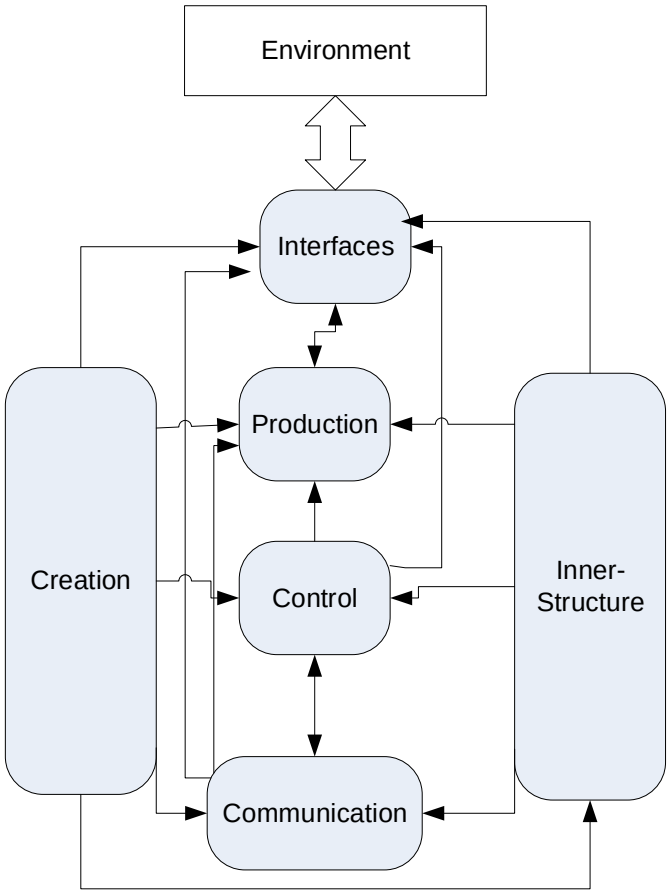

Figure 3.6 Proposition of Initial Relationships Among Components

This proposition can be assessed in the following sections and chapter, but the first step in the definition of autopoiesis or the inflexibility of information systems is the identification of the components.

3.2.7 Refinement of the Model

The proposed model of organisation is challenging to use because it involves loops of interaction as a result of changes in a component that can trigger more changes in other components. These loops are not shown directly as a part of the proposed model in figure 3.6,

but they are the result of a chain of interactions that a component can trigger. For instance, the arrows from figure 3.6 show that a change in the creation component may change the inner-structure. Then, a change in the structure may change a communication component, and so on. Additionally, the proposition of each component may not be accurate for the understanding of the potential effects of a change. For this reason, this model is refined by techniques of thematic analysis applied to journals that contain real cases related to the change of organisations and the role of IT systems. Appendix A1 contains more details about this work, but the result of this study are summarised and analysed in this section. Table 3.6 summarises the findings of the description of the six component.

Table 3.5 Summary of the proposed components

Component	Description
Interfaces	They represent substantive activities that directly involve stakeholders and the environment. The activities related to customers collect information from them to increase the probability of interchange of goods or services. In the case of suppliers, the activities follow principles of autonomy, which define standards that help the control of new suppliers. Other stakeholders such as government, community and partners interchange information that affect the control
Inner-structure	There are four main sub-components: personnel, technology, the hierarchy of power and physical infrastructure. Personnel is the responsibilities and skills that a position should have. Technology is the set of tools that help other activities, providing some extra capabilities to the people who perform an activity or replacing them in the activity. Hierarchy of power has been described as the configuration of groups in the form of functional or team division. Physical infrastructure has been described as plants, offices and their management.
Creation	Creation components are the decision making process and knowledge management. It was identified four kinds of decisions: Production, financial, interface and inner-structure. Every kind of decisions is related to the change of each component except financial decisions, which can affect several components at the same time. Knowledge management means formal representations of the structure and the learning process, which use data from the interface.
Control	From the data, control is mainly two kinds of controls: financial and self-regulation. Financial control supervises the budget and the scope. Self-regulation supervises the feedbacks from complaints (external) and contradictions (internal).
Communication	Communication activities are coordination activities, which need to manage the dependencies of collective tasks, cooperation and the level of connection.
Production	Their activities and standards define production. Activities are routines, which relate roles, capabilities, actions and materials. Standards of production can be seen as guidelines, which at the same time control their behaviour.

Figure 3.7 shows the relationship between the components, using the concept of direct effects. An example of a direct effect is the relationship between the interface and the production component. According to the findings, part of the interface is the knowledge management of customers, which can produce better services or products. Thus, an arrow from the interface to the production component illustrates this effect. However, the direct effects of each component can draw a diagram that is highly connected, because components such as creation and inner-structure affect almost every component. Technology as the structure is one of the primary sources of change, and its impacts on other components are almost in the same form of authority or personnel. The data shows that technology is even more significant in the impact of change, but the sample of data, information systems journals, may show a bias for this kind of change.

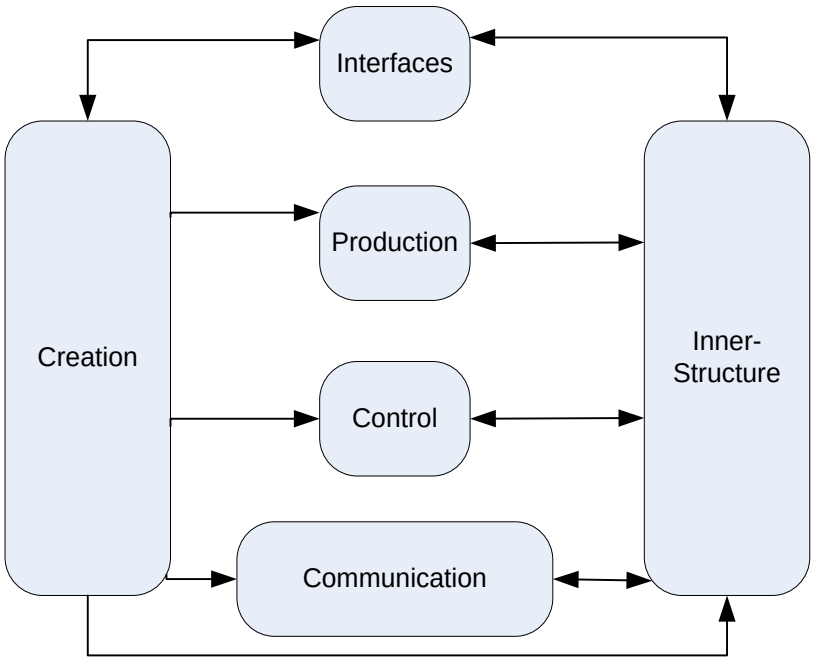

Figure 3.7 Direct effect connections of Creation components and Inner-structure

Several loops in figure 3.7 confirm the concerns from the theoretical proposition of figure 3.6. It is needed to remind that these loops come from the interaction of the components recursively. These loops indicate mechanisms of feedbacks inside the organisation such as the knowledge management of customers and suppliers. Additionally, these feedback loops can affect the creational component from the interface, spreading potential changes to every component of the organisation. The environment takes a significant role under this perspective because every interaction can change the whole organisation.

Table 3.7 summarises the relationships and the components that can trigger a change directly. The diagonal of the matrix contains N/A, because only indirect changes can affect the same component. For instance, in a first look, a change of face to face sells to online sells changes the interaction of the customers. The consequence of this change can affect the relationship with suppliers. Then, a side effect of this change can trigger a new change on the same component.

Table 3.6 Summary of effect relationships

Affect	Interface	Creation	Communication	Control	Production	Inner-structure
Interfaces	N/A	Knowledge			Product / service	Feedback
Creation	Product / Service decision Innovation	N / A	Knowledge	Financial Decision	Strategic alignment Knowledge	Product/ Service decision
Communication	Coordination		N / A	Coordination	Coordination	Coordination
Control	Financial control			N / A	Financial control	Financial control
Production			Standards	Standards	N / A	Activities
Inner - structure	Technology and Personnel		Technology Power	Technology	Technology	N / A

The high dependency of each component suggests a minimal structure that is capable of responding to the environment, adapting the current structure to new perturbations from the environment. However, the use of the cell as a metaphor can limit the mechanism of adaptation in comparison with second-order autopoietic systems such as plants (Nikolić, 2015). Luckily, the same relationships of autopoietic systems of first order can describe autopoietic systems of second-order, extending the properties of adaptation when the components are systems of first order while maintaining the property of survival (Maturana and Varela, 1980). The result of the codification process showed some components that can be classified as second-order systems. An example is the functional specialisation of departments inside the organisation to improve the efficiency, which can be compared with the specialisation of tissues of threes or the specialisation of colony's workers in ants or bees (Trewavas, 2014). Another example is the capability of self-description that can be compared with the self-description of nervous systems or plants (Maturana and Varela, 1992; Trewavas, 2014).

Organisations show capabilities of complex systems like humans or swarms, but the structure of cells can be enough to define an organisational structure, which should maintain the boundary of the organisation after several changes, including the development and support of IS. However, the loops of change suggest potential problems with the identification of side effects as a result of the interaction among the components. Additionally, these relationships have a new dimension of complexity in second-order autopoietic systems, because these side effects can also be the result of a structural coupling or a particular perturbation.

Therefore, this research focuses its efforts on the proposition and analysis of the first component that the autopoiesis should maintain through the changes, its interfaces or boundary.

3.3 The Boundaries of Organisations and Information Systems

The component named interface is a metaphor of the boundary of a cell, and this is the first component to identify in the autopoietic test. The relationships proposed in section 3.2.6 suggest that a change in the interface's component can affect another component, generating loops. Thus, this research should focus on the study of interfaces or boundaries of organisations and how they can affect to IS, but the current technology such as IoT and e-commerce puzzles a definition of boundaries based on physical boundaries. However, the features of physical boundaries can help the definition of boundaries, using other theories such as the boundaries as difference proposed by Luhmann (2006).

The concept of the boundary in physical objects is firstly identifiable using the sense of the observer because the observer can perceive the surface as the limits of the object. The second distinction of physical objects is its causal interaction with the environment and all the possible physical interaction that the surface can do. Boundaries can be defined as ontological parasites, because its existence depends on the object, creating an ontological dependency (Erices, 2017). Some features of physical boundaries are:

- Every physical object has a boundary.
- The existence of a boundary rigidly depends upon the specific objects that it belongs.
- This boundary makes a distinction between the environment.
- The object cannot exist without a boundary.

The boundary is a process of distinction, which depends on the observer and his/her ability to identify symbols and/or signs from the object in its environment. Although, organisations are identifiable by an observer in an environment, in a first look they depend on the interaction points between the organisation and the outsider. Some interaction points are physical such as the trade of a product in a specific place and time, but in other cases, the interactions are

abstract such as the case of an online purchase. This lack of a physical "surface" put the boundary of the organisation in functional terms of distinction such as the proposition of Luhmann (1984) in his book "Social Systems". A functional distinction or differentiation from Luhmann perspective means:

- There are functional systems from society such as politics, economy and science.
- An organisation such as an enterprise is embedded in the society and then depends on the functional systems.
- An organisation is differentiated from the environment by its function.
- It is possible to keep this differentiation of the organisation, reacting and adapting the organisation from the perturbations of the environment.

These sub-systems that shape the environment sooner or later interact with the organisation, putting pressure on the point of interaction between the organisation and the environment.

3.3.1 Organisational Semiotics and the Organisational Boundary

The role of organisational semiotics is the understanding of every point of interaction with society, which can be translated into potential stakeholders, their responsibilities and how they can affect the organisation. Current approaches have defined boundary objects as a form to define boundaries on a pragmatic level (Carlile, 2004), analysing these objects as part of co-design processes (Gasson, 2008). Indeed, the pragmatic level can define a boundary from a functional point of view, linking function with the intention of actors or agents, but the boundary objects may not suit in the study of flexibility. Although these objects are generic enough to represent methods, processes or documents, they do not show the potential actions or capabilities of the organisation, and also there is a disconnection between the organisation and IS.

The boundary of organisations should make a distinction between the organisation and its environment, but the use of the internet and ICT pushed human organisations beyond the ´physical boundaries. Potential actions, the organisation and its environment are indivisible, making a distinction based on the relationship of these components, which is similar to the concept of affordance proposed by Gibson (1977). Affordances represent what the environment offers to an animal, and also what an animal can do in the environment. From the autopoietic perspective, what animals can do depends on their structure, and how they can interact with the environment without losing their autopoiesis (domain of interactions). Stamper and Liu (1994) have used the theory of affordances to describe norms of organisations as the invariants that can apply to every person or agent. This invariant or "particular state of affair" is the realisation of an agent about the existence of an object or an action from the

environment. Stamper and Liu (1994) have represented these affordances with a well-formed formula called Norma. For instance, an agent (John) that perceives a chair can be presented as:

John chair

When John perceives the chair, he and the chair become a modified agent (a complex agent), which can "afford" new actions or invariants. This is an example.

John chair sit

However, John can sit only if the environment allows him to sit. In this context, the environment may include social restrictions such as the place or the time. For instance, if John is the GP in an emergency room, and he wants to sit in the middle of an emergency.

Organisational semiotics studies the affordances of agents, recognising signs as a form to extend the perception of agents beyond the here-and-now (Liu and Li, 2015). A semiotic entity (a sign) restricts or enables behaviours of the agent, persisting that action to the future thanks to the sign. For instance, when a person signs a contract, he/she is becoming a member of an enterprise (an employee), persisting the current action (sign a contract) to the future. That sign gives responsibilities and duties to that employee, and also new affordance to the employer such as to fire to the employee.

NORMA offers a graphic representation of affordances, where agents and affordances are nodes, and lines link them. Figure 3.8 illustrates an example of this relationship in an ontology chart. Ellipses represent agents, roles are labels in the line, and the boxes are affordances. The antecedents are placed to the left, showing a dependency on the affordances of the right. For instance, the enterprise and person are antecedents of the affordance "employs". Without an enterprise or a person, there is no employ. Then, the new role of the person is the employee, which is a complex agent with new affordances (i.e. get fire).

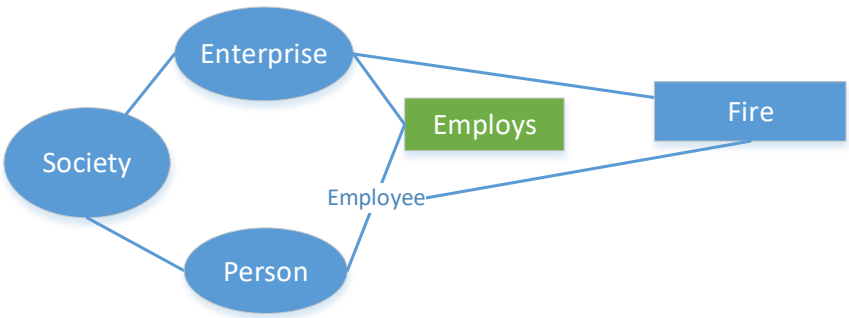

Figure 3.8 Example of Ontology Chart

These antecedents and dependencies are called ontological dependency, and they suggest that some activities or affordances are not possible without another one. For instance, an

enterprise can fire an employee due to the employs' affordance. An enterprise cannot fire a person if they are not employees, so the affordance of firing somebody requires a sign that represents the affordance employ from the past beyond the here-and-now. In this case, the affordance "employs" is green, and represents an affordance that generates an ontological dependency with the affordance "fire". Additionally, the "employs" affordance is between an organisation and an entity or agent from the environment (a person), making a distinction between something outside and something inside the organisation, behaving as a boundary.

The ontological dependencies that generate this sign on new affordances are similar to the concept of ontological parasites of surfaces. Firstly, person and enterprise are part of the society, putting them in the same environment, but making a distinction of something new from this interaction. Secondly, the affordance firing cannot exist without the affordance employment, so this new entity allows new affordances, defining it as a new complex agent. Thirdly, if the affordance named employment does not exist, because one of the agents is missing, the new complex agent cannot exist. Finally, the new complex object is unique, because the enterprise and the person are unique. Thus, the affordances of an organisation have similar properties of physical boundaries, suggesting that methods to identify and analyse affordances can lead the analysis of boundaries of organisations.

The methods of organisational semiotics to analyse the affordances of agents such as PAM and SAM can address the analysis of boundary of organisations. The problem articulation method (PAM) can define the context of the problem, examining and distinguishing the business or organisation from the environment. Stakeholder analysis can show the people involved with the organisation. PAM defines six categories of stakeholders, and they are shown in figure 3.9

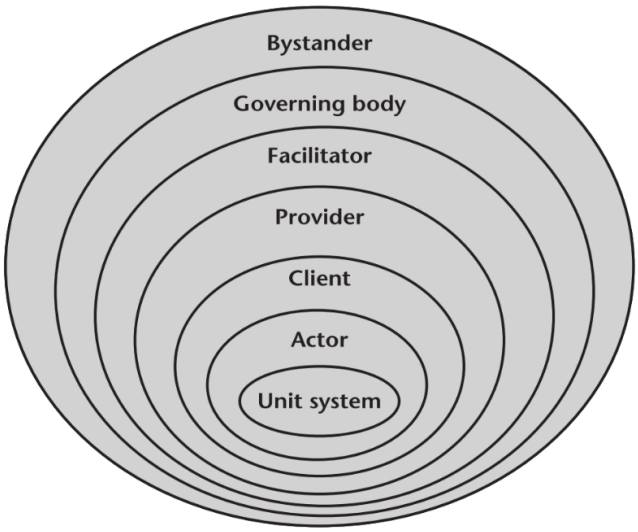

Figure 3.9 Stakeholders and their impact on the organisation (Liu & Li, 2015)

The definition of stakeholders and their responsibilities are used to create an ontology chart, which can define agents and affordances. The semantic analysis method (SAM) analyses the affordances and the ontology dependence of them. This means that the ontology chart can suggest affordances as boundaries from the ontology dependencies among the organisation, its agents and the environment. Once the affordances are identified, the norm analysis method (NAM) identifies norms that restrict or enable the behaviour of agents. According to Liu and Li (2015), norms represent collective affordances and the behaviour of complex agents. NAM observes the context, conditions, agents, operations and actions of norms, using the following form.

whenever <context>

if <condition>

then <agent>

is <deontic operator>

to <action>

This norm description can define certain dependencies when a context and a condition is applied. Additionally, the trigger analysis can show if an action can start as a consequence of another action, or in absolutes time such as every month or week. This trigger analysis can identify pre and post conditions to apply a norm, and how the norms are connected (Salter and Liu, 2002). Norms and their dependencies govern the behaviour of the organisation and how they can interact with the environment, showing a structure of signs that allows the cognitive domain or current interactions of the organisation. Thus, the study of the boundary of organisations can show the cognitive domain and the potential components that define the autopoiesis of the organisation. Figure 3.10 shows the methods described to identify the affordances of the organisation and its involved norms, and the boundary consequently.

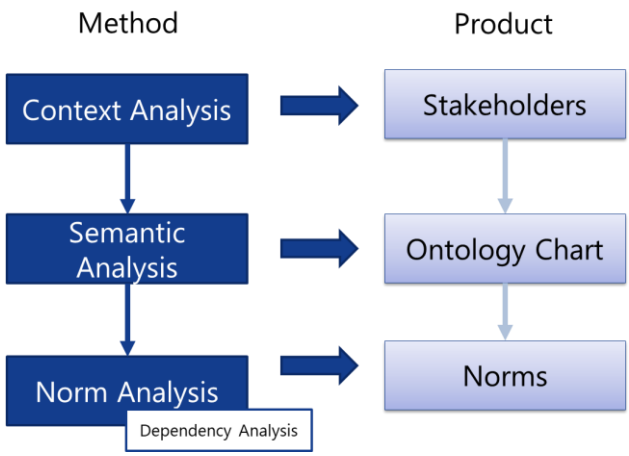

Figure 3.10 Proposed Method and products to identify boundaries

The identification of the cognitive domain of the human organisation restricts the domain of interaction of the technical IS. This means that the identification of affordances of human organisations will define the universe of affordances that the technical IS can aspire to cover. The IS flexibility should know the sub-set of affordances that technical IS covers, the universe of affordances, and also which affordances of the organisation are more susceptible to change.

3.3.2 Social Sub-Systems as Legacy Systems

The identification of the boundary can lead an analysis of the environment and how it interacts with the organisation. The society is the environment of organisations and every change in the environment is a potential change in the affordances that define the boundary. Thus, the identification of the sub-systems of the society and how they affect the signs that extend the here-and-now of the organisation can drive the analysis of IS flexibility.

The functional systems proposed and identified by Niklas Luhmann (1984) are similar to the external forces of changes proposed by Predişcan and Roiban (2014). Functional systems in the society or social sub-systems use the communication as the main production of the system, and Luhmann makes a distinction from the assessment of events regarding binary codes that represents something good/bad for the sub-system. There is no consensus about the number of functional systems in the society, but some authors have proposed at least five for public organisations to ten functional systems (Guenduez and Schedler, 2014; Roth, 2014). This definition links sources of changes with the functional sub-systems of the society, postulating that the society and their systems of differentiation can affect organisations. These sub-systems are a kind of legacy that organisation impose when an organisation “born”, so the organisation is in the obligation to define how to deal with them. Therefore, the identification of these legacy systems can identify how and where they can affect an organisation.

The analysis of legacy systems has been proposed by Liu *et al.* (1999) in the methods named “Analysing and Modelling the Behaviour of Legacy Systems (AMBOLS)”. In this work, the concept of the legacy system includes human and computer interactions, but the designer (or his/her team) should decide how many functional sub-systems want to analyse. This decision will impact on the cost of the project, because it may involve the analysis of the current signs such as laws and regulations of a government. These sub-systems will allow or restrict the change and growth of the organisation, giving a strategic point of view to the analysis, because the organisation will need to define how the current components such as the creational components can affect the affordances or boundary involved in this interaction.

A change in the boundary may trigger a change in the organisation, and consequently a misaligning between the business and the IT systems. The co-design for business and IT (COBIT), proposed by Navid Karimi Sani (2011), shows an example of a method to align

business and IT when a situation of change happens. This method can address the development of changes in business that can affect IT, identifying the current system, the target system, the current technical system and the gap between them. However, COBIT is not designed for the implementation of IS flexibility, because the target system is a known situation or a desired situation from the problem identification. On the other hand, the analysis of IS flexibility may be infinite because the target system analysis proposed by COBIT should analyse all the possible changes of the organisation to provide enough IT structure to cover the domain of interactions of the organisation. This endless exercise may finish in an IT system very similar to an ERP system aligned correctly to the organisation, but at the moment that the analysis and the implementation of the IT system finish, the organisation may have been changed again. Thus, a method to enhance the IS flexibility should address the scope of potential changes, identifying affordances the formal system that can drive changes in the IT system. These drivers can lead the application of strategies in the IT design to provide capabilities to change in the structure. Figure 3.11 shows the proposed phases based on the co-design for Enhancing IS Flexibility by Applying Organisational Semiotics and Autopoiesis (ISFOSA).

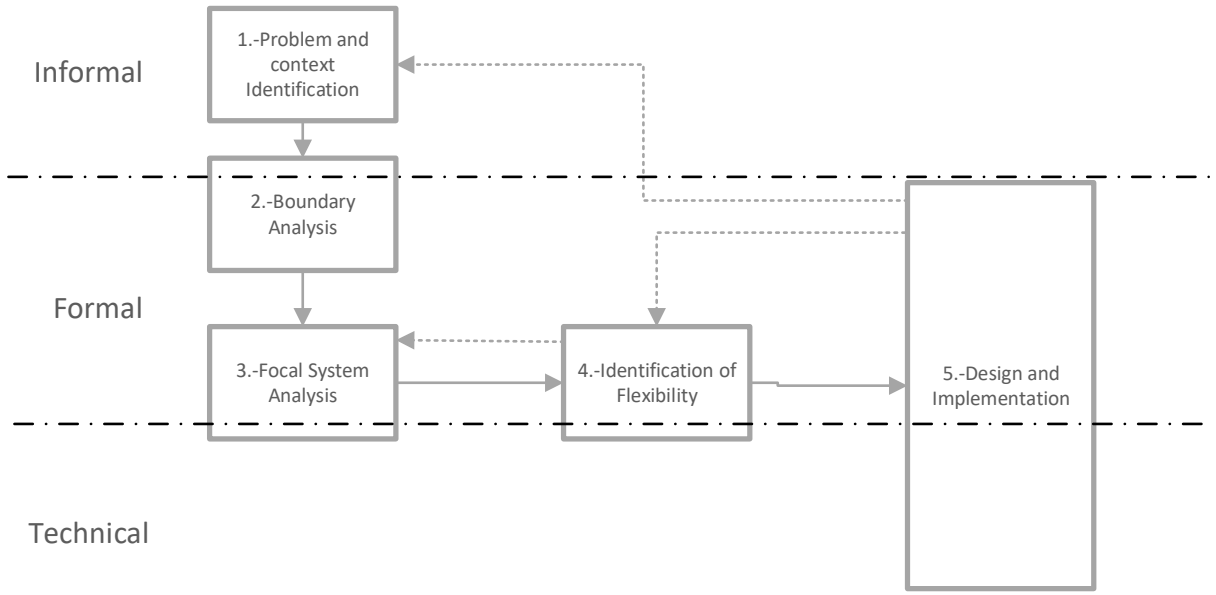

Figure 3.11 Proposed Methodology

Phase 1: Problem and Context Identification

This phase is similar to the co-design phase, which identifies the problem situation but also identifies the context of the organisation. The identification of stakeholders can address the

analysis of the context, the aim of the analysis can define the problem and the potential need for IS flexibility. Other methods such as root problem analysis or cause-effect analysis can complement the problem identification step. The output of this phase should be:

- Definition of the problem
- Identification of social sub-systems
- Proposition of stakeholders

Phase 2: Boundary Analysis

This phase should identify the affordances of the organisation that defines the boundaries. The analysis of the formal system focuses on the identification of affordances that can define the boundary of the organisation, without a detailed definition of the affordances of the focal systems. Figure 3.11 shows the methods and products of this analysis, which connect the previous phase with this phase. SAM should identify affordances of the organisation and the universal from the society, understanding how the organisation interact with the environment, and as far as possible the identification of departments of the organisation, instead of people and specific agents. The NAM should complement the affordances and complex agents identified in the SAM but at a macro level. The output of this phase should be:

- Ontology Chart
- Norms

Phase 3: Focal System Analysis

This analysis identifies the boundary of the focal system, providing more details in the identification of affordances. This analysis is similar to AMBOLS because the output should be the official requirements of the system. However, AMBOLS is split between the focal system analysis and the identification of flexibility to cover the analysis of the current situation and the analysis of potential changes. The focal system analysis identifies the legacy systems that should be included in the new system, and also the current situation inside the organisation related to the focal system. This phase should identify the stakeholders involved directly in the IS, including their affordances and norms. Figure 3.12 shows the method and the steps for this phase.

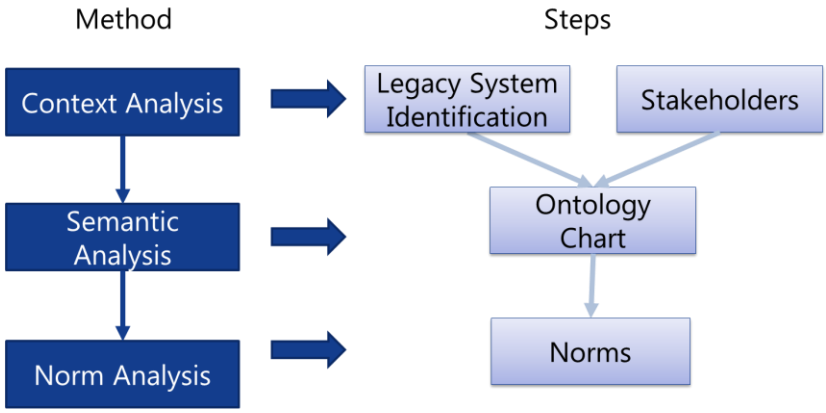

Figure 3.12 Proposed Method and Steps for Phase 3

The output of this phase should be:

- Stakeholders directly involved in the focal system
- Ontology chart
- Norms

Phase 4: Identification of Flexibility

This phase compares the macro analysis and the result of the focal system analysis, identifying potential dependencies between affordances. In case that an affordance of the environment is not included in the focal system, but it is needed or desired in the analysis and then the development. Figure 3.13 shows the steps of phase 4.

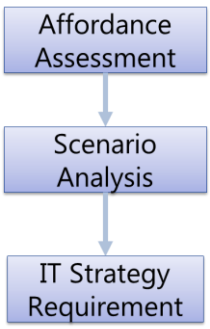

Figure 3.13 Steps of Phase 4

Affordance Assessment: It is assessed the identified affordances of the boundary and its representation in the system. An analysis of the macro affordances and its impact on the system can address the requirement of IS flexibility.

Scenario Analysis: The analysis of potential scenarios can provide more information about potential changes. The designer and stakeholders can agree to implement some of these scenarios, drawing back to the focal system analysis.

IT strategy requirement: This step proposes strategies from the summarised factors on table 2.3 such as modularity, connectivity and technology, which can provide IS flexibility capability to the IT structure. These strategies are functional or non-functional requirements from the system.

Phase 5: Design and Implementation

The proposed strategy, the ontology chart and norms of the focal system analysis can address the design and implementation of the system. There are several methods to develop this phase such as the translation of these artefacts to classes (Bonacin and Baranauskas, 2015), or the implementation of agent systems (Filipe and Liu, 2000; Weizi et al., 2009).

3.4 Summary of the Chapter

This chapter proposes that information systems can behave as living systems, using the concept of autopoiesis as a network of processes that (re) produce and maintain the life, and the theoretical background of organisational semiotics to analyse and identify these processes. For this reason, this chapter reviewed the key concepts of autopoiesis, proposed an autopoietic model of organisation, and a methodology to identify the main component of this model, the interface or boundary.

The key concept of autopoiesis is useful to study IS flexibility because it can draw what can change and what cannot be changed, because an autopoietic system is structurally determined. This means that the system can interact with the environment only if its structure allows it, and also that the system is structurally coupled with the environment. When these relationships are recurrent and between autopoietic systems, it emerges autopoietic systems of a superior order such as human being, plants and society. However, the initial ideas of autopoiesis from biological systems were not compatible with the autopoiesis of societies, creating a theoretical approach of autopoiesis of society, which did not include any link with information systems. For this reason, section 3.1 reviewed and proposed the minimum components of livings systems, which can be used to propose a model of organisation based on autopoiesis.

The link between organisation and information systems is made by the theoretical background of organisational semiotics, which claims that an organisation can be seen as information systems. This link was useful to analyse if they are autopoietic systems, resulting in the proposition of a model with six components and a set of arrows, connecting them. The result of later research did not decrease the complexity of the model, because the relationships of the components create loops as a result of a change of the components that trigger new changes. Additionally, this refinement of the model found some patterns such as the functional

division of the organisation and feedback loops, which are similar of autopoietic systems of second order. For this reason, this research was focused on the analysis and proposition of the first component needed for the autopoiesis, the boundary or interface.

Section 3.3 proposes a new vision of the boundary of organisations, using the concept of affordances as potential actions or invariant of organisations. Affordances can allow new affordances, making a distinction between a before and after the creation of this affordance. Then, the analysis of affordances of organisations and the affordances of the focal information systems can provide a methodology to compare potential changes that the IS should include to enhance the IS flexibility.

Chapter 4

Research Methodology

This chapter provides the research's methodology, discussing which research paradigms can suit in the current research. This research fits with design science research and case study research, illustrating their main fundaments and how both philosophies can work together. Finally, this chapter explains the adopted paradigm and techniques for this research.

4.1 Research Paradigms

Several research paradigms have been applied in the research of IS, where the positivism paradigm has dominated the IS research, and the survey has been the most popular method in top journals such as MIS Quarterly and Journal of Management Information Systems (JMIS) (Chen and Hirschheim, 2004). The following table shows a resume of the current research paradigms of IS.

Table 4.1 resume of the current research paradigms of IS (adapted from Tsang (2014))

	Positivism	**Interpretivism**	**Critical Realism**
Ontology	Objective Reality	Social Construct of reality (depending on the observer)	Objective, stratified reality
Epistemology	Discovering and generating scientific claims	Interpretation of subjective meanings according to a frame of reference	Creation of theories regarding the structures and mechanisms that generate observable events
Methodology	The tendency for quantitative research	The tendency to qualitative methods	The tendency to qualitative methods emphasised in the explanation

The aim of this research considers an approach to design flexible IS, where the organisational changes and their capabilities are seen as a source of future changes and uncertainty. Although positivism recognises the un-separated relation between the phenomenon and its context using case studies (Pare, 2004; Poba-Nzaou et al., 2008), the organisational context is seen as a social construct through the behaviour of agents and their interpretation of reality, discarding the objective reality of positivism.

Critical realism is a research paradigm used in information systems because it researches how abstract objects such as social structures and social affordances interacts with information systems (Mingers et al., 2013; Volkoff and Strong, 2013). This research paradigm accepts the limitations of human's objectivity under controlled conditions or "closed systems experiments" to predict behaviour (Bhaskar, 2008; Mingers, 2002), focusing on the explanation of a phenomenon instead of the replication.

The research paradigm is the interpretivism because the lack of agreement of IS flexibility has already shown problems about its definition, creating an incompatibility with the positivist paradigm. On the other hand, critical realism is more compatible with this research because it recognises a subjectivity in the human activity, but it still relies on a reality that cannot be captured. The analysis of IS flexibility relies on the knowledge of the organisation participants and potential changes, making a heuristic analysis of flexibility but in a speculative form. For this reason, this research follows the philosophical stand of radical subjectivism of organisational semiotics (Liu and Li, 2015, p. 27), which can be considered a branch of interpretivism because of its dependency of the observed agent and the interpretation of the research about the signs of the organisation. The methodology based on organisational semiotics proposed in chapter 3 should be assessed as a methodology, including its utility to enhance the IS flexibility by the design of a solution. For this reason, design science is a paradigm that can address the evaluation and improvement of the proposed methodology.

4.2 Design Science Research

The design of "solutions" in the information systems field has been a problem-solving approach that seeks alternatives for feasible solutions (Simon, 1996). Design science research in IS (DSRIS) address the construction of useful or purposeful artefacts for IS by addressing the real problems of organisations (March and Smith, 1995; Pries-heje and Baskerville, 2008). These artefacts in IS can be constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations (implemented and prototype systems) (Hevner, et al., 2004). The approach proposed in chapter 3 to enhance the IS flexibility is a method, fitting with the kind of artefacts covered by design science, so the methods or steps proposed by them can address this research.

Several studies have proposed frameworks or methodologies to research with design science, but they share the components of a design theory proposed by Jones and Gregor (2007):

- Purpose and scope: The purpose can come from an analysis of a problem situation, involving a step that includes the environment. Some authors such as A. Hevner (2007) proposes a cycle of relevance which proposes requirements and a set of criteria of acceptance. Other authors such as Peffers, et al. (2007) named to this step identification of motivation or problem, but it does not include a definition of metrics in the identification of the problem.
- Construct: The entities of interest should be represented in the artefact as a result or inference of the observation from the environment. Some authors assume that the definition of a problem from the environment is enough to define the artefact (Kuechler and Vaishnavi, 2011), but Jones and Gregor (2007) proposed conceptual units that should explain the phenomena and the environment with the current knowledge.
- Principles of form and function: Blueprint of the artefact to link its properties, function and features. In general, the construct and the principles of the artefact are part of the development (Vaishnavi and Kuechler, 2015) or design (Peffers et al., 2007) of the artefact.
- Artefact Mutability: The artefact mutability recognises that the artefact can change through the design process. For this reason, the current frameworks iterate between the steps to include the possibility to explore another solution or improve the identification of the problem (Alan Hevner and Chatterjee, 2010).
- Testable Proposition: The main idea of the design of artefacts is its utility, so the artefact should be tested (Jones and Gregor, 2007). The form of tested depends on the artefact, the problem and the tested conditions (Venable et al., 2014). For instance, if the construction and design of the artefact are expensive, the criteria should be the efficiency. In general, the proposed frameworks and methodologies include a stage of evaluation of the artefact, which includes the use of the artefact or a prototype in a real case (Kuechler and Vaishnavi, 2011; Peffers et al., 2007; Venable et al., 2014).
- Justificatory Knowledge: Design science encourages the use of previous knowledge to link theory with practice, but avoiding the proposition of something that already exists. Kuechler and Vaishnavi (2011) included steps in the methodology to suggest something based on current studies. Other authors include a review of the current state of the art in the design and development stage (Peffers et al., 2007).

The development of the artefact in design science is open to the artefact and the problem, which can be seen as a gap in design science or as a flexible approach to adapt

to the problem. Indeed, design science can address the development of the proposed methodology, assessing it as an artefact. However, it is needed to adopt other methods to develop and test it, so it is needed a generic skeleton of design science, which could be adapted to other methods. The stages proposed by Kuechler and Vaishnavi (2011) is one of the most cited works in design science, it achieves the principles explained above, and also is generic enough to adapt it with other methods. Figure 4.1 illustrates an overview of this research's method, which consists of the following stages.

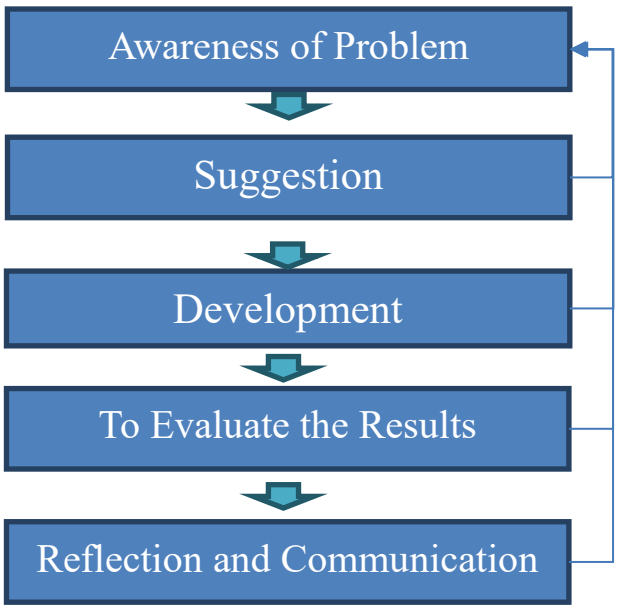

Figure 4.1 Phases of design science (Based on Kuechler and Vaishnavi, 2011)

Awareness of Problem: This phase consists of the definition of the problem, the domain, scope, aims and objective.

Suggestion: Suggestion's stage proposes experimental designs, using current studies related to the problem.

Development: The development phase considers the refinement of an artefact, which can be a construct, model, method, instantiations or a better theory. The development may require the construction or implementation of the artefact.

Evaluation: This is the evaluation of the artefact based on a criterion, which can be implicit or explicit in the awareness of the problem section. In the case of theories, it is possible to correct the theory after some observations.

Reflection and Communication: This phase consists of the report of conclusions from the evaluation, which should communicate the results into language accessible and exciting to practitioners.

Design Science Research is a research paradigm focused on artefacts that can solve problems instead of a research methodology (Baskerville, 2008). Under this paradigm this research creates an own process of research, using case studies and organisational semiotics.

4.3 PhD Research Design

Case study research is a research method challenging to generalise because it usually attempts to understand problems embedded in social contexts, containing variables that cannot be controlled. Case study research is different from case studies for education because this latter does not need accurate information, being enough relevant information for the understanding of students. Positivists and interpretive research use case study to observe different features of the reality. For instance, positivists can research the regularities of a case while interpretive cases can research deep understandings of systems' interactions (Darke et al., 1998). For this reason, case studies have been useful in IS research because it is feasible the application of different kind of research paradigms such as positivism (Pare, 2004), critical realism (Wynn and Williams, 2012) and interpretivism (Corvera Charaf et al., 2013). However, case studies have been stereotyped as a week method, which cannot generalise knowledge (Yin, 2009), needing to use structured methods and forms to encourage validation.

Current approaches of case studies usually follow a formal process (or protocol) to guarantee internal validity, and strategies for external validity. According to Yin (2009) and Thomas (2015), the components of case study research design are: 1) Purpose and questions, where the case study should be focused on the research of question of the kind "how" and "why" in contemporary events; 2) Proposition, which is the approach or "solution" to the questions; 3) Design frame and methods, which is the definition of the unit of analysis and the methods to collect the data; 4) the process of the case study is the performance of the case study, analysis of data and reporting. There are several strategies of case studies such as single and multiple, sequential or parallel, holistic and embedded case. A single case is usually a unique case, which cannot be replicated in multiple cases. Sequential or parallel are multiple case studies, which need to study separate elements. Holistic cases mean that the unit of analysis cannot be separated and embedded refers to sub-units of the organisation that can be studied. Therefore, the

components and strategies from case study research can address the application of case studies to other research paradigms.

Case study as a research method can study a contemporary phenomenon, making compatible with the design science research. Both methods emphasise the understanding of interactions between organisations and information systems either through the usefulness of an artefact or the interaction of an artefact in a specific context. For instance, although design science research can evaluate properties of artefacts such as usefulness and goal achievement, the researcher chose the case to assess these properties (Venable et al., 2014). On the other hand, case study research can use several sources of data such as interview, documents and observations, which are useful for the proposition and validation of an artefact.

This research defines two cases to develop different parts of the same artefact. The first case attempts to develop the concept of boundary and methods to identify it. This case analyses the changes through the time of an organisation (Rolls-Royce), understanding "how" this organisation maintain the "boundary", which represent "where" IS flexibility is needed. This case can provide insights into the understanding of organisations as living systems, considering the holistic nature of organisations and their information systems. The second case study addresses the use of the methodology for the development of information systems, considering the boundary as the main component. The second case develops more steps in the methodology because it is feasible to analyse the current context from interviews, safety procedures and government regulations. Both cases are conducted to develop an organisational model, but they cover the first component, the "boundary" as the first step in the proposition of a model based on living systems.

Figure 4.2 shows the proposed research design, which includes the phases of design science research in white boxes and case study research method in blue boxes. At the right of the diagram are shown the phases of design science, which can represent more than one task of the diagram. The first two tasks are explicit in design science, but they contain the research questions and part of the proposition, which are components of design science.

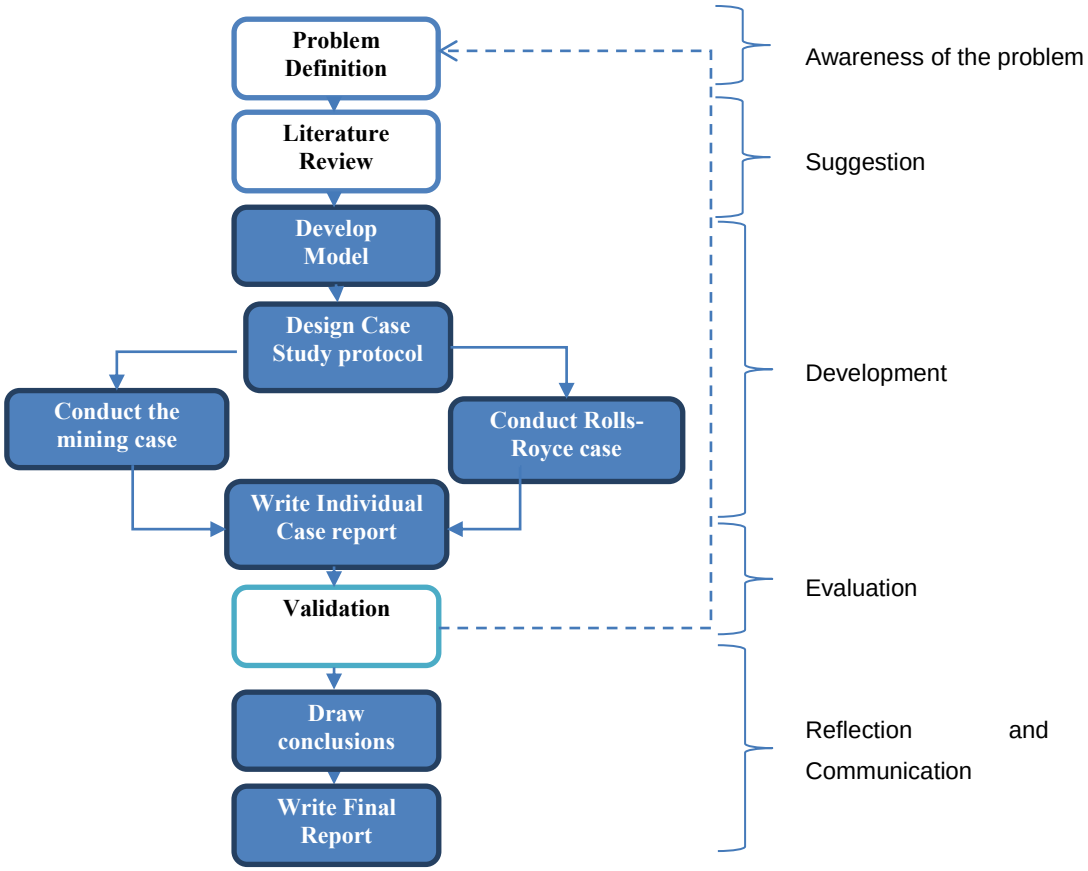

Figure 4.2 Design Research method based on design science and case study

This research uses the same phases of design science as a base, considering the following phases:

Problem Definition: This phase is the awareness of the problem defined in design science. Additionally, it defines research questions to address the literature review and the research.

Literature Review: Literature review is a part of the suggestion, and the main aim is the understanding of the current approaches to propose a "solution" to the defined problem. The understanding of the previous points can be useful to propose a better definition of the flexibility of IS and the limitation of the organisation to be flexible. This work recognises the nature of organisations to survive, and then the flexibility under this point of view is the understanding of the capability of the organisation to change maintaining the substantive activities that generate resources to survive.

Development: The development phase considers the refinement of the artefact and its development using case studies. The development of the model proposes a new model based on the literature review, considering the interpretation and creation of information from the organisation. This approach is in chapter 3 and the proposition of the core components of the organisation, which are useful in the proposition of an assessment

model for the co-design or in the representation and analysis of the organisational structures. The development phase improves the artefact using two case studies.

Validation: The validation is proper of design science, which attempts to test the artefact in a real situation. This research understands the validation from two points of view, the former from case study design and the later from the design science research.

Evaluation from Case Study Research: The evaluation is not an "official" step of the case study, because its concern is on the validation of the process, especially for unique cases (Thomas, 2016). Quality criteria for the research design assess processes or protocols, which depend on the kind of study and phase of research. Yin (2009) proposed construct validity, internal validity, external validity and reliability as possible tests from social science. Construct validity identifies the rights operational measures. Internal validity seeks a causal relationship between conditions. External validity defines the domain where the research can be generalised. Reliability defines protocols for the operation of the study to be repeated with the same or similar results. Retrospective case studies are not well developed, and there are no methods of validations and evaluation (Thomas, 2016). However, they can use some validations from case study research such as the reliability of the process and the external validity. The case study protocol can guide the researcher in the process of data collection, increasing the reliability of the case study. According to Yin (2009), a case study should have at least an overview, field procedures, case study questions and a guide for the report. Additionally, Thomas (2016) recommends recognising the analytical method as a part of the protocol (or checklist in his case), because the methods can address the form of linking between theory and the research questions. This research adopts the steps of Yin (2009) with the ideas of the checklist from Thomas (2016), to propose the following protocol.

- **Case Study Questions:** The previous step can help to the definition of some specific questions of the case. It is essential to define questions that suit with the level of details and the source of data. Yin (2009) proposes five levels of questions, where the first three levels are related to the case, and the superior levels are related to the research.
- **The context of the Case:** Description of the subject and the object of the case study, including literature review, which can help to frame the questions. Additionally, it should consider an explanation of the interest in the chosen case study, thinking about the kind of study (evaluative, explanatory or exploratory).
- **The approach:** The approach can be an illustration of an idea, the test of a theory or the construction of a theory, but it depends on the premise.

- **Data Collection Procedures:** Description about the data-sources and any procedure involved in this task.
- **Analytical method:** Description of the assumptions, decisions, and methods used during the case study.
- **Outline of Case Study Report:** Summary of the results. It should include the main claim and its relation to the evidence.

Evaluation from Design Science Research: Evaluating new IS artefacts involves answering the question "How well does it work?" (March and Smith, 1995). According to Venable et al. (2014), the form of evaluation of this artefacts is quick and straightforward, so it is possible to interview experts in information systems field, using the factors from the table 4.2 to assess artefacts (Prat et al., 2014). These factors can lead an answer from experts in the field (Hancock and Algozzine, 2006).

Table 4.2 Factors of evaluation of the assessment model as an artefact (Prat, et al., 2014)

Factor	Description
Goal	The method can help the identification of potential problems in the development of new capabilities related to technology
Environment	Utility, understandability, ease of use, ethicality, side effects,
Structure	Completeness, level of detail, consistency, simplicity
Activity	completeness, consistency, accuracy, performance, and efficiency
Evolution	We characterise robustness as the ability to respond to the fluctuations of the environment. Thus, robustness is related to evolution. Learning capability is the capacity of a system to learn from its experience and the reactions of the environment.

Reflection and Communication: Both cases provide results that can be analysed, concluded and communicated to the practitioners. It is possible to return to any stage of the research if it is needed. This research considers as communication conferences and journal that accept a significant proportion of interpretive studies such as Journal of Information Technology and Information Systems Journal (Chen and Hirschheim, 2004).

4.4 Methods for Data Processing

Case study and design science provide enough flexibility to use and adapt different methods to process data. The data can come from several sources, and the process of codification and classification is significant. One of the most prominent approaches for qualitative data is grounded theory, because it can analyse content from several sources, and can generate a theory from data (Strauss and Corbin, 2008). This approach allows

the use of papers as data, which can be analysed to resemble the reality from journals with real cases (Kumar and Stylianou, 2014). However, grounded theory is an inductive approach that does not accept pre-codes or any theoretical framework, making a contradiction with the abduction and deduction stages of design science (Dresch et al., 2015).

For this reason, the proposed framework cannot be developed with the approach of grounded theory, but some of their principles like the flexibility in the source of data, and the process of codification can be mixed with other methods for qualitative analysis such as thematic analysis (Braun and Clarke, 2006). This method can combine different philosophies and methods, but every assumption should be made in a clear and transparent form. Thematic analysis can process data from previous researches under an interpretive position, following some principles of qualitative data analysis such as theoretical frameworks, reduction of data and data display proposed by Miles and Huberman (1994). Clarke and Braun (2013) propose the following six phases:

1. Familiarisation with the data: This phase aims the familiarisation of the researcher with the data, without any analytic observation.
2. Coding: It consists in the generation of labels that represent the semantic and conceptual meaning of the data. This phase ends when the researcher codes the items, collating codes and relevant data extract.
3. Searching for themes: This process searches for patterns into the codes relevant to the research questions. This phase finishes when the researcher collates all the codes into themes.
4. Reviewing themes: This phase checks if the themes suit with the codes and the full data-set.
5. Defining and naming themes: In this phase, the researcher analyses each theme, proposing a name for each theme.
6. Writing up: The researcher should write an integrative story about the data, persuading the reader with a coherent story contextualised in the existing literature.

The analysis can be broad or thick, depending on the research's scope and questions. It is also feasible to adapt the research questions according to the form of data collection (Braun and Clarke, 2006).

4.5 The Approach to the Cases

The proposed research methodology is based on design science and case studies in an incremental form because it is aimed to avoid the following problems:

- The IS flexibility depends on the observed period: This problem considers the challenging task to observe an organisation which change, during the span of time of this research. The definitions of IS flexibility involves long-term changes (Gebauer and Schober, 2005), which can be longer than the period of this research. For this reason, it is considered the observation of an organisation, which changed the activities related to the boundary supported by an information system. This analysis can give some guidelines to identify changes' drives from the environment, which can be applied to the enhancement of IS flexibility.
- Problems to test construct, form and function at the same time: ISFOSA depends on the concept of boundary, its identification and analysis to enhance the IS flexibility. This concept can fit with the constructs components proposed by Jones and Gregor (2007), which are the essential components of design theory. A case study to test the concept of boundary or half of ISFOSA can minimise risks related to the applicability of the theoretical concept of autopoiesis. Additionally, feedbacks from an instantiation of part of the artefact can define principles of implementation such as potential scenarios of analysis, avoiding the lack of connection between IS and organisation showed in current propositions.
- The strictness of design science and case study: Both research methodologies have struggled with critics about strictness in the research community. For this reason, this research methodology follows the advice from Yin (2003), using a case study protocol to maintain an internal validation and feedbacks from experts as external validation. Additionally, this research tests half of the artefact in one iteration and the whole artefact in other iteration but following these validations.
- Low applicability of the past studies: A second case to instantiate the whole artefact can show the applicability of ISFOSA. The time frame of this research can limit the assessment of this artefact because the construction of the system can take more time than the time available for this work. For this reason, the criteria shown in table 4.2 assesses ISFOSA, providing feedback for future improvement (artefact mutability).

These problems are addressed by two incremental iterations, which are developed in two case studies, explaining in the following sections.

4.5.1 Incremental Iteration 1 the First Case

This case studies an organisation that has changed its form to make profits and how the IS enabled them. The changes of product or services in an organisation is a change in

the boundary, which is one of the critical concepts in ISFOSA. The study of documented changes in an organisation can overcome the limitations of time in this research.

This case is defined as a retrospective study that involves the collection of data from documents and archival records (Thomas, 2016), during the change of an organisation from a good dominant (GD) logic to a service-dominant (SD) logic due to the decrease of the original equipment market. This change was addressed by the implementation of several strategies and technology, showing the role of IS in the maintenance of the boundary or the autopoiesis. The proposed methodology addressed this case in the following form:

- Problem Definition: The purpose of the ISFOSA is the enhancement of the IS flexibility, but this case is focused on the research question "How can the information systems support the survival of organisations?". This research question is addressed by the study of the boundary of the organisation and the role of the IS to enable the changes, so the purpose of the artefact is not changed, but it is tested one part of it.
- Literature Review: The literature review was developed when the model was proposed, but it was reviewed the current literature of the process of servitisation about this organisation and potential sources of data.
- Develop Model: This model was developed beforehand, but it was divided its application into the phases one and two. The first one is the problem and context identification which identifies the problem, social sub-systems and stakeholders. The problem was covered in the problem definition part. The stakeholder analysis addressed the identification of social sub-systems. The phase two developed the ontology chart of the context situation identified, linking the stakeholders with the norms of the organisation.
- Conduct the Case: The elements proposed in the model were identified by the codification of the historical data such as journals, books and news. These codes were used as input to the phases one and two, resulting in the ontologic chart and norms shown in the case.
- Write Individual Case Report: The report was written as a chapter of this thesis.
- Validation: This case follows the internal and external validations proposed by Yin (2009). The internal validation is achieved by the definition of a case's study protocol, which describes the steps of the case study. Interviews can address the external validation, asking about the processes involved in this case.

The feedback from the validation is significant to consider in the development of ISFOSA methodology, and they were implemented in the next case.

4.5.2 Incremental Iteration 2 the Second Case

The analysis of the boundary can help to identify requirements of IS flexibility, but the distinction of the boundary is only the first part of the analysis. This second case expands the analysis of the boundary to the identification of requirements of IS flexibility, which can derive to the proposition of strategies to enhance the IS flexibility. This capability enables potential changes triggered by new technologies such as light communication networks and other technologies. The second case aims to use the feedback obtained from the previous case to enhance ISFOSA, but this feedback can be applied to the whole methodology because ISFOSA analyses the boundary twice. The analysis of the macro boundary can identify potential changes in the organisation, and the analysis of the boundary in the focal system can identify potential changes in the IS from the potential changes of the organisation. This case instantiates the whole methodology in the following form:

- Problem Definition: The purpose of the ISFOSA is the enhancement of the IS flexibility, so this case is focused on “How to develop IS with flexible capabilities?”.
- Literature Review: It was reviewed the current literature related to the case, which includes the application of tracking systems for underground mines and the current state of light communication.
- Develop Model: In this case, the ISFOSA methodology is the developed model.
- Conduct the Case: The elements proposed in the model were identified by the codification of the available data of the project such as journals, laws, regulations and interviews. These codes were used as input to ISFOSA methodology, resulting in analysis of the boundary of the organisation, the focal system, the proposition of guidelines and a prototype.
- Write Individual Case Report: The report was written as a chapter of this thesis.
- Validation: The validation follows the same principles of the previous case.

This second case addresses the analysis and design of information systems with IS flexibility capabilities, which can be found as requirements of flexibility.

4.6 Summary of the Chapter

This chapter proposed a methodology based on design science and case study to develop the proposed methodology. This chapter reviews the current research paradigm such as positivism, interpretivism and critical realism, discussing their compatibility with the study of IS flexibility. It was concluded that an interpretivism paradigm can cover the

lack of definition of IS flexibility and the problems of interpretation of this concept in former studies. It was reviewed design science as a research paradigm because the proposition of this research is a methodology, which fit with the kind of artefact covered by design science. Although design science research can provide a skeleton for the research design, it does not propose methods or philosophical ground to conduct research. For this reason, the research design uses the processes of case study to develop the proposed methodology.

The research design is explained in this chapter, but it was proposed a research design iterative and incremental to assess constructs and principles in different stages, minimising risks and improving the possibility of feedback.

Chapter 5

Case Study One: The Maintenance of the Organisational Boundary and the Autopoiesis

Organisations as enterprises with high environmental pressure have shown a high probability to change, creating problems in the adaptation and development of information systems. Current studies have proposed technical features to face the change such as flexibility and modularisation of IS, but they do not analyse how the information systems can support the survival of organisations. The concept of boundary and its maintenance is crucial for the autopoietic test, and consequently the autopoiesis and the survival of an organisation.

This chapter applied the first two phases of the ISFOSA method in the process of servitisation of Rolls-Royce to identify the boundary through the changes. This case uses secondary data such as journals and books of Rolls-Royce to apply thematic analysis. This analysis codes the data to identify the components to apply ISFOSA such as agents and affordances. The result of the method is the identification of affordances between Rolls-Royce and external agents (the boundary), enabling the analysis of the dynamics and pattern of behaviours through them.

5.1 Justification of the Case Selection

The transformation of Rolls-Royce from a product-service dominant to a good-service dominant can show some patterns between the information systems and the boundary to understand the survival of organisations. This case covers the following research question:

How can the information systems support the survival of organisations?
The process of servitisation of Rolls-Royce involved several of changes that can affect the boundary. The following list explains some of these changes.

1. New business/strategic development: The servitisation of Rolls-Royce implied a change of the focus from manufactory to services. The Total-care bundle meant the development of a new business, changing the strategy of the organisation.
2. Technology: The implementation of new technologies such as ERP and microcontrollers in the jets provides new capabilities for the organisation. The integration with microcontrollers gave new online data about the state of the engine, improving the fault detection.

3. Organisational Changes: New services brought new divisions to take care of these services. Rolls-Royce creates a new procurement department in charge of the procurement of the after-service, which includes the forecast of fault.
4. External factors: The change to servitisation took several years, which include the period of the terrorist attack. This attack affected the demand for flight tickets, and the demand for jet engines consequently.

Rolls-Royce faced several changes in the process of servitisation, where several of them should affect its IS. Although the impact of the servitisation may affect the whole company, this study analyses the boundary. This chapter hypothesises that the change in the form of making profits will affect the interface components in the organisation, defining a starting point for the analysis of boundary.

According to Yin (2009), there are five levels of questions, which can address the study. The first level of question is relevant for the entire research (the research question), and it could address several cases. The following sub-questions are directly related to the case, and for each sub-question contains a set of questions that can address the data collection and the development of the proposition.

1. What is the process of servitisation?
   a) What is the definition of this process?
   b) Which features can we found in this process?
2. How was this process conducted in the Rolls-Royce case?
   a) When this process started?
   b) Which division or department was involved? How?
   c) What is the current offer or services related to this process?
3. How servitisation affected the boundary of Rolls-Royce? Why?
   a) Is the interface the part of the servitisation?
   b) How did the information system support or enable this change?

5.2 The Context of the Case

Vandermerewe and Rada initially proposed the process of servitisation in 1988 as a combination of goods and services, which do not produce a tangible good (Baines, et al., 2009). Servitisation can be defined as a process that changes an enterprise from goods-dominant logic (sell product) to a service-dominant logic (sell product-service systems). This process attempts to understand the customer needs to propose new services. However, the adoption of services is a challenging process, because service logic is a new domain for manufacturers, which can imply the change of the strategy and the transformation of the organisation. There are no standard formulas for this process, but according to Baines *et al.*

(2009), the following activities are considered good practices: A.- To identify good capabilities of the organisation to understand which capability needs to develop; B.- To identify the value of a service in each phase; C.- To define service units and their responsibilities of loss and profit; D.- To collaborate in arrangements with partnerships, outsourcing's enterprises and customers; E.- To change the culture of service thinking by training, empowering, or separating service in the organisation.

Rolls Royce has been operative over 100 years, changing its business as a manufacturer of luxury cars to business in civil aerospace, defence aerospace, power systems, marine and nuclear energy. Current researches have studied the servitisation of the civil and defence aerospace division for several years, because they changed the principal revenues (around 50% in the last year (Rolls-Royce plc, 2017) from selling jet engines to sell flight hours with its service called total care (Baines and Lightfoot, 2013). Additionally, according to Tiwari (2005), the airspace's environment has changed his dynamic in the following form:

- Supplier Relationship: Large companies such as Boeing and Airbus have changed the relationship for a closer relationship in a network structure instead of a hierarchical structure. This relationship has brought cost reduction and the development of new products.
- Reduction in supplier base: In the first half of the 1990s, the supplier was reduced by 50%, consolidating the leading manufacturers and suppliers in the sector.
- Increase in technology transfer between commercial and military aircraft: The Research and Development from government programs encouraged the application of this technology in commercial products.
- A system view of the industry: The industry has changed the focus on only components and their performance to a holistic point of view that considers an extended lifecycle. This perspective uses the technologies from Telecommunication and Transportation in the monitoring and controlling of components.

These changes in the environment triggered enhancements such as a strong growth around the year 1995 when another manufacturer offered an aftermarket service to Cathay Pacific (Derber, 2013). Thus, the year 1996, Rolls-Royce set up its organisation to improve the Maintenance, Repair and Overhaul (MRO) business, investing in IT and opening fourteen MRO facilities as a result of joint adventure agreements in 1998 (Pugh, 2001). According to Baines and Lightfoot (2013), Rolls-Royce classifies as an advanced service provider, which has changed in the following form:

- Performance and Metrics: They needed to change the focus of the indicators from a manufacturing approach to an alignment with the performance of every customer. It is

not enough with the existence of indicators, but they should demonstrate their value to the customers.

- Change in their facilities and location: Rolls-Royce opened several facilities close to the customers' operations, enabling them to a faster diagnosis and response.
- Change in their organisational structure: Rolls-Royce has changed their structure, offering extensive activities of front-office aligned with the customers' activities. Examples of these changes can be found in the division of responsibilities in sub-business, and in the relationship-style contracts with suppliers.
- Implementation of Information and Communication Technologies (ICTs): ICTs can provide the platform to collect data, inform and take actions in the processes of maintenance, repair and use.
- Change in the people deployment and their skills: The reinforcement of MRO business brought changes in people's skills. They needed to improve their capability to empathise with the customer, being flexible, proactive and service-centric.
- Change in their business processes: The change in people's deployment involves more interaction points with the customer. Every interaction point needs an inter-organisational relationship with robust connectivity with the stakeholders.

Rolls-Royce's case explorers the mechanism that made their process of servitisation successful.

5.3 The Approach of the Case Study

This case wants to assess the concept of survival by the maintenance of the boundary of the organisation. ISFOSA can address the analysis, which can also contribute to the understanding of IT systems to support changes. The data needed for the analysis is:

- Stakeholders: The first set of codes to define are agents, but the stakeholder analysis can help the identification of them.
- Ontology Chart: This step is the analysis of the relationship between agents to identify affordances. The ontology chart can show affordances, agents and their ontological dependency.
- Norms: The rules that govern the behaviour of agents and affordances can provide a deep insight into the boundary and its maintenance.

The selected data is used to identify the components of the norm analysis, looking at the themes of table 5.1 in the literature related to Rolls-Royce (See Appendix B).

Table 5.1 Initials codes and sub-codes

Codes	**Description**
Context	It refers to the situation
Condition	what happens to cause the start/finish of the norm
Agent	who is responsible for the start/ finish. Stakeholders are potential agents
Deontic operator	The <deontic operator> can be obliged, permitted or prohibited
Action	An Action
Pre-Condition	The conditions for invoking/applying the norm in the situation
Post-condition	The consequence after successful execution of the norm detailed

Additionally, the analysis of norms and their dependency can identify patterns at the boundary level. Table 5.2 shows the well-known formula divided by columns, but this table includes an extra field to indicate a dependency with a pre-condition norm.

Table 5.2 Example of Norms with pre-conditions

ID	**Whenever**	**If**	**Then**	**Is**	**To**	**Pre**
1	The person is applying for a job	That person meets the requirements	The company	Permitted	Employ that person	
2	A customer wants to buy a product	The customer and the seller agree on the Price	The seller	Permitted	To sell that product	1

Table 5.2 shows an example of this pre-condition, which means that without the first norm, the second norm is not feasible. The column field has a number that references another norm.

5.4 Results

The last changes in Rolls-Royce have been the result of the mitigation of uncertainty and the strengthening of its Maintenance, Repair and Overhauling division (Durugbo and Erkoyuncu, 2016). The data available studied the changes of Rolls-Royce under two perspectives. The first perspective is the changes in the supply chain management to implement a lean production. The second perspective is the implementation of Information Communication Technologies (ICT) to improve the integration of the production and the service provision to the customers.

5.4.1 Changes in the Supply Chain Management

Several changes have been done in the supply chain management to reduce the cost of inventory and the risk for research. The changes in the relationship with the suppliers cannot be seen as an isolated event, because they have been triggered as a result of the change to lean production. The proposed method to identify boundaries can help us to identify the activities and tasks that enabled to Rolls-Royce in this change.

Stakeholder Analysis

Rolls-Royce wanted to reduce cost from suppliers, but the changes in the regulation from the government, classifying and reducing the number of suppliers pushed new forms of collaboration. Additionally, the role of suppliers has changed to an active role that can participate in the investment and research with Rolls-Royce as a result of the high investment needed for the development of new products and the changes in the market. Table 5.3 shows the potential stakeholders, their roles and responsibilities.

Table 5.3 Potential Agents

Stakeholder	Category	Responsibility
Supplier	Provider	Supply parts for the construction of engines. Additionally, they should be able to Connect their Information Systems with Rolls-Royce to achieve Just-in-Time (JIT) inventory and lean production. Achieve metrics for the JIT inventory, avoiding bottlenecks.
Procurement Department	Actor	In charge of the procurement and the maintenance of suppliers
Competitor	Collaborator	Share list of suppliers with Rolls Royce
Rolls Royce Engineer	Actor	It visualises the bottlenecks of its suppliers as a bottleneck in its supply chain and hence invests in developing the supplier's ability to deliver on time, at the lowest cost and highest quality

The supply chain management implemented Toyota practices such as JIT inventory and lean production, which involved several agents working together (Timothy Baines and Lightfoot, 2013). The investment partner was identified as a generic name because this partner can be a supplier in a high category or the government.

Semantic Analysis

The semantic analysis shows the agents and their relationship, but a context or situation should analyse it due to its potential extension. Figure 5.1 shows an ontology chart with the

affordances (square boxes) between Rolls-Royce and their suppliers in the context of the purchase and delivery of items needed for the production of an engine.

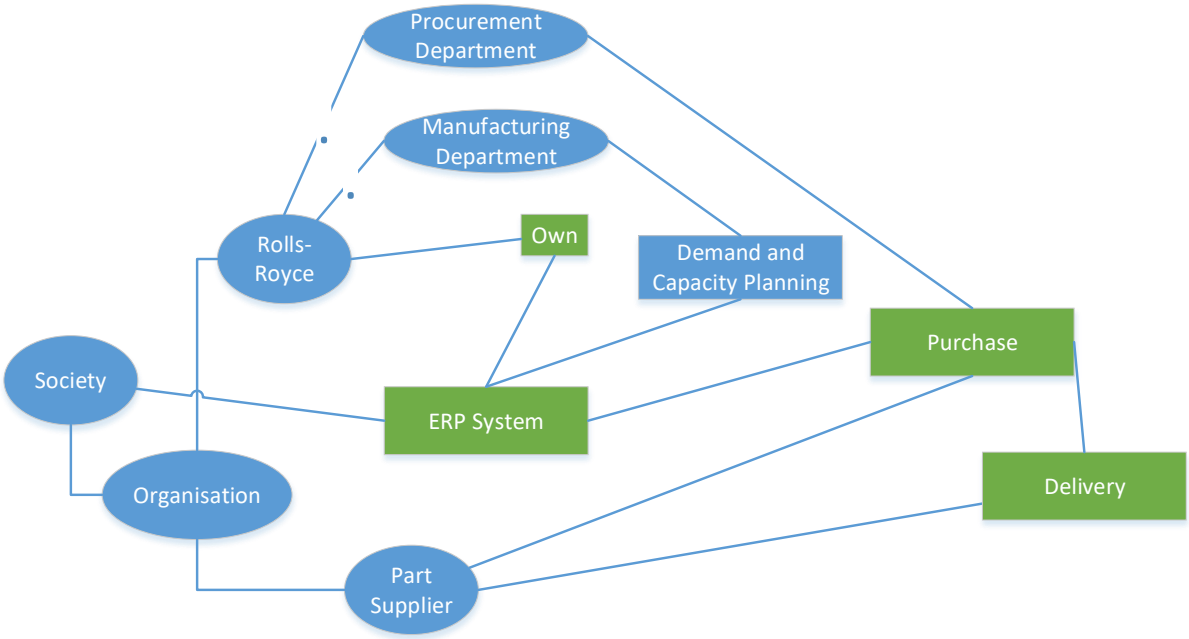

Figure 5.1 Ontology Chart of Purchase and Delivery

The JIS inventory is supported by the ERP system, which can simulate and plan the capacity for the manufacturing, sending a flow of information about the current state of the production to the suppliers in case that the manufacturing process needs an item. The supply management is a significant process that involves the following activities:

- Selection and segmentation of suppliers: The classification and acceptance of new suppliers is an activity that can create new affordances. Rolls-Royce invites to invest in new products to the suppliers with the best results. Some criteria for this selection are related to the capability of the supplier to achieve Rolls-Royce's demand and the location of the suppliers with the customers for the after service maintenance. Additionally, Rolls-Royce shares its supplier's database with their competitor as good practice of the aerospace industry.
- Supplier Monitoring: Rolls-Royce is monitoring their suppliers, assessing the quality, delivery performance, reliability and responsiveness. Rolls-Royce tries to avoid any disruption in the process, providing advice to its critical suppliers.
- Supplier Connectivity: The company promotes and requires information flow with the suppliers using Information Technology. They implemented an e-procurement platform that can manage invoicing, accounting, and delivering in connection with the suppliers.

Figure 5.2 shows the ontology chart related to the supplier management, identifying their principal agents and affordances.

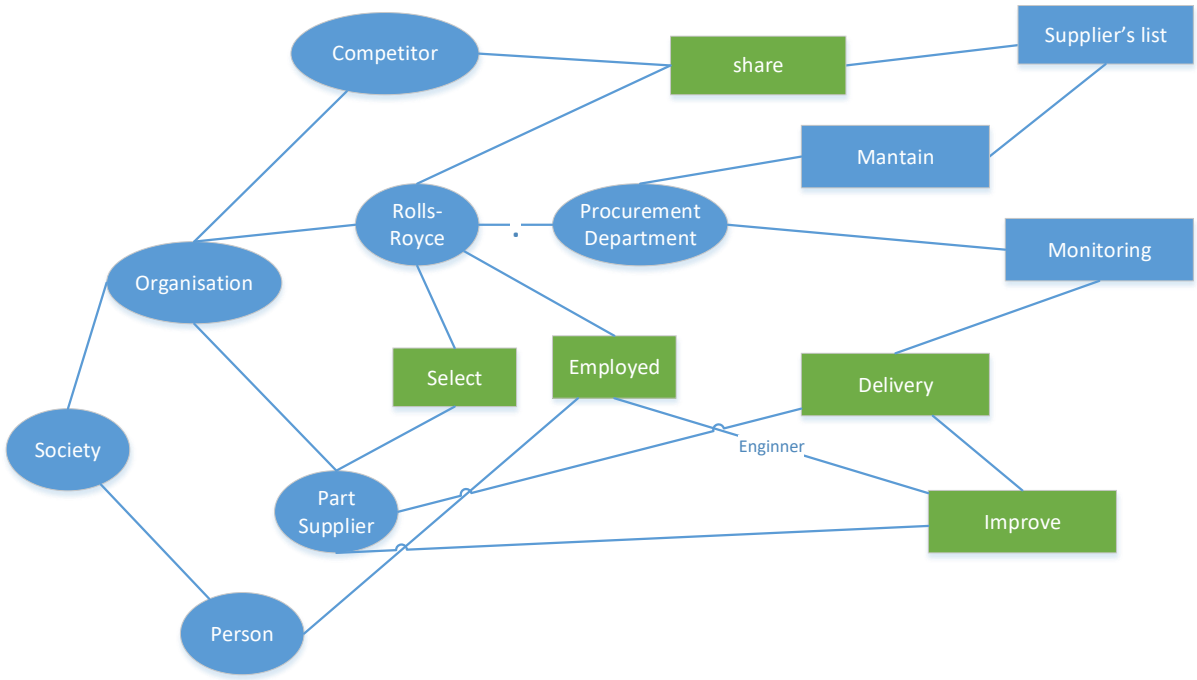

Figure 5.2 Ontology Chart Supplier's Management

Norm Analysis

This case focuses on the analysis of affordances that interact with external stakeholders, summarised in table 5.4.

Table 5.4 External Stakeholders Affordances

External Stakeholders	Affordance
Supplier	Process a purchase Deliver a purchase Improve their logistics with the help of Rolls-Royce Be selected from Rolls-Royce
Competitors	Share list of suppliers with Rolls Royce
Person	Employed
Society	Own ERP system

The norm analysis examines the dependency on the selection of suppliers. Table 5.5 shows a norm analysis with the fields of the norm structure illustrated in section 5.3. The fields "whenever" and "if" are the pre-condition to trigger the behaviour. The column "Then" is the agent that can act (column "To"). The column "is" is a deontic operator, which can be "obliged", "permitted" and "prohibited" which prescribe what people must, may, and must not do. Rolls-Royce is meeting every year to evaluate potential partners and new suppliers, so they are monitoring and adding partners constantly. The following table shows the most representative norms related to the process of supplier management.

Table 5.5 Supplier Management Representative Norms

ID	Whenever	If	Then	Is	To	Pre
1	Every year in the supplier council	The potential partner meets the requirements	Rolls-Royce	Permitted	Select new suppliers	
2	Every delivery	The purchase arrives late	Procurement Department	Obliged	Analyse suppliers	
3	Analysis of supplier is triggered	The analysed supplier is lower the average time of delivery	Procurement Department	Permitted	Analyse the supplier's processes	2
4	The procure department analyses the suppliers' process	There is no solution to the bottleneck	Procurement department	Obliged	Delete the supplier from the supplier's list	3
5	An engine is in production	The production needs a part	Procurement Department	Obliged	Order the part to one of the suppliers	1, 4

As we can see in table 5.5, some affordance depends on the result of a previous affordance. For instance, it is not possible to order a new item for the production or repair of an engine if there is no supplier selected in a previous stage.

5.4.2 Information Communication Technologies for the Service's Provision

The use of ICTs for the service's provision of Rolls-Royce is significant because it combines the use of technology and business strategy.

Stakeholder Analysis

The stakeholders related to the service's provision are related to the generation of incomes. Additionally, the ICTs are activities related to the implementation of new technologies and research. They are connected because Rolls-Royce is improving their process and engines continuously.

Table 5.6 Stakeholders for Rolls-Royce's provision

Stakeholder	Category	Responsibility
Supplier Partner	Collaborator	This partner can be a supplier that Invest capital in the development of a new engine. This kind of relationship can minimise the risk.
MRO	Actor	In charge of the maintenance of engines
Aircraft Developers and Airlines	Customer	Buy engines or contract service to Rolls Royce
Manufacturing Department	Actor	Build new engines
Government	Bystander and collaborator	Government is a bystander because it can change laws and regulations, affecting the behaviour of Rolls-Royce. In the past, the government standardised the suppliers and their classification
University	collaborator	Several universities have collaborated with Rolls-Royce doing research.
Employer	Actor	This employer represents the skill that Rolls-Royce promotes when they collaborate with Universities.

In this case, it is possible to see some agents with more than one role. For instance, the government that can rule and can collaborate with the organisation. Another case is the supplier, which in this case is a partner that invest money in research.

Semantic Analysis

This analysis divides the scenario in the analysis of the agents involved in the contract of services and the purchasing of an engine, and the agents involved in research activities. Figure 5.3 shows the first ontology chart, where the green boxes are affordances related to external agents. Although Rolls-Royce has a strong after service offer in each division (aerospace, energy and marine), the data available is about the civil aerospace business. For this reason, the primary customers are airlines and aircraft developers. The service contract includes engines and maintenance, but Rolls-Royce customises their offer to potential customers.

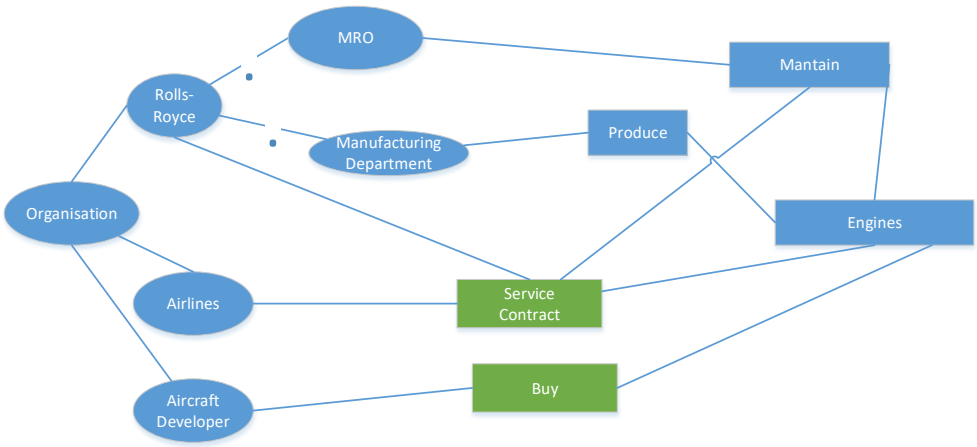

Figure 5.3 Ontology Chart of the service contract and buying process

Figure 5.4 shows the ontology chart related to research activities such as the production of methods and technologies to improve the manufacture of engines, and the prediction of failures. The maintenance, repair and overhaul department is in charge of the maintenance activities, which includes a strong emphasis on the prediction of failures. The strategy of Rolls-Royce aims to the minimisation of risks due to research, making a partnership with suppliers. Additionally, the company has participated in research projects with the government for the construction of engines for the defence sector, using part of this technology in the civil sector (Pugh, 2001). Another example of the research is the investigation made in collaboration with universities, which can also create skilled workers for the company in medium-term.

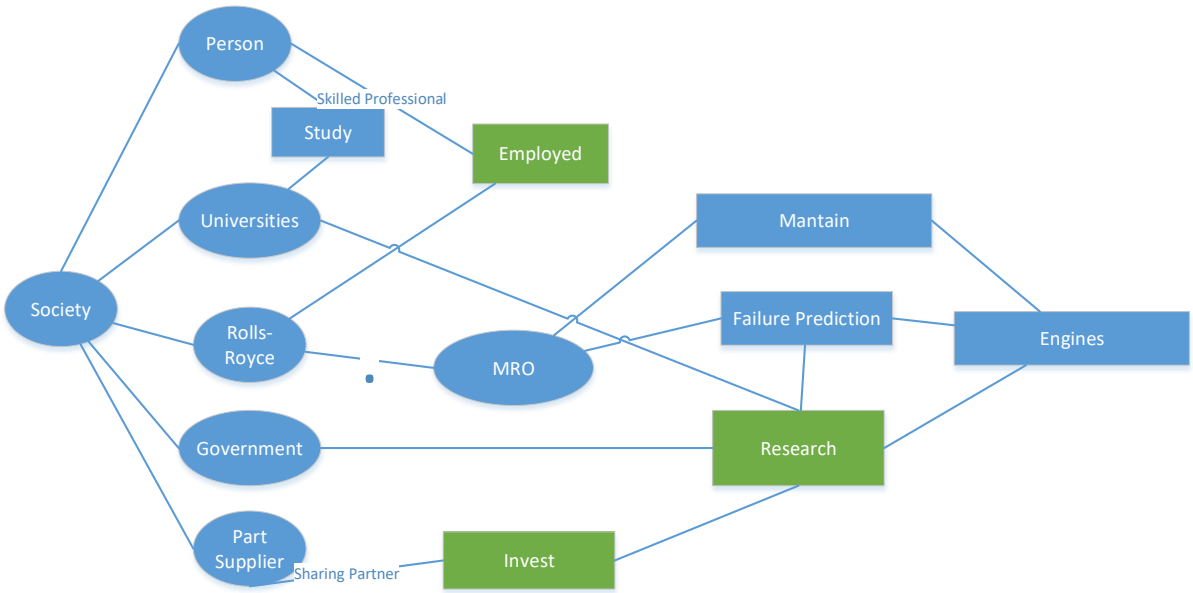

Figure 5.4 Ontology Chart of the research activities

Norm Analysis

A representative case to analyse the norms is the service contract affordance. A service contract includes engines and their maintenance in the form of power-by-hour. According to Baines & Lightfoot (2013), in this kind of contracts, the customer can charge a penalty to the manufacturer if the product fails. Likewise, the manufacturer can ask for compensation if the customer fails to use the product. The service agreement depends on the contract and the customer, but the application of penalties and compensation is a standard process.

Table 5.7 Norms of the Service Contract Affordance

ID	Whenever	If	Then	Is	To	Pre
6	An airline is interested in contracting a service	Rolls-Royce and the potential customer agreed on the level of service	Rolls-Royce	Permitted	Sign a Service contract for engines and **maintenance**	
7	The control room (prediction of failures) detects a failure	The failure signal is frequent	MRO	Obliged	Provide a **maintenance**	6
8	**Maintenance** happens	The problem is the result of wrong use	Rolls-Royce	Permitted	Charge a compensation	6,7
9	**Maintenance** happens	The problem is the result of a failure in the engine	Airline	Permitted	Charge a penalty	6,7

The norm description 8 and 9 are permitted because it is registered in some cases when the customer did not charge a penalty to Rolls-Royce due to its quick response to the problem.

5.5 Discussion

The discussion of this case addresses the link between the boundary, organisational semiotics, and the process of servitisation.

5.5.1 Assessing Boundary of Organisations Using Organisational Semiotics

The concept of affordance can define the boundary of the organisation by the interactions with external agents, shaping a non-physical boundary as the "system as difference" concept proposed by Luhmann (2006). These affordances do not only show what the organisation can do, but the restriction of the organisation limited by the boundary and then the IS flexibility. Organisational semiotics can address the identification of these affordances by steps of PAM, SAM and NAM, which are included in ISFOSA.

The analysis of context proposed in phase one of ISFOSA identifies stakeholders, roles and responsibilities. The roles of stakeholders can show the agents that interact with the organisation and the environment of the organisation, linking their responsibilities with the affordances and the boundary. The use of ontology chart for the semantic analysis can guide the identification of these affordances and the norms that restrict their behaviour. This restriction of the organisation shows the limitation of the boundary and then the IS flexibility.

Figure 5.5 summarises Rolls-Royce's affordance (green boxes such as purchase and delivery) and their external stakeholders (Orange boxes such as customers and competitors). In general, the affordances can represent a potential action of an agent in the environment as a result of the interaction with another agent.

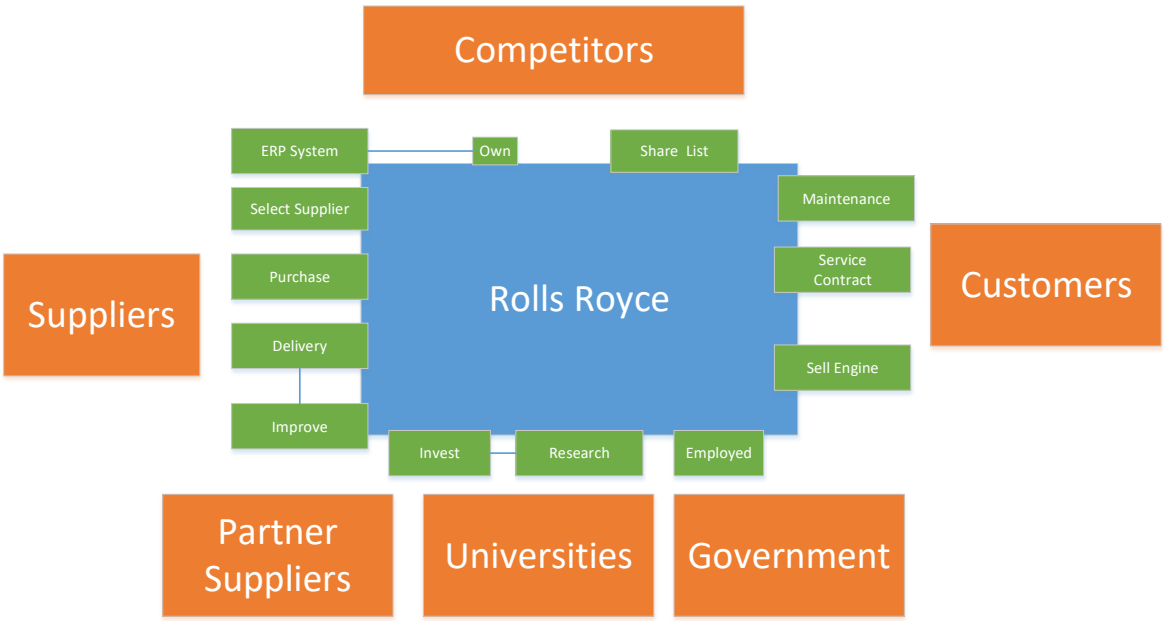

Figure 5.5 Summary of Affordances and External Agents

The analysis of the norms linked to the affordances that interact with external agents can show potential changes in the organisation and the need for IS flexibility. For instance, figure 5.5 can help in the analysis of potential changes and their sources in the following form.

- Economic Changes: The demand for engines of Rolls-Royce depends on the demands of aeroplanes and flights consequently. The affordances in interaction with customers should have other affordances to monitor and propose new products or service contracts.
- Changes in science and education: The skills of Rolls-Royce are challenging to find, so they depend on changes in education. Additionally, the government provided funds for research, so every change in the regulation of these funds will affect the company.

The identification of these functional systems can identify potential changes allowed by the organisation, and where IS should be flexible. Laws, regulations and the economy may affect the company, so it is needed to identify how these changes can affect the IS.

5.5.2 How servitisation affected the boundary of Rolls-Royce?

The servitisation process affected the boundary because it changed the form of relationship with the agents, putting new restrictions from the environment to the organisation. The affordances related to the maintenance of the boundary can be as same as necessary as the affordance of the boundary.

The affordances close to the customer implemented new forms of incomes in the form of the service contract. This new affordance brought new norms and affordances to monitor and control the system. For instance, the new type of contracts related to the Total Care service needed to define service agreements, penalties and compensation. On the other hand, the changes related to the JIT inventory and lean production have opened new forms of collaboration and control. However, these affordances were not possible if the "machine of signs" of the organisation does not allow them to change. For instance, the Total-Care needed the study of the failures beforehand to launch that service contract, and also Rolls-Royce needed to implement the collection of almost online data from the engine to predict failure. Both cases show that the affordance of monitoring and controls of data allow new affordances, and the collapse of the prediction of failures (including the inventory to have everything on time) may imply losses to the company.

On the other hand, the analysis of external stakeholders such as the government, supplier and technology and their restrictions into Rolls-Royce can show how the organisation is allowed to change. The following restrictions are the most repeated in the analysis:

- Financial Penalties: previously, it was found that service contracts usually include clauses related to the source of failure to charge penalties and compensations. Another example of financial penalties is the level of service agreement, which includes KPIs such as days for repairs and number of failures.
- Government Restrictions: Rolls-Royce has developed turbines for defence's aerospace, which involves a set of requirements such as certifications, segmentation and sharing of suppliers.
- Production Restrictions: The optimisation of the production's line was a significant improvement in the past. They implemented the 40 days' engine initiative, which allows 30 days for sourcing of parts, and ten days for assembly. The company achieved this goal with lean production and JIT inventory.

- Supply Restrictions: The most repeated restriction of suppliers is the requirement for lean production and JIT inventory. Suppliers should connect their information systems with Rolls-Royce to see the current state in the production of an engine.
- Technology Restriction: One of the most robust capabilities of Rolls-Royce is their capability to produce research and innovation. However, there are some restrictions that the organisation should follow to avoid any problem related to the integration.

5.5.3 How this change affected the other components?

Rolls-Royce's case is useful to understand that they maintained the affordances of the boundary with several feedbacks loops between an affordance from the boundary and other Rolls-Royce's affordances. Figure 5.6 shows an example of this pattern of a feedback loop in red and green lines. The red loop shows a set of affordances that can affect the availability of the sharing list affordance. The green line loop suggests a similar example, which includes the monitoring of deliveries from the suppliers to decide in a future if the selected supplier should stay or maybe should improve.

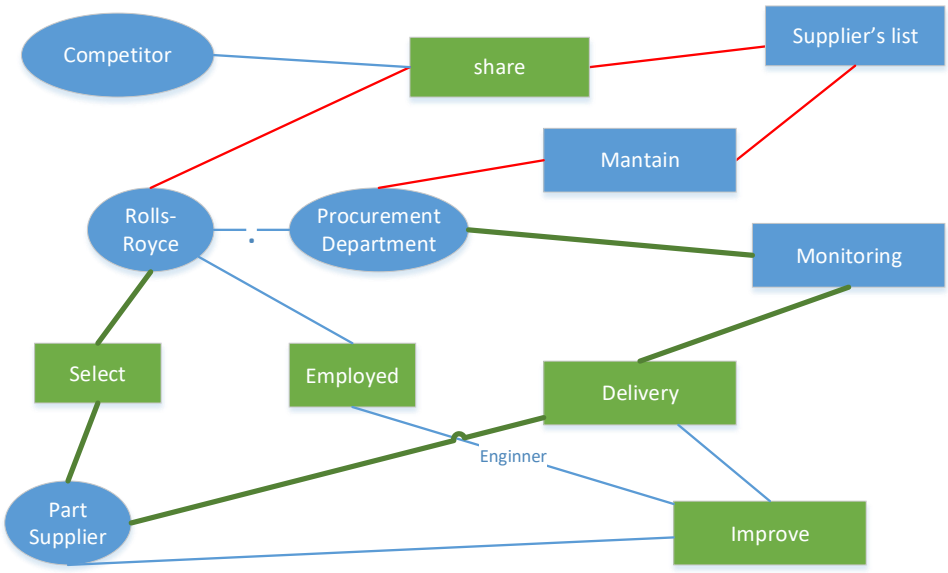

Figure 5.6 Ontology Chart Feedback loops for Supply Chain Management

Rolls-Royce has implemented several IT systems to enhance the tasks of monitoring and control of the boundary affordances. Thus, the changes to servitisation included the use of information technology in these affordances.

5.6 Validation

The validation assesses the method as an artefact, examining if the goal, the environment, the structure, the activity and the potential evolution of the artefact is coherent with use and purpose. These factors are adapted from table 4.2 and showed in table 5.8.

Table 5.8 Factors to assess the method applied in the Rolls-Royce's case

Factor	Questions
Goal	The goal of this artefact (the steps of the first two phases of ISFOSA) is the identification of the boundaries of the organisation, their potential activities and dependencies. This goal leads to the following question. Do you think that this method can be **useful** for **the identification of boundaries, activities and its dependencies**?
Environment	Do you think that potential users (professionals and academics) can **understand** this artefact? Do you think that this method **is easy to use**? Do you think that this method is performed **ethically** right? Do you think that this method can have any **side effect**?
Structure	Do you think that this method is **complete**? Do you think that this method is **detailed**? Do you think that this method is **consistent** with the main aim? Can this method be defined as **simple**?
Activity	Do you think that this method is **consistent** with every stage? Do you think that this method is **efficient**?
Evolution	Do you think that this method can be **adapted** to another case? Do you think that this method can be **improved**? How?

The result of this assessment is shown in the following sub-sections.

5.6.1 Goal

In this case, the primary goal is the identification of boundaries of the organisation, their potential activities and dependencies. The interviewers agreed that they understood and saw the affordances of the organisation as the boundary. Some statement includes some description of the output. For instance, the interviewee number one said "the products such as stakeholder and norms analysis can be useful for the boundaries". Another example, it emphasises the concept of the unit system for the identification of boundaries. The interviewee number three said "I think this is very useful because as soon as you identify for example the

context and the unit systems, we are in one way or another in the process of defining your boundary".

5.6.2 Environment

The environment was assessed by examining the understandability, ease of use, ethics and side effects. The interviewers considered that academics and professionals could understand the method, but they need a training organisational semiotics such as ontology chart and norms. One of the interviewees said "I needed more explanation to understand", while another said, "I think it depends on if this person knows about semiotics and some basic background information". However, they considered that the method seems easy as long the user understands all they need. The interviewees did not see any negative effect or an ethical problem. One of them made a positive judgement, saying "it can affect the organisation positively that by identifying boundaries and then looking at what it is important and what is not important" (interviewee two).

5.6.3 Structure

The evaluation of the structure comprises how complete and detailed is the artefact. The interviewees agreed about the completeness, the interviewee two said "It does what supposed to do" or another interviewee said "The method identifies boundaries" (interviewee one). The interviewees defined as positive the level of details because the method can obtain outcomes with different levels of granularity in every stage.

5.6.4 Activity

The assessment of the activity examines the simplicity, efficiency and consistency of the activities with the aim. The interviewees understood the connection between the stages and the main aim, saying "instead of consistent, I would use another word, like logical" (interviewee one), so the consistency was positive. The interviewees found the method simple and efficient, because the method achieves the aim, using a few steps in the analysis. An interviewee was concerned with the use of the word simple, saying "Simplicity can mean is not good, but it is just simple and easy to use" (interviewee three).

5.6.5 Evolution

The interviewees agreed about the possibility to adapt the artefact to another case, saying "In every case, we found stakeholders and boundaries, so yes" (interviewee one) or "it is generic so you can use it in any organisation that have similar characteristics" (interviewee two). As a part of the evolution of the artefact, the interviewees suggested the following improvements:

- The diagrams can use different colours for the boundary affordances to make it easier to understand (this change is already implemented)
- Organisations are always changing. For example, if a new technology is introduced to an organisation, it means that it is going to change the dependencies within the boundary of the organisation so maybe some of those things can be captured.

5.7 Reflection

The steps and principles of a methodology can be an ambitious artefact to propose because it involves several activities models and methods. This iteration addressed the development and evaluation of a part of the artefact, which contains the central construct of the artefact, the concept of boundary and autopoiesis. An incremental and iterative methodology based on design science is a new concept that can be tested as an artefact for research. The following sections reflect about the methodology ISFOSA and the research design as artefacts.

5.7.1 Reflections from ISFOSA

The current application of ISFOSA can provide some learning to improve it, but this reflection can be guided by the analysis and identification of the components of a design theory (Jones and Gregor, 2007) applied to ISFOSA.

Purpose: The purpose of the first two phases of ISFOSA is the identification of boundary instead of the enhancement of the IS flexibility. This purpose was changed from the original in the study to link the result with the validation of the case.

Construct: The main elements of these phases are the identification of affordances as boundaries, norms and agents. The current constructs are not enough for the IS flexibility, so the following iteration should include an analysis of the factors of IS flexibility proposed in table 2.3, which summarises some strategies to enhance the IS flexibility.

Principles of form and function: The phases one and two of ISFOSA can identify the affordances related to the boundary of the organisation. However, more steps or methods are needed for the analysis of IS flexibility.

Artefact Mutability: The interviews for the external validation of the artefact provided suggestions to improve the steps of these phases. The following phases use the same method to identify the boundary of the focal IS, so this feedback can also improve these phases.

Testable Proposition: The proposition of boundary was tested with the instantiation of the case and also the interviews. According to the interviews, these two phases achieve its proposition.

Justificatory Knowledge: The concept of the boundary as the distinction is not new and a brief literature review was included in section 3, but the construct and principles are new for IS research.

Principles of Implementation: The principles of implementation can be found in the proposed case study protocol. This protocol includes a definition of a set of question, the context of the case, the approach to the case, the data collection procedures, analytical method and the report.

Expository Instantiation: This case is an instantiation of the first two phases of ISFOSA. The result of this case was shown to the interviewees, and they agreed about the achievement of the main purpose.

The validation showed the achievement of this case to the primary purpose, but it also discussed the knowledge of the researcher in organisational semiotics to use this methodology.

5.7.2 Reflection from the Research Design

The proposed research design is an artefact which can follow the same principles of design science because this research design is a methodology to research, conducting case studies with design science. For this reason, every case can count as an iteration of the research design, but the validation of this artefact is seen only in the use of it. The same components of a design theory can address the reflection of the research design as an artefact.

Purpose: The purpose of the research design is the design of a methodology as an artefact.

Construct: The main elements of the research design are the identified problem, the literature review, the artefact, methods and the validation of the artefact (the activities of the research).

Principles of form and function: The process' flow shown in section 3 defines the stages, activities and links.

Artefact Mutability: This process of reflection can improve the research design as an artefact. The process of codification was challenging because of the sources of data. The following case should include primary data to observe the need for flexibility as an organisational phenomenon.

Testable Proposition: The instantiation is the testable proposition for this research design. An additional testable proposition should be proposed. An example could be the publication of the current research design in journals or conferences to obtain feedback from external observers.

Justificatory Knowledge: It was reviewed the main frameworks of design science, proposing the current research design.

Principles of Implementation: The principle of implementation depends on the activity. For instance, if the activity is the codification, the principles are the guidelines for codification.

Expository Instantiation: This interaction has already shown that this research design can help the design of a methodology.

The research design as an artefact achieves the purpose in this iteration because this case was conducted and the process involved was identified from the interviewees of ISFOSA.

5.8 Summary

This chapter conducted a retrospective case study, using secondary data to identify and analyse the boundary of the organisation. The analysed data was codified to define affordances, agent and responsibilities of Rolls-Royce, during its period of servitisation. Phase one and two of ISFOSA used the identified elements to perform a stakeholder analysis, context analysis, semantic analysis and norm analysis to identify a set of affordances that interact with external agents. These affordances are named the boundary of the organisation, and they helped to the analysis of the boundary when Rolls-Royce changed the supply chain management and the information communication technologies.

The result of this case shows that the IS supported patterns of feedback and control in the boundary of the organisation. The norms that restrict the boundary are similar to the functional systems of society, showing potential structural coupling between the organisation and the environment. These interactions and their restriction are potential sources of changes and then potential needs for IS flexibility.

This case was validated by interviews to assess the usefulness of the artefact. These interviews said that the methodology achieves its purpose, but it depends on the knowledge of the researcher about organisational semiotics. The validation proposes improvements in the ontologic chart and the identification of changes as a result of new technology.

ISFOSA can be improved, but it is needed the application of the whole methodology to fit with the original purpose to evaluate the artefact in an instantiation.

Chapter 6

Case Study Two: Enhancing the IS Flexibility by Applying Organisational Semiotics and Autopoiesis

This chapter uses ISFOSA method to propose a tracking system in underground mines. The needed IS will use a new technology named Visible Light Communication (VLC), which is in an early stage, requiring a design that allows changes in the IS. For this reason, this case tests ISFOSA as a method to enhance the IS flexibility by the proposition of requirements for IS flexibility. These requirements use the strategies identified in the literature review, and the norm dependency is briefly discussed.

6.1 Justification of the Case

Tracking systems in underground mines is a milestone in the optimisation of processes and the safety of mines. Several types of research have proposed techniques for tracking with radio frequency (RF) (Iturralde et al., 2013; Wang and Cui, 2013), but they have shown limitations such as low transfer rate, short covering range, low quality of the signal and risks in a high concentration of gas (Ranjan and Sahu, 2014). For this reason, new methods based on Visible Light Communication (VLC) can avoid the current problems of radio frequency and provide a new platform to implements the current methods of tracking (Iturralde et al., 2017; Krommenacker et al., 2016). However, this technology is in an early stage, and the research team expects to develop several prototypes before releasing a stable version of VLC devices for mass production. For this reason, every proposition of an information system, using this technology may change in the short term. Additionally, the implementation of this technology can impact an underground mine in the following form.

1. New business / strategic development: This technology can automate some processes in the extraction of copper, concreting the intention of the stakeholders. However, the lack of reliable technology to communicate has restricted this strategy.
2. Technology: Certainly, VLC is a change in the technology of communication of the mine, which can trigger new technological changes.
3. Organisational Changes: The implementation of this system will trigger organisational changes in the monitoring and control of miners in underground environments.

4. Government/legal changes: This activity is highly dependent on the government for three reasons. Firstly, the government is one of the owners of the company. Secondly, some initiatives of the government can provide funds for research in the development of new systems and devices. Thirdly, the government controls the regulations of safety, having the power to change them.
5. New policies: Every activity of underground mines should follow the regulations of the government of Chile. Currently, the policies involved are related to safety for underground mines and management of explosives. A change in one of these regulations will change the activities.

Therefore, this case tests an artefact to help with the design of an IS with flexible capabilities. The research question that addresses this case is How to develop IS with flexible capabilities? The following sub-questions are directly related to the case, and for each sub-question contains a set of questions that can address the data collection and the development of the proposition.

1. What is the current state of tracking people in underground mines?
   a) Why is needed tracking people in underground mines?
   b) Is there any restriction?
2. How is the tracking of people implemented in the case?
   a) Is there any information system already implemented for this purpose?
   b) Can we find any system (manual or automated) involved in the tracking of people?
3. How can we address the design of an information system with flexible capabilities?
   a) Can the proposed method identify the need for IS flexibility?
   b) How should the information system support this capability?

6.2 The Context of the Case

Chuquicamata, one of the most significant copper's mines in Chile, will change its production to underground mines in the year 2020, building new tunnels and infrastructure (Olavarría et al., 2015). Figure 6.1 shows a transverse section of the tunnels in construction, the left side of the picture is the current open pit copper mine of Chuquicamata. The right side shows an example of the tunnels, their ventilation and transport ways.

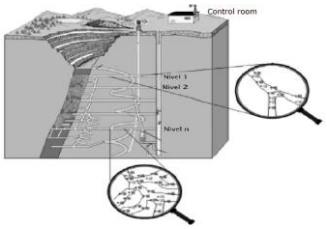

Figure 6.1 Transverse section of the Chuquicamata and their plan to open tunnels

Chuquicamata wants to automate the extraction of copper to the year 2030, but they need to implement a feasible system of tracking and communication Chuquicamata only controls some critical points such as the entrance the tunnels, or in some branch inside the tunnels. These controls are mainly manual, where the only electronic access is in the entrance to the tunnels, which control the access with electronic gates connected to an isolated system. This system is isolated, and it contains the people allowed to enter, and a log with the entrance and exit of them. Chuquicamata has not been able to implement feasible IT systems for tracking people, because the current technology of communication such as communication has a limited range for underground mines, and the main problem is the loss signal when the receiver is travelling into the underground tunnels far from the surface (Gao et al., 2016). Visible Light Communication is a technology developed in the last years for different purposes such as transport, indoor environments and health. The applications of VLC in transport and vehicle awareness can diminish the fatalities, combining the data collected from other vehicles and traffic infrastructure (Cailean and Dimian, 2017). In indoor environments, VLC can provide access to remote applications (Schmid et al., 2016), and can track people and transfer data in E-health applications (Abdaoui et al., 2016).

The VLC is not just a technology of communication, but it can provide a platform for the Internet of Things (IoT). As a communication technology, it can replace the technology in specific contexts of underground mines. As an IoT technology, it can enable the development of new devices of IoT, taking advantage of the current prototypes of VLC. Tracking people with VLC is a starting point for a smart environment in underground mines, but the division of tasks in modules and a central unit may simplify the complexity of tracking several people and machines at the same time. Getic Lab has implemented prototypes of VLC for the automation of access points to underground mines. Figure 6.2 shows the prototypes developed by the Getic Lab. The left picture shows the sender device that sends data using the light attached to the helmet. The right picture is the receiver that perceived the light, translating the light into information.

Figure 6.2 Sender and Receiver prototypes for VLC

Getic lab wants to develop new prototypes to use the concept of access control inside the tunnels, extending the use of VLC to track people and to control robots shortly.

6.3 The Approach of the Case Study

The first case uses the first two phases of ISFOSA to identify the boundary of Rolls-Royce, and potential dynamics from external agents that can trigger changes in the IS. The role of externals agents such as universities and the government showed potential restrictions that affected Rolls-Royce during its change. For instance, the policy implemented by the government to classify and minimise the suppliers improved the process of supplier's management. Additionally, the case one illustrated that Rolls-Royce implemented several strategies to maintain its boundaries such as the forecast of failures, the management of suppliers and the research with universities to maintain the flow of skilled employees. Some of its strategies showed feedback loops to maintain the affordances, which includes a form of external agents' selection, and a form of monitoring of the affordances in the boundary. For instance, the affordance involved in the interaction with suppliers (delivery) required a selection of the supplier, and this affordance (delivery) is monitored. Thus, the affordances of the boundary are as crucial as the affordances that maintain the boundary, using feedback loops to select and discard the agents involved in these affordances.

However, the analysis of the boundary is only a part of the methodology that identifies potential norms that can restrict or enable affordances from the organisation. The validation of the case one addressed the improvement of ISFoSA, which includes the analysis of boundary and the proposition of strategies to guide the design and the implementation of the system. The approach of this case uses ISFOSA methodology to assess if the concept of legacy systems and the strategies for IS flexibility can enhance the flexibility of the IS.

The information was coded mainly to identify agents (stakeholders), restrictions, conditions, actions, pre-condition and post-conditions. Appendix B explains the source of information such as the law from the Chilean's government, protocols, safety instructions and interviews. Additionally, the interviews were coded in themes to understand the current situation. The following table shows the sources of data to develop every phase.

Table 6.1 Source of data of case two

Phase	Source of Data
1	Interview with the research team
2	Documents from the organisations and laws
3	Documents from the organisations, laws and the research team
4	Research team and observations
5	Observations

The data was processed in the same form of the previous case, identifying the components such as agents, affordances and norms to perform the analysis.

6.4 Results

ISFOSA contains five phases, which can go back to repeat one of the previous phases. The results are shown for each phase, but every update of a previous phase is placed as a part of the current phase.

6.4.1 Phase 1: Problem and Context Identification

The problem and context identification included interviews to understand the current situation of the access control in Chuquicamata for underground mines. The company does not have any tracking system in underground mines, and the available technology does not work correctly in this environment. However, the company has a control access system that contains physical barriers (gates) connected to an IS close to the gates. This system for control access is isolated from other IS, so this system depends on humans to register ID cards (which use RFID technology) and the information of the miners. Additionally, the current situation in Chuquicamata is:

- Currently, the underground mine is not operative, and the tunnels have a few kilometres.
- The access to the tunnels is highly controlled and has to follow the current regulations.
- The interviewees needed to take 12 hours of training before visiting any tunnel. Miners should take more extended training.
- This training is required and regulated by Sernageomin (Servicio Nacional de Geología y Minería) (National Service of Geology and Mining).
- Inside the tunnel, the miners have to sign a document with the date, time and the person who entered into that section of the tunnel. This method is the only method to "track" people inside the tunnels.

Sernageomin is the entity of Chile that regulates the operation and safety of the mining industry, and it is in charge of the ministry of Mining (Chile, 2018). This entity supervises all the activities related to the safety of mines, following regulations in the document named "Mining Safety Regulation" (Reglamento de Seguridad Minera) (National Library of Chile, 2013). Additionally, Sernageomin publishes statistics of the accidents in the mining industry every year, providing a summary of the accident's causes and potential solutions to avoid them. The last report about fatal accidents showed that underground mines have the highest

number of fatal accidents in the last four years (Sernageomin, 2017). The following causes of accidents have the highest number of fatalities, and they can show where the system should emphasise the safety.

- Accidents for high falls (Caídas en Altura): Chilean's regulation defines as a high-risk activity every activity performed on a surface higher than 2 meters. According to Sernageomin, every miner that work on a high surface needs special equipment such as a harness and a safety rope, and a complete health's check every three months. Only the direct supervisor of a miner can authorise this type of activity, and he/she should write the authorisation in the journey diary of the mine.
- Accidents for trapped limbs (Aprisionado): This accident occurs when a machine traps a part of the body of a worker. There are several potential sources for this accident, but it is needed to inform the shift manager or the occupational safety chief.
- Accidents for boulder's fall (Planchón): An accident for a boulder's fall occurs when part of the walls or ceiling in the mine fall. There are several causes for this type of accident, but the following procedures can avoid them:
    - Regular checks of the structure, fortifying weak spots.
    - Implement and follow protocols when an explosion is triggered.

One of the duties of every mining company with underground tunnels is the generation and maintenance of maps with risk spots, showing robust infrastructure and risk zones. Additionally, the shift manager must approve the access to a risk zone.

- Accidents for rock blasting (Tronadura): Rock blasting procedure is one of the most hazardous procedures in underground mines because it is needed the use of explosives. The protocol of rock blasting includes:
    - A strict plan, which includes the affected zones and the path of the explosives.
    - A person certified by the army in charge of the explosive.
    - A supervisor in charge of the blasting, which checks the plan, the required signs, and the access to the zone.
    - Workers must check the zones involved in this process, and the adjacent zones.
- Accidents for lack of oxygen: The lack of oxygen is one of the major causes of accidents in coal mines. For this reason, every underground mine has to check the concentration of oxygen before allowing every access to the tunnel.

This step found the following social legacy system:

- Formal Legacy Systems: the current safety regulation of Sernageomin and the regulation of explosives by the army represents the formal systems. According to the interviewees, the departments in charge of the supervision of these regulations is the department of risk's prevention.
- Informal Legacy Systems: One question from the interview was if the miners have an informal system to protect them inside underground mines. The answer was that miners are not allowed to go alone, and they speak through the radio when they are moving to another zone.

Table 6.2 shows potentials stakeholders of this macro-analysis, their roles and responsibilities.

Table 6.2 Potential Stakeholders

Stakeholder	Category	Responsibility
Mine	Owner	Part of the society that produces copper, following the regulation of the local government.
Department of Risk's Prevention (DRP)	Actor	Department in charge of makes, modify and delete the safety norms to achieve Sernageomin's regulations.
Department of Information Technology, Telecommunication and Automation (DITTA)	Actor	This department is in charge of the current information systems. In this case, it is the department responsible for the current Information Systems.
Superintendencia de Geología y Minería (sernageomin)	Bystander	Department of the Mine's Ministry, which can propose and supervise the safety regulations for underground mines.
Miner	Actor	This actor has to follow the norms and regulation of the company. The miner has access to a set of zones, which can be granted by a direct supervisor. The miner is allowed to a set of activities and can use a set of machines.
Planner Engineer	Actor	The person responsible for the risk's zones, and the blasting plan
Shift Manager	Actor	The person in charge of Access to the mine. He/she is in charge of the coordination for maintenance and emergency protocols.
Blasting Supervisor	Actor	The person in charge of accesses to blasting zones.
Occupational Safety Chief	Actor	He/she can give or remove attributions to the miners. For instance, if a miner did not pass the health test to work on high surfaces, the Occupational Safety Chief can remove attributions to perform some activities.
Local Information System	Actor	From the problem situation analysis, the local system can change their capabilities, acting and controlling devices in the future.

6.4.2 Phase 2: Boundary Analysis

The interactions related to the process of tracking people and the control access lead the semantic analysis. Figure 6.3 shows the boundary affordances of the mine, focusing the analysis on the identification of the interactions between the mine and the Sernageomin. The Department of IT, Telecommunication and Automation (DITTA) manages the current information system that controls the physical gates of the tunnel's entrance. The department of Risk's prevention maintains the norms of safety, which follow the safety regulations. Figure 6.3 emphasises the affordances of miners, which can work in tasks and have access to defined places. The underground tasks occur in certain places (not every place in the mine is underground), where the shift manager can give or remove authorisation to these places.

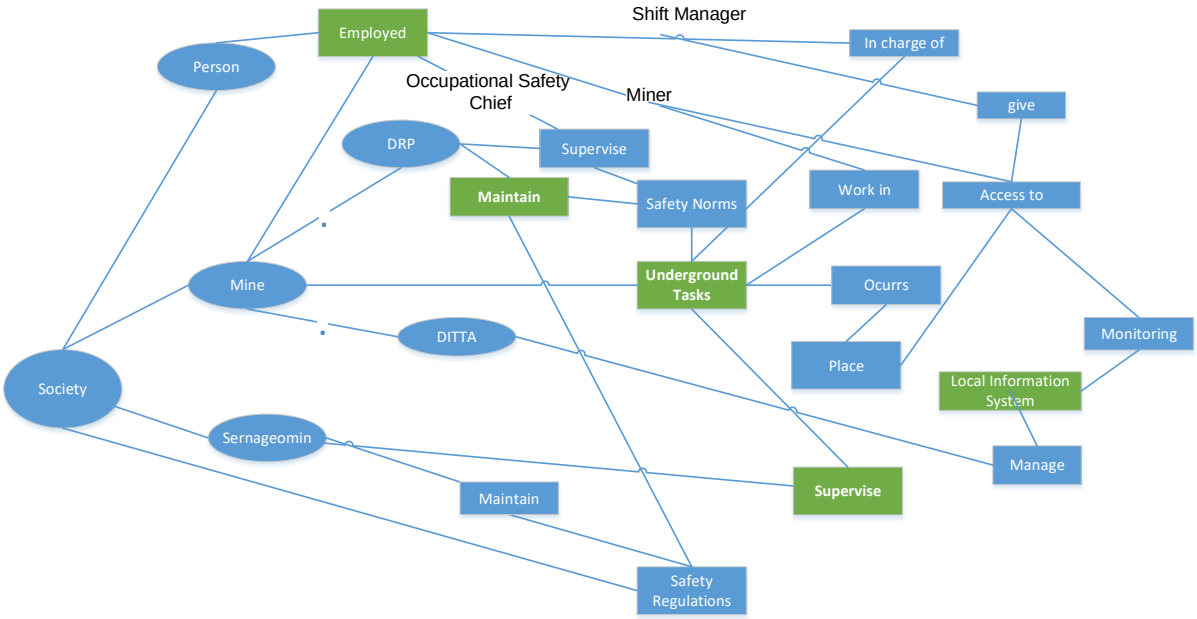

Figure 6.3 Ontology Chart of the interaction between the mine and Sernageomin

Figure 6.4 shows the interaction with the army because they are in charge of the certification of explosives management. A blasting supervisor is in charge of the rock blasting tasks, so he/she has to be certified for the management of explosives. Blasting tasks is a type of underground tasks, so it contains the same links, but the person in charge is different.

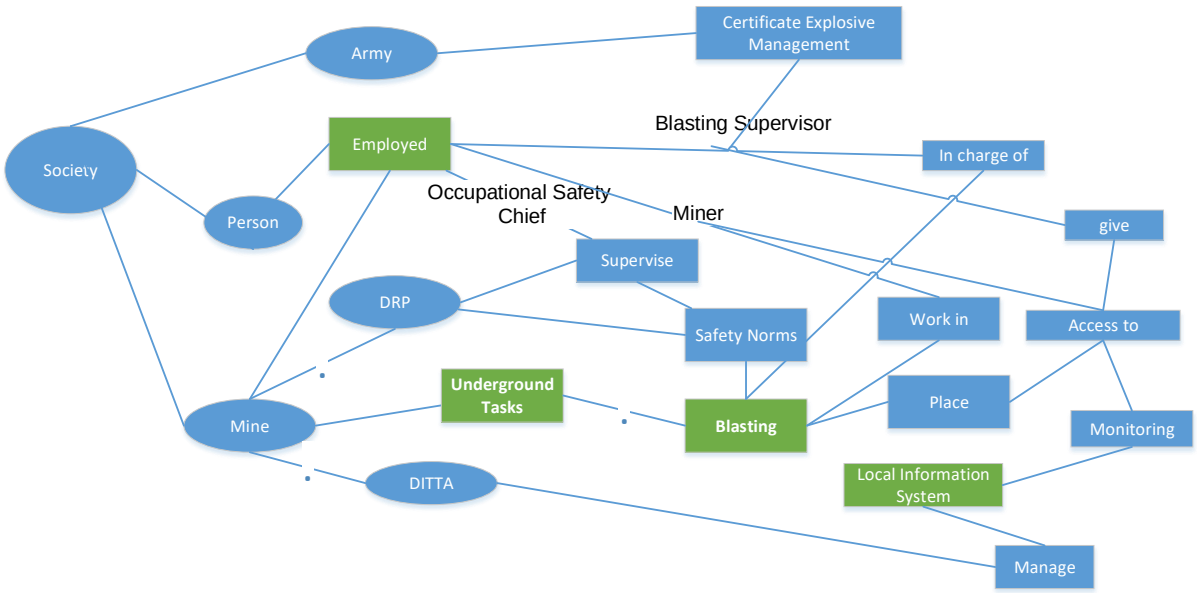

Figure 6.4 Ontology Chart of the interaction between the mine and the army

In this case, the following affordances where identified as boundary affordances:

- Maintain Safety Norms: This affordance interacts with the government's regulation.
- Underground Tasks: This task is supervised by the government regularly. In case of an accident, it is needed to report every detail to the government.
- Employed: HHRR of the company is in charge of this affordance.
- Local Information Systems: DITTA is in charge of the management of information systems. This department may be in charge of the implementation of a new system, and this system should adapt to new technologies.
- Blasting: This affordance is similar to the underground task affordance. The change in the ontology chart can indicate that a context rules every activity in underground mines.

6.4.3 Phase 3: Focal System Analysis

The system that controls the gates to give access to the tunnels is a technical and isolated system. The interviewees pointed out that the related area or department in charge of this system is the Department of Information Technology, Telecommunication and Automation (DITTA) (Departamento de Tecnologías de la Información, Telecomunicaciones y Automatización).

The focal system analysis examines the agents and affordances involved in the control of access, so it is needed to extend the analysis of this affordance to understand potential agents. Figure 6.5 shows a summary of these affordances.

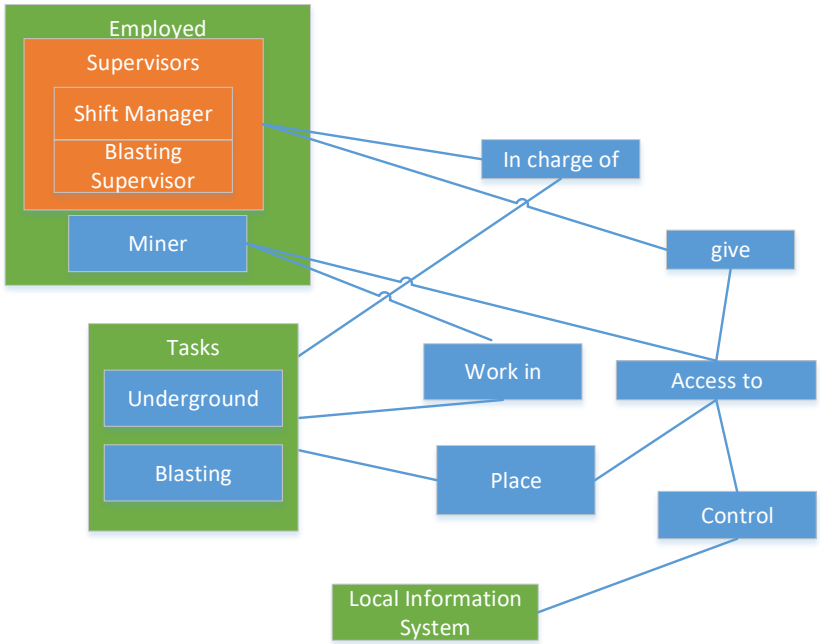

Figure 6.5 Affordances Related to the Control Access

The ontology chart on figure 6.5 can show that the management of profiles is needed for the system, because it can grant permissions to access to certain places, doing a set of tasks. Additionally, a task can have types of tasks, changing access to a place. The following table shows representative norms related to the control of access.

Table 6.3 Representative Norms of the Control of Access

ID	Whenever	If	Then	Is	To	Pre
1	A new worker is added to the system	The miner pass the training and the health requirement	Shift Manager	Permitted	Give access to a place (tunnel)	
2	A miner is entering the tunnel	The miner is granted access	Information System	Permitted	Open the gate and record the date and time	1
3	A miner is entering the tunnel	The miner is not allowed to enter	Information System	Obliged	Deny the access (No open the gate)	1

However, the context can change the agent in charge to authorise accesses in the system. For instance, the authorisations given by the shift manager to access a zone are not the same

when a rock blasting is occurring. Thus, the context of the environment is a potential actor that can change the norms.

6.4.4 Phase 4: Identification of Flexibility

Affordance Assessment

The phase 1 identified norms from the environment that can change norms or affordances of the system. The norms identified in table 6.4 are affected in the following form.

Table 6.4 Analysis of the norms of the boundary and the norms of the focal system

Macro-Norms	**Norm**
Maintain Safety Norms	Norm1 these safety norms can change the agent that can grant access to the mine
	Norm1 these safety norms can change the requirements of health (the condition)
Underground Task Regulation	Norm1 these safety norms can change the requirements of the training course (the condition)
Rock Blasting	Norm2 and Norm3. In the case of blasting, the privilege to Access to the tunnel change, allowing only the right people for this case. The concept of the right people is a requirement of the army.
Technology	Currently the system open gates, but in the future, it should track people in real time, using VLC.

The company can grant access, update the requirements and control the access to the mine in case of blasting. Then, the design of the IS should also address the possibility to represent context for the access, because the blasting can change who can enter the mine.

Scenario Analysis

This scenario analysis covers potential changes from changes in the regulation of rock blasting process. The analysis of the regulation of rock blasting can show that the tunnel can have states that depend on the current process, so the analysis should consider the following issues.

a. The environment should act. When the Information System is controlling physical things, it behaves as a new actor.
b. This actor should take decisions according to the context.
c. The authorisation to a zone depends on the context.
d. The context of the zone means that the zone has states.

Figure 6.6 shows an example of this situation, for instance where a miner can have access to a section of the tunnel that is in a normal function and another section, which is in a rock blasting process. The led represents the VLC device that receives data from the miner to check his / her authorisations to different sections of the tunnel in a central system.

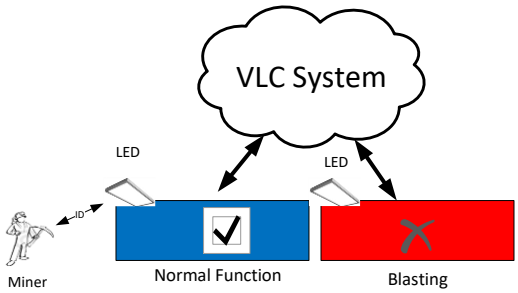

Figure 6.6 Example of VLC Access

The identification and tracking of people have been proposed by trilateration (Iturralde et al., 2017) or Cell-ID (Krommenacker et al., 2016), so a potential change is in the technology to communicate and identify the miner. This scenario analyses the case of trilateration with 3 LEDs and a photodetector that is attached to a miner's helmet because trilateration has worked with other technologies such as RFID (Iturralde et al., 2013). Figure 6.7 shows the components needed for the estimation of a location, which needs the position of three known points represented by three LEDs. The photodetector can receive the data from the LEDs, which contain the ID of the LED and its position. The trilateration circle represents a device or circuit with the capability to calculate the position using the formula proposed by Iturralde et al. (2017).

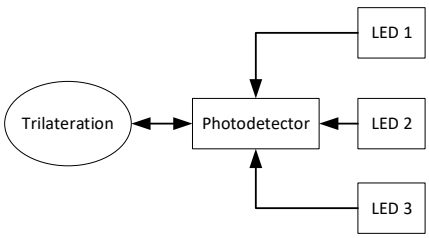

Figure 6.7 Components for Trilateration Estimation

Table 6.5 shows the stakeholders found in the analysis of potential changes that can trigger the implementation of VLC as an IoT device. The zone and the miner device are represented as actors because they can perform actions and they have states.

Table 6.5 Stakeholders from the Scenario Analysis

Stakeholder	Category	Responsibility
Zone	Actor	Represent the environment of the system, and it can have states to show contexts.
Miner Device	Actor	The miner device should receive the data to estimate the miner's location. Additionally, it can control potential hardware.

Figure 6.8 updated the ontology chart of figure 6.5, showing the relationship between the zone and the devices. Additionally, the machine is put as an affordance, because they can work on zones autonomously soon. The ID and state of a zone determine this agent because they can represent a context that evolves in a period.

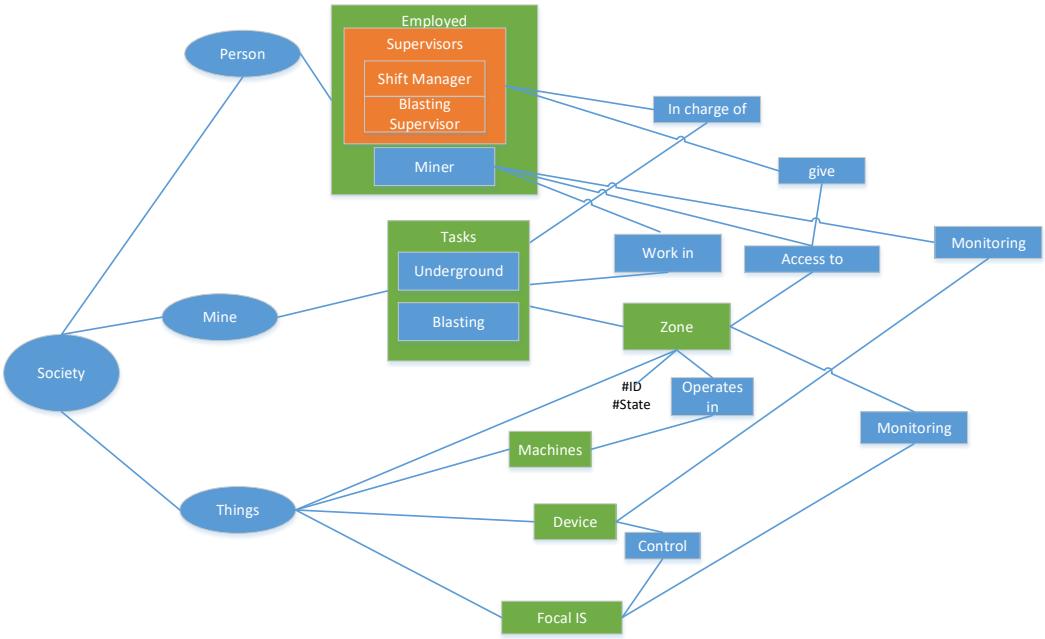

Figure 6.8 Updated Ontology Chart of the Focal System

Table 6.6 updates the norms from table 6.3, which main changes are the representation of zones instead of places, the inclusion of the state as condition, the capability to alert to the shift manager, the capability to monitor zones instead of controlling them.

Table 6.6 Updated Norms from the Scenario Analysis

ID	Whenever	If	Then	Is	To	Pre
1	A new worker is added to the system	The miner pass the training and the health requirement	Shift Manager	Permitted	Give access to a place (tunnel)	
2	A miner is entering a zone	The miner is allowed to access to a zone in that state	Information System	Permitted	Give access to that zone	1
3	A miner is entering a zone	The miner is not allowed to enter to that zone in that state	Information System	Obliged	Deny the access and send an alarm to the Shift Manager	1

IS Flexibility Requirement

This section should address three types of requirements. The first and second types of requirements are functional and non-functional requirements from the stakeholders. The third type of requirement links the strategies of IS flexibility with functional or non-functional requirements to design and implement in the following phase. These last requirements (and strategies) should address potential changes, and provide IS flexibility to the system.

The requirement derivation from organisational semiotics follows the same deductions process made by Liu (2005), which includes the deduction of domains, system components, artefacts and norms.

- Deduction from domains: The domain where analysed in two parts. The first part analysed the organisational domain to identify potential sources of changes. This domain showed that the access control should cover the tracking of people by zones. These zones are significant for specific operations such as blasting, which can cover several zones, but it should not cover the whole mine. In the focal system domain, it was identified meanings such as “access to”, “monitoring”, “give access”, “in charge of” and “control of a device”.
- Deduction from system components: The analysis of the system components identified the current system that controls the gates. However, this system does not interchange information with the company system, which already has the information about the miners. The design should consider a potential connection with the central IT systems to access this data.
- Deduction from artefacts: The current artefacts are the identity cards of the miners, stored in the company system. A local system only registers the RFID tag of the cards and the name of the miner to grant access to the tunnel. The security gates of the tunnel read the cards and check with the local system. The system does not alert to somebody, because the gates are a physical barrier, but in the implementation of control access by zone, it is needed to alert to somebody.
- Deduction from norms: The shift manager must grant access to the tunnel to a miner, depending on the health and safety requirements, and the training courses. Each time that a miner wants to enter the tunnel the system must check the access of that miner to a specific zone in a specific state.

Additionally, table 6.7 assess every IT attribute for IS flexibility, describing potential problems and strategies that can improve the flexibility of the system.

Table 6.7 IS Flexibility Assessment for the Focal System

IT attribute (purpose)	Potential Problem	Strategy
Compatibility (Share platform)	The system will need to share information with the system that contains the miner's data	The system should store the data in a central unit, following standards to share data such as XML and web services at the data level.
Modularity (Change of functionality)	The control of access and the tracking of miners could derive to machines, adding new functionalities.	The high probability to change some of the functionalities suggest the implementation of the identified strategies in each level (data, process and interfaces)
Connectivity (Communicate)	The system will need to extend the connection with other systems and devices	The development should cover strategies of flexibility in every layer
Scalability (Growth)	The system will need to absorb new zones, miners, potential machines and devices	The scalability is needed in the level of interface, because the dependency of laws and regulation may change the responsibilities of users.
Continuity (Affordance Continuity)	A change in the interfaces (sensors) will change the continuity of the system.	Different versions of devices can bring problems of continuity, but in this case, the devices should use abstract representations. Processes and the data should not change.
Rapidity (Fast delivery of Information)	This factor is critical in case of an accident, so the technology of devices should be fast, and the system should have high-speed connections	VLC devices should be used at a local level by zone. Optical fibre should connect zones and a central unit
Facility (Easy to use)	New devices or developments should understand the system and the current technology	The implementation of new devices and IS should have manual and enough documentation
Modernity (Disposable Technology)	There is no form to guarantee that the system is modern, but new releases of the system and the devices should be considered	The prototypes and the design of the system should consider maintenances and update of hardware and software

The following requirements can be identified from this analysis

Goal: Track people and machines in underground mines

Sub-Goal 1: Manage Zones

Sub-Goal 2: Manage Contexts

Sub-Goal 3: Manage Miner's Profile

Sub-Goal 3.1: Add, delete, and update potential tasks

Sub-Goal 3.2: Add, delete, and update access to zones in a specific context

Sub-Goal 3.3: Add, delete, and update roles

Sub-Goal 4: Manage Miner's Roles

Sub-Goal 4.1: Add, delete, and update roles and responsibilities

Sub-Goal 5: Manage Devices

Sub-Goal 5.1: Add, delete and update devices

Sub-Goal 5.2: Add, delete and update devices in a zone

Sub-Goal 6: Provide IS Flexibility

Sub-Goal 6.1: Use standards such as XML and web services to share data

Sub-Goal 6.2: Use abstraction in the data objects and sources

Sub-Goal 6.3: Use abstract representation of processes

Sub-Goal 6.4: Use objects to coordinate other devices

Sub-Goal 6.5: Use of optical fibre to connect devices

Sub-Goal 6.6: Use protocols of documentation

These requirements can address the design and implementation of the system. The sub-goal 6 contains mainly non-functional requirements that should be part of the design and implementation of the system.

6.4.5 Phase 5: Design and Implementation

The requirements from the previous section push the design to modular components, putting the environment as an active agent in the system using devices that can act or sense. Additionally, it is needed to provide abstract layers to represent zones, coordinate devices, represent miners and machines.

From the work of Qiao, Liu, and Guy (2007), and Huang, Liu, and Gulliver (2011), it is possible to define four kinds of agents for intelligent buildings: Central agents, local agents, Monitor and Control (MC) agents, and personal agent. A central agent receives inputs from users, organise the goals of the whole systems, and control local agents. Local agents oversee a zone, receive messages from central agents and decide an activity according to the current context. MC agents can communicate with the hardware of external devices, enabling the control of these devices from the system, and wrapping the form of sensed data. Personal agents can interact with the occupants of the building, acting to the system as an MC agent.

This classification is useful for underground mines because it considers that personal, monitor and control agents can be moved from one zone to another.

Figure 6.9 shows an early description of the system (Fuentealba et al., 2017), where people and machines can be a sense in every moment, using VLC technology.

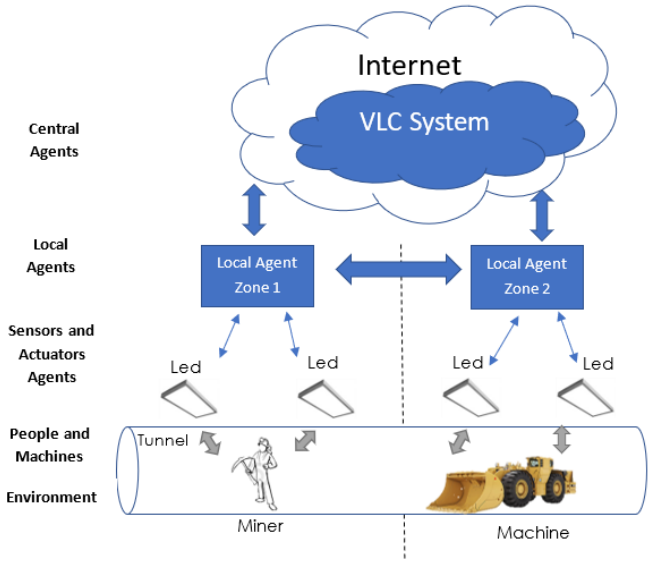

Figure 6.9 Description of the System with VLC

The following classification of agents are proposed:

Environment: This agent represents the environment and how states in the environment can affect several zones, people and machines. For instance, the condition of the environment can change the mathematical model that represents the channel of communication in VLC (Iturralde et al., 2017).

Sensors and Actuators: In this example, the sensor represents the photodetector that receives the pulse from a sender. While the LEDs are the actuators that send specific information. The form of communication (VLC) is restricted to the logic of the agent, which can need specific information such as the channel, to understand the difference between pulses or not in the light.

Local Agents: In this example, a local agent is an agent linked to a zone in the tunnel, which at the same time can coordinate the lights that need to be turned on. However, in a complex system, this local agent can be split in two. The former with the responsibility of the management of the zone, receiving the orders from central agents. The later in charge of a set of services. For instance, localising people in the tunnel, where a coordinator is needed to sense the light from the photodetector, while the LEDs are controlled to transmit information. Figure 6.11 shows the flow of communication among agents, where a local agent can manage and control a set of sensors and actuators to achieve a function (or service).

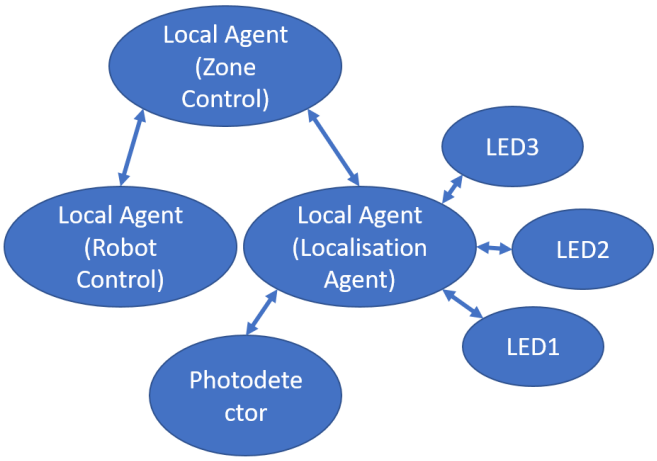

Figure 6.10 Graph of communication of local agents with several functions or services

Central Agents: In this example, the central agent can link the information of the whole system, showing in real time where people are. The localisation is proposed for safety purpose because, in case of an accident, the location of people is a significant factor. However, this model of agents can be extended to control the access of miners to specific zones. The following norm represents this proposition (the second norm in table 6.4):

Whenever A miner is entering the tunnel

If The miner is authorised

Then the Information System

Is Permitted

Figure 6.10 shows a graph of communication among the proposed agents to describe the system.

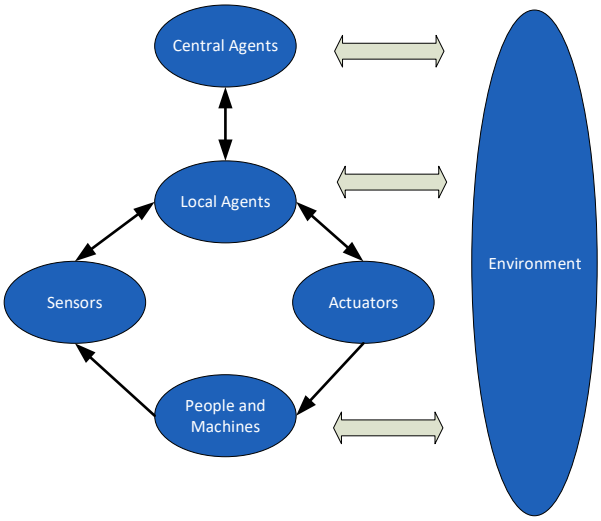

Figure 6.11 Graph of communication among agents

The detection of a miner entering to the tunnel can be analysed with a scenario of three LEDs in known positions inside a tunnel of 6m of length, 6m of wide and 5m of height (Iturralde et al., 2017). The feasibility of the first part of this norm (the identification of a miner) is tested with the construction of a prototype that can run on the devices built by Getic Lab for VLC. These devices were built with Raspberry Pi to send data from LEDs and read them with photodetectors. It is possible to design and build agents with different approaches such as biological agents and rational agents. In this example, the well-known belief-desire-intention (BDI) agent model can implement a system with agents, because there is an extension of the platform JADE for BDI model named JADEX. This platform is programmed in Java, which ensures the compatibility in several architectures such as Windows, Linux and Raspberry. These technologies provide a quick environment to construct and test applications based on agents. Figure 6.12 shows, the first part of the analysis of the agents, which consists of the agent identification and its initial interaction. Localisation Agent is a local agent that can run on the central system or in intermediate nodes, with a medium capability of processing such as Raspberry Pi. This agent is responsible for obtaining and updating the position of a person in central servers. VLC agent encapsulates the access to the devices that send and receive data, but the environment (or its representation in an agent) can affect them. Person agent is responsible for calculating the localisation of the person, using the trilateration technique. Additionally, it was defined the agents that interact in the device attached to the miner, which include at least the VLC agent to process the signals that receive and send the data.

Figure 6.12 shows the interactions of the “person” agent when the localisation agent needs the position of this agent. However, the task “Calculate Localisation” can be demanding, because it depends on the availability of the VLC agent.

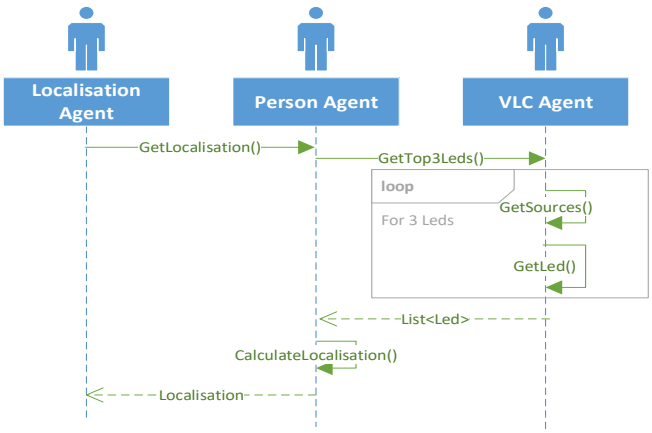

Figure 6.12 Interaction of agent person with VLC agent to calculate the Localisation

For this reason, this prototype took advantage of the JADEX platform splitting the task in the following the form:

- VLC Agent: An agent implements a service to provide three LEDs with the strongest signal. A plan is triggered every time that the service “GetStrongestLed()” is called. This plan set up the configuration of the photodetector, but in this prototype is used as a control.
- Person Agent: It is a persistent agent that know (or want to know) its localisation. For this reason, the localisation is a belief for this agent that trigged every 10 seconds the “CalculateLocalisation” method.

Figure 6.13 illustrates the flow of interactions between these agents. The localisation agent and the VLC agent have direction connection between them. The dotted lines between VLC agent 1 and VLC agent 2 represent the interchange of information through vLC.

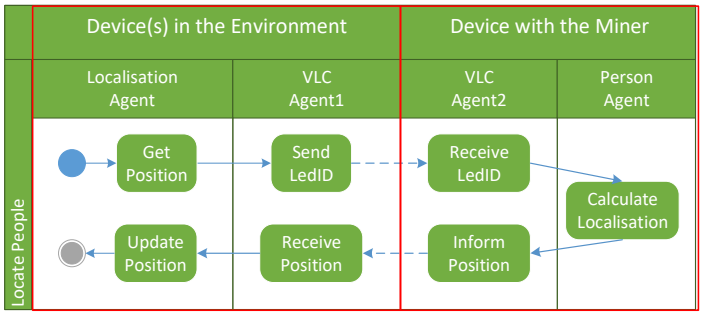

Figure 6.13 Agent Identification

Although JADEX implements FIPA Message Structure and rich event system to interchange information among agents (GmbH, n.d.), this prototype took advantage of the service architecture for agents, simplifying the communication.

6.5 Discussion

The identification of boundaries of this case, using the concept of legacy systems can help to the development of new technologies. These new technologies can change the form of interaction in the system, providing new affordances to the organisation. However, the analysis based on the “human legacy systems” can address the implementation of new technologies without harming the organisation.

6.5.1 Designing information systems with flexible capabilities

The concept of flexible capability wants to guarantee a potential change. Indeed, phase 4 suggests good practices of construction such as modularisation and the functional division. However, the maintenance of the affordances in the boundary restricts the IS flexibility. For instance, a miner can enter a tunnel if he / she was granted with access to the tunnel. The government of Chile required training and health conditions to grant this access, depending on this norm to the regulations of Chile. A change in this law can change the agent responsible for giving or removing authorisations a location. The following dependencies can be found in that norm.

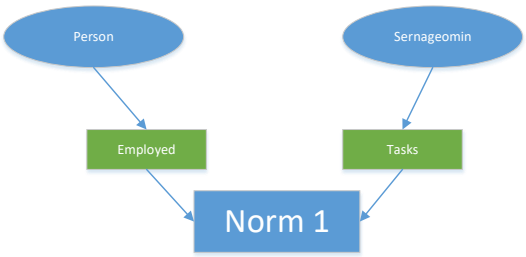

Figure 6.14 Norm and affordance dependency

This dependency shows that the definition of employed and tasks should follow a pattern of generalisation for the development of information system because it can minimise a future change. This pattern of generalisation addressed the proposition of goal 4, which should manage the roles and responsibilities. If the implementation of the system considers this goal, the agent that grant access can be changed without altering the IS. Additionally, the proposition of non-functional requirements of IS flexibility addressed the design to use patterns of smart environments to provide layers of abstraction.

6.5.2 The Autopoiesis of Organisations and the IS flexibility

The concept of affordances of organisations can address the identification of the autopoiesis by the identification of the boundary affordances. The ontologic charts can provide a mechanistic view of the organisation, where the affordances cannot exist without the connection of other affordances or agents. These connections are the ontological dependency that can show a dependency to produce meanings and affordances of the organisation as a form of autopoiesis of organisation.

The application of ISFOSA to the current case identified the following elements.

- Boundary Affordances: a boundary affordance is an affordance that makes a difference between the organisation and the environment. Examples of this kind of affordances are employed and supervise, which are potential actions that the

organisation can perform in the environment or an action that a stakeholder can perform in the organisation.

- Affordances and agents: The set of affordances and agents from that belong to the organisation because of this definition of boundary. The boundary affordances at the same time depend on them because the boundary cannot exist if they do not belong to the organisation (ontologic dependency).
- Environment: Agents and affordances that do not belong to the organisation. They can perturb the organisation, receiving compensation or response as a part of this compensation.
- Structural coupling: A set of perturbation and compensation that are recurrent from the environment. This kind of interaction can be found in the norm of the affordances, which defines under which context the affordance can be performed.

Figure 6.17 shows a diagram of the proposed form of autopoiesis of organisation that contain the identified elements.

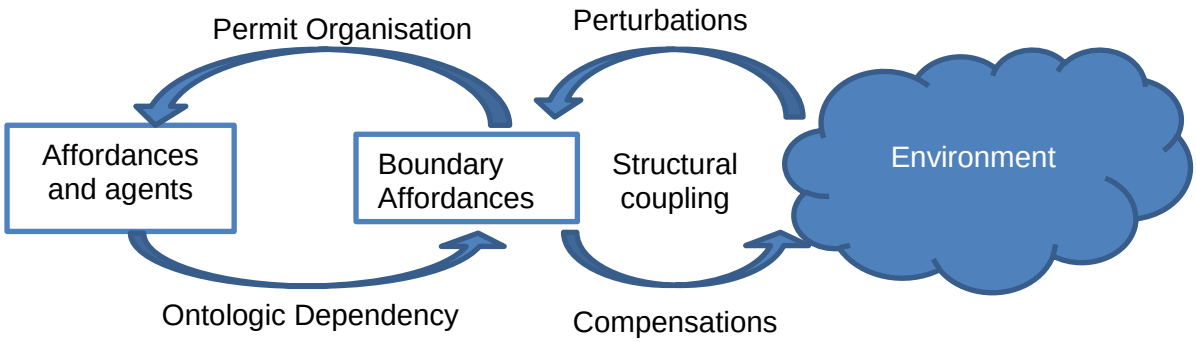

Figure 6.15 Autopoiesis of Organisation

From the side of information systems, these affordances produce information, and the norms of the organisation restrict them. These affordances are the representation of events that the autopoiesis of information systems should support.

The need of IS flexibility relies on the identification of the structural coupling of the organisation with the environment. Social theories such as the functional systems proposed by Luhmann can address the identification of potential changes because they can affect the norms of the organisation and the ontological dependency.

The strategies of IS flexibility can address the development of the information systems, providing flexibility by the enhancement of the structure of the information system. However, this enhancement is not blinded as the current approaches, which propose the abstraction of software components without a clear need for it.

6.6 Validation

Similar to the case one, the validation assesses the method as an artefact, examining if the goal, the environment, the structure, the activity and the potential evolution of the artefact is coherent with use and purpose. These factors are adapted from Prat et al. (2014) and showed in table 6.8.

Table 6.8 Factors to assess ISFOSA

Factor	Description
Goal	The goal is the enhancement of IS flexibility for a system to track people in underground mines. The following question tests this goal. Do you think that this method can be useful for the enhancement of IS flexibility for a system to track people in underground mines?
Environment	Do you think that potential users (professionals and academics) can **understand** this artefact? Do you think that this method **is ease to use**? Do you think that this method is performed **ethically** right? Do you think that this method can have any **side effect**?
Structure	Do you think that this method is **complete**? Do you think that this method is **detailed**? Do you think that this method is **consistent** with the primary aim? Can this method be defined as **simple**?
Activity	Do you think that this method is **consistent** with every stage? Do you think that this method is **efficient**?
Evolution	Do you think that this method can be **adapted** to another case? Do you think that this method can be **improved**? How?

6.6.1 Goal

In this case, the primary goal is focused on the enhancement of IS flexibility. The interviewees agreed that they understood the affordances of the organisation as the boundary, and they understood the connection with the affordances of the focal system represented by norms. They also agreed that the assessment of IT attributes to enable flexibility to lead the proposition of requirements. For instance, the following statement can be cited “the affordances as the boundary was understood, and also how they affect the norms of the focal system. I agreed that potential changes could be addressed as part of the analysis, but their requirements need a deep understanding of software development”.

6.6.2 Environment

The interviewees considered that academics and professionals could understand the method, but they need training in organisational semiotics. Although the concept of macro-norms can address the scenario analysis, the interviewees pointed out some improvement in the systematisation of this phase. One of the interviewers said, “Although the diagrams can be understood, it is needed the understanding of organisational semiotics to follow the method”.

6.6.3 Structure

The interviewees suggested an improvement in the scenario analysis because the identification of requirements needs several assumptions. They said, “It is needed to formalise the translation from the diagrams to requirements”.

6.6.4 Activity

Interviewees understood the connection between the stages and the main aim, so the consistency is right. They agreed that the method could identify requirements of IS flexibility so that the IS flexibility can be enhanced. They said, “The flow of the steps seems fine and simple, but the identification of potential scenarios for this technology required a very close knowledge”.

6.6.5 Evolution

The interviewees agreed on the potential use of this method in other cases. However, their primary concerns are related to the systematisation of phase 4 and 5. They suggested more steps or diagrams, showing when the information system can act in the process.

6.7 Reflection

This iteration instantiates the whole artefact to enhance the IS flexibility of an information system. The following sections reflect about the methodology ISFOSA and the research design as artefacts.

6.7.1 Reflections from ISFOSA

The reflection of ISFOSA analyse the components used in this iteration.

Purpose: The purpose of ISFOSA is the enhancement of IS flexibility. This purpose is ambitious because it should cover every potential change, making unfeasible the development of IS flexibility. This case shows that the analysis of the legacy systems from the society can provide a heuristic approach to enhance the flexibility.

Construct: The main elements of this artefact are the affordances, norms, agents, requirements and strategies for development. The development is part of ISFOSA, but it is needed more cases to include it as a part of the construct because there are several forms of development, which can go further this research.

Principles of form and function: This methodology can identify the components of the construct, but part of the methodology should be formalised, providing official guidelines for the identification of flexibility and the selection of the right strategy for the development.

Artefact Mutability: The interviews suggested the formalisation of guidelines for the phases four and five, which depends on the knowledge of the developer or researcher.

Testable Proposition: The proposition was tested with the instantiation of the case and also the interviews. As a reflection of a testable proposition, the methodology could include agreements of assessment with the potential customer or user. This step was made informally by the presentation and conversation of the results to the head of the Getic lab.

Justificatory Knowledge: A review of tracking systems and VLC systems was included in this case. They were used to develop the prototype.

Principles of Implementation: The principles of implementation are similar to the previous case, but in this case, the development of the prototype only followed the proposed strategies. Principles of prototyping may enhance the methodology.

Expository Instantiation: This case is an instantiation of ISFOSA. The result of this case was shown to the interviews and a functional prototype. The interviewees agreed about the achievement of the purpose and also the construction of a functional prototype.

ISFOSA can be enhanced with its application to other cases because this iteration showed the need for guidelines or the formalisation of the activities performed in the case.

6.7.2 Reflection from the Research Design

The proposed research design is an artefact which can follow the same principles of design science.

Purpose: The purpose, as the design of a methodology as an artefact, did not change through the research because the research gap was identified beforehand. Certainly, the methodology was tested as a part and as a whole, but they pointed out the same aim.

Construct: The main elements of the research design are the identified problem, the literature review, the artefact, methods and the validation of the artefact (the activities of the research). However, the development of a prototype shows a gap in the research design, which are the proposition of guidelines or criteria of assessment of the prototype.

Principles of form and function: The process' flow of section 3 guided the development of each construct. The research was performed without problems.

Artefact Mutability: The process of codification included primary data such as interviews, laws and official documents from the mine, but the access to the personnel who work in the mine was almost impossible. However, this problem is recognised as an external factor of the research.

Testable Proposition: The instantiation is the testable proposition for this research design. A publication from this work was accepted in a conference, improving the testable proposition by the feedbacks of this conference.

Justificatory Knowledge: It was reviewed the main frameworks of design science, proposing the current research design.

Principles of Implementation: The principle of implementation depends on the activity. For instance, if the activity is the codification, the principles are the guidelines for codification.

Expository Instantiation: This interaction has already shown that this research design can help the design of a methodology. However, the time constraint did not allow to iterate again, which could improve some issues of the research design such as the assessment of a prototype.

The research design as an artefact achieves the purpose in this iteration because the case of this iteration achieves the purpose. However, some of the criteria about the construct should be added to another research or new iterations.

6.8 Summary

This chapter conducted a case study, using primary data such as interviews, observations and official documents, and secondary data such as articles and laws. The data was enough to use ISFOSA in a real situation to identify requirements, select strategies for IS flexibility and to build a prototype. The application of ISFOSA can address the enhancement of IS flexibility because it can identify the boundary of the organisation, the boundary of the focal system and how the organisation can impact the focal system.

According to the interviews, ISFOSA is useful because it achieves the enhancement of IS flexibility, but it still depends on the knowledge of the researches, which need to be formalised in official guidelines for the phases four and five.

Chapter 7

Conclusion, Contribution and Future Work

This chapter summarises the research work, the propositions and main findings. This work has been addressed with the research questions and problems stated in the introduction. As a result, this research has delivered a methodology for the identification of the boundaries of the organisation, and proposition requirements to address the IS flexibility. However, the method was focused on the identification of only one aspect of the model, which is considered an essential part to propose/identify the autopoiesis of the organisation. This chapter will conclude the primary factor of the thesis, explaining the main contributions, and future works.

This chapter summarises the research work, the propositions and main findings. The introduction addressed this work with the research questions and the stated problems. As a result, this research has delivered a methodology for the identification of the boundaries of the organisation, and proposition requirements to address the IS flexibility. However, the method focuses on the analysis of one aspect of the model only, considered an essential part to propose/identify the autopoiesis of the organisation. This chapter will conclude the primary factor of the thesis, explaining the main contributions, and future works.

7.1 Concluding Remarks

Chapter 1 describes the background, motivation, aim and objectives of this research. This chapter discusses the lack of a standard definition of IS flexibility, and also the absence of methods to identify and develop it. This research set its scope in the analysis and understanding of IS flexibility, proposing an approach based on living systems and co-design (Autopoiesis) to analyse organisations and potential changes. From an empirical point of view, this research proposes a concept of affordances as the boundary of organisations to identify requirements of IS flexibility. These requirements attempt to enable changes through the IT structure.

Chapter 2 seeks to answer the research questions in the literature, reviewing definitions, factors and methodologies of IS flexibility. From the literature, this work defines IS flexibility as a capability of IS that relies on how the knowledge of the organisation's participants can be included in the design of the IS, to support changes inside and outside the organisation. This definition directed the research to identify strategies of IT structure and the identification of

requirements to support changes. Additionally, this chapter reviews methodologies or approaches that state to provide flexibility to information systems.

Chapter 3 proposes a model of organisation, using the autopoiesis of living systems as a metaphor to describe organisations. The autopoiesis is the capability to maintain the network of processes that keep living things alive. This capability allows the survival of living systems through the changes in the interactions with the environment, but without stopping the autopoiesis. This concept led to the proposition of a model of organisation, components and relationships, but the complexity of the model (almost a fully connected graph) derived in the decision of the analysis on only one component, the boundary. The properties of physical boundaries helped to the proposition of affordances as the boundary of organisations. A methodology based on PAM, SAM and NAM named Information System Flexibility by Organisational Semiotics and Autopoiesis (ISFOSA), drive the identification of affordances of the organisation that define the boundary, and then the need of IS flexibility.

Chapter 4 provides the research's methodology, discussing which research paradigms fit in the current research. This research proposes a methodology that combines the protocols and the activities of case studies with the primary processes of design science. This methodology can address the creation of artefacts, using case studies to test it. This chapter explains the two incremental iterations of the research design, which is focused in the instantiation of a part of ISFOSA to test the concept of boundary, and then the whole methodology.

Chapter 5 is the study of a case to understand, which capabilities or features allow an organisation to survive despite several changes. When Rolls-Royce enhance its services, implemented several changes that can affect the IS. This process called servitisation is a representative case of an organisation that "survived" after several changes. This case tested the proposed methodology to identify affordances as boundaries. As a result of this case, the methodology achieves the aim, the identification of boundaries through the analysis of the affordances that interact with external stakeholders. Additionally, the study found that Rolls-Royce maintains its affordances with internal process based on feedback loops.

Chapter 6 is a case study that tests the application of an artefact in a case of real life. In this case, the proposed methodology to enhance IS flexibility analyses this problem in five phases, where the fifth phase designed and implemented a prototype. This methodology was applied in the analysis of a location system for underground mines, using a new technology named Visible Light Communication (VLC). The methodology conducted the analysis of this case and the proposition of an information system. Although the feedback accepted this method as a form to identify the requirement of IS flexibility, it also pointed out a potential improvement in the scenario analysis.

7.2 Contributions

This research has delivered a theoretical model of organisation and a methodology to identify one of the components of that model. In the following sections, it will postulate the theoretical, methodological and practical contributions of this research.

7.2.1 Theoretical Contributions

The concept of boundary and affordance proposed in chapter 3 can identify where the flexibility could be needed. The identification of the need for IS flexibility can be complemented with the current approaches of flexibility such as Byrd and Turner (2000), and Palanisamy (2012). They have focused their work on the concept of flexibility in the identification of factors to assess the flexibility, but they do not propose where the flexibility is needed, or methods to develop it. This research recognises the subjective perception of flexibility as a consequence of the lack of a standard agreement about its definition. For this reason, this work proposes a definition of IS flexibility linked with the awareness of sources of changes, and the maintenance of the autopoiesis of organisations.

On the other hand, current approaches of autopoiesis of an information system such as Huysman, Blonk, & Spoor (2009), and Bača, Schatten, & Deranja (2007) have not developed any method to address the analysis and design of autopoiesis. Thus, the proposed model of organisation and the methodology to identify the boundary are an initial attempt to cover these two theoretical issues.

7.2.2 Methodological Contributions

This research contributes methodologically by the proposition of a research method, in chapter 4, that combines design science and case study research. The reflection made by design theory shown the following contributions:

- The concept of the purpose of an artefact can address the identified problems from the environment, but they may puzzle the test and enhancement of the artefact. The examples provided by Jones and Gregor (2007) and the initial purpose of ISFOSA address an aim that can be decomposable, at least in the definition of construct and guidelines. For this reason, the definition of an aim and several objectives can help the development of the artefact in iterations with tangible deliverables.
- The constructs should be justified, but they also should be testable. An example in this research is the boundary, which was tested as a concept derived from affordances. The concept of system as differences from Luhmann (2006) can support the construct of affordance as the boundary, but the feedback from the case one provided more insight to improve the construct and the form of presentation.

- Case studies can address the instantiation of design science: the design theory recognises the instantiation as a form of validation of the artefact. Case studies can address the instantiation by the definition of a protocol to maintain the internal validation.
- The case study protocol can be linked with some components of the design theory:
    - Questions of the case study can refine the purpose and the justification of the knowledge: The different levels of questions proposed by Yin (2009) can improve the purpose of the artefact in the current instantiation and also refine the knowledge used of the artefact, and the context of the case.
    - The context of the case can provide the principles of implementation: The context of the case can define the features of the current instantiation, providing principles of implementation of the artefact.
    - The approach the analytical method and the data collection procedures of the case can provide principles of form and function: The approach to the case can define how the artefact (or idea to test in the case) should work and how to get the data to build instantiation. These procedures can define the principles of form and function of the artefact.

Case studies can provide methods and components for a design theory, and also it can guide the process of instantiation to test the artefact. This research took advantage of this benefit to instantiate part of the artefact, which is significant to test the construct of the artefact. This strategy can minimise risk for research.

7.2.3 Practical Contributions

The practical contribution is given in the proposition of a methodology to analyse organisations, identifying the affordances with external stakeholders to suggest strategies of IS flexibility. ISFOSA aims to fill the gap in the knowledge, which is the lack of methods to enhance the flexibility. The second case showed that ISFOSA is a practical contribution that can address the development of an IS, but it can identify potential problems in the implementation of new technologies. Although the methodology needs to be improved, the identification of human systems as “legacy systems” and the scenario analysis of the potential changes can help to the identification of requirement for IS flexibility. These requirements define where is needed the flexibility and also potential strategies to resolve it (as non-functional requirements).

7.3 Limitations

It can be found several limitations in this research related to the IS flexibility, the cases and the role of the researcher.

The time constraints limit the evaluation of an approach to enhance the IS flexibility. Several sources of change can trigger a change in an organisation, and this change may not be immediate. This fact limits the study of changes and flexibility in a positivist form because the researcher should evaluate before and after the organisation absorb the change. Additionally, the observation of an organisation in a period cannot guarantee that an event in the environment can trigger a change in the organisation. For instance, in the second case, a change in the laws related to the safety of underground mine can trigger a change, but that law changed in 2013 and around six years before. That period is longer than a PhD. For that reason, it was used a case in the past to test the artefact.

The access of the data limited the development of both cases. The case of Rolls-Royce used secondary data, restricting the study to the available data. The mining case has limited access to the data because the company was not keen on the disclosure of their information, and also the Visible Light Communication Technology of Getic Lab is in the process of patenting. This limitation of the access of data affected the triangulation of the coded data, leaving some codes out of this research.

The role of the researcher is also considered as a limitation, because the artefacts were developed and tested by the researcher, putting a potential bias due to the knowledge of the researcher. This problem is similar to the critic made by Maturana and Varela (1992) in the book “Tree of knowledge” to the role of the research in the field of biology. They discussed that the researcher thinks to be outside the experiment and its observation when the capability of distinction of the system depends on the knowledge of the researcher. The feedbacks of the second case pointed out that issue, where knowledge related to patterns and software development of the research may affect the results. However, this research validated the methodology instead of the result.

7.4 Future Work

The validation of this research suggested an achievement of the main aim, but the validation of this research has suggested the following future work.

7.4.1 Improvement of the Organisational Model

The concept of an autopoietic model of the organisation needs to be simplified. The concept of the boundary as affordance can help us in the simplification of the model because the

communication component is implicit in every activity of the organisation. The future work involves the research of the following components:

- Boundary: This component was defined as interfaces, but the concept of affordances as boundary provides a better definition.
- Production Components: They are substantive activities that maintain the boundary affordances.
- Control Components: Components of the organisation that rules the behaviour. An example in the Mining Case are the policies related to safety.
- Inner-Structure: This component defines the hierarchy of control and messages.
- Creation Components: These components are related to the concept of meta-norms. In both cases was found external stakeholders that can affect the organisation such as the government. Proposing a link of this component with them is possible.

7.4.2 Improvement in the Scenario Analysis

The scenario analysis can identify potential affordances and changes when an organisation implements a new situation. ISFOSA address the analysis by the identification of norms from the boundary analysis, repeating the focal system analysis to represent these potential changes. The normative approach of ISFOSA can identify scenarios answering the question of what should happen, but there are several propositions of scenario analysis that can improve the method (Vergragt and Quist, 2011).

7.4.3 Improvement of the Research Design

The research design proposed an iterative and incremental approach to develop an artefact using design science and case studies. This research showed the strength of this combination, but there is still some weakness related to the improvement of the research design. The first weakness is the validation of the artefact as a whole instead of parts. This research suggests the evaluation of construct beforehand the primary purpose, but it can be considered the evaluation of another artefact. Design science does not cover this issue, and the application of a canonical methodology of design science may identify the assessment of a partial artefact as a different artefact.

Additionally, this research developed a prototype as a form of instantiation to validate the utility of ISFOSA, but some criteria to assess the prototype should be included as a part of the research. The interviews claimed that the instantiation of the second case fit with the purpose, but the assessment only of the prototype may discover new forms of improvements.

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Appendix A1

Improvement of the Organisational Model

This appendix contains an improvement of the model presented in the chapter 4. This improvement uses only the methods of grounded theory to generate theory from data (Strauss and Corbin, 2008), using journals with real cases as the analysed data (Kumar and Stylianou, 2014). The philosophical principles of grounded theory do not accept pre-codes or any theoretical framework that can be used as codes, because codes should emerge from data.

However, the principles related to the treatment of data such as the flexibility in the source of data and the process of codification, can be mixed with other methods for qualitative analysis such as template analysis and data matrix (Cassell and Symon, 2004). Miles and Huberman (1994) have stated the significance of the presentation of data, using data matrix to make the accessible large amount of data. Although they do not mention any constraint in the source of data, they work with interviews and they presentation with tables. Each row can be an interviewee, and each column can be a research question, concepts, span of time or code. This research stands in an interpretive point of view to processes data from previous researches, following the principles of Miles and Huberman (1994) for qualitative data analysis such as theoretical frameworks, reduction of data and data display.

Criteria of Data Collection

This study uses secondary data such as journal articles and online documents from practitioners, which can be used as field observations (Corbin and Strauss, 1990). The analysis of the survival capabilities like the responsiveness of the organisation can be challenging because these skills are related to the ability to maintain the structure and relationships of the components of the organisation to perform their main activities. Under this assumption, the data can be collected from Journals as anecdotal descriptions of situations that implicate a change in organisations, focusing on their Information Systems from a technical, formal and informal perspective. Examples of this data source can be found in the work of Kumar and Stylianou (2014), which proposed an approach to analyse secondary data with grounded theory.

Descriptions about the way that organisations deal with the change triggered from external perturbations in academic articles on the period of January of 2000 to December of 2015 are the main source of data. The following keywords were used: organisational and Information

Systems change, adaptation of Information Systems, an adaptation of organisations, *organisational survival, Information Systems survival, and organisational responsiveness and Information System responsiveness*. These keywords are related to the understanding of what makes the organisation responsiveness and adaptable and how their Information Systems help it. The data collection methodology followed these steps:

1. The first sources of data are relevant journals from Information Systems field such as MIS Quarterly and European Journal of Information Systems
2. The second stage is the selection of the journal papers, using abstracts as the source of information. The following factors were considered in the selection
    a. Journals that did not contain real cases were excluded
    b. Journals with a superficial description of survival, responsiveness and change were discarded because they did not provide enough data to analyse the cases
    c. Journals that did not include technical IS or the IT domain were excluded
3. Journals papers were coded by the criteria explained in the following section

Process of Coding

The components of the framework, proposed in the chapter 4, are the first codes or themes to look for in each journal. They are six codes: Interfaces, production activities, communication activities, control activities, inner-structure and creation components. Miles and Huberman (1994) proposed a conceptual clustered matrix to present their findings from interviews. That matrix contained the reference to an interview per row, and a column for each concept. In this case, this matrix shows the main themes for each column and journals for each row. The content of each cell is a code that reference in which form the theme was found in the journal. Example of an initial list of themes and codes can be found in the following table.

Table A1.1 Initials codes and sub-codes

Themes	Codes
Interfaces	Interchange, Suppliers, Stakeholders, environment, border activities
Production activities	Production of products or services, substantive norms of production
Communication activities	Coordination, workflows, communication and substantive norms of communication
Control activities	Control activities, substantive norms of control
Inner-structure	Structure, hierarchy and power
Creation components	Meta-norms, self-regulation, knowledge management, strategy, mission and vision

Additionally, an effect matrix can relate the effect of one code with another, proposing potential relationship among these components (Miles and Huberman, 1994). These two main matrixes can present the result of the analysis, proposing an improvement of the model. The following sections summarise the codes found in the form the journals, which can be seen in appendix A2.

Interfaces

This component represents the border of the organisation, which is composed of the interactions with customers, suppliers, partners, personnel and stakeholders. This work assumes that organisational changes can be triggered from the environment, but the processed works do not mention direct links from the environment. In general, the interactions of the organisation with an external actor are regulated by continuous feedbacks of monitoring of the internal needs and the acquisition of the resource by means of the customisation of the channel and the interchangeable object. The following table shows a summary of the interface category, showing the role of the external actor, the kind of interactions and the mechanism of management.

Table A1.2 Interfaces' Codes

Role	Activity	Mechanism
Customers	Product/service management New Customisation Channels Transparency	Knowledge Management Historical Data Analysis User Requirements Competitors Complains Infrastructure Enable IT Integration Technology (remote devices)
Suppliers	Supplier Management Autonomy Outsourcing	Infrastructure Enable IT Integration Accreditation Policy Standards Controls Knowledge Management Share of knowledge
Personnel	Personnel sustainability	Personnel Skill Acquisition Plan Outsourcing
Stakeholders	Government Management	Control of Regulation Integration in standards IT Integration
	Community Management	Community Awareness
	Partner Management	Infrastructure Enable Inter-organisational integration by means of the Internet

The interaction with customers is made by the knowledge management, which opens the possibility to offer new or customised products or services. The strategies are different

because in some cases the organisation has historical data from the customer to analyse and predict patterns, but in other cases, the organisation has feedbacks mechanism like complains policy or requirement management. From the table A1.2, it is possible to see that the good practice of enterprises that have survived a long time is the management of each resource in a kind of pro-active form. In the case of suppliers and stakeholders, the organisation manages their interaction by means of standards, knowledge management and IT integration. Standards and accreditation can enable the autonomy of the suppliers and help the process of finding new suppliers. Part of the control can be feasible due to the integration of IT to measure and control some factors such as the inventory or budgets. The knowledge management is a significant factor that helps the interaction with outsourced suppliers, because the organisational knowledge can be useful for operational questions, but also the shared knowledge can imply a norm to follow. Personnel management in the interface was not in the initial pre-codes, because personnel can be seen as a part of the inner structure. However, the challenges of some enterprises to obtain and maintain skilled workers have pointed out some plans to acquire human resources or the outsourcing of part of them.

Table A1.3 shows that interface components affect mainly to production activities and the structure, wherein some cases the effect can be difficult to classify as positive or negative because they depend on the organisation. For instance, a policy of claims can be seen as positively in the performance of an organisation, because this interaction can be translated into data from the customer. However, if the organisation does not have any implementation of this functionality in its IT structure can be negative for the structure. The following effect matrix shows some relationships that have interface components with other parts of the model.

Table A1.3 Effect Matrix of Interface

Effects on	Direct effects	Meta effects	Side Effects
Production	-Changes in product/service can affect the flow of construction		-Changes in suppliers can affect the flow of construction
Inner-Structure	-Claim standards need support from IT		-New products or specialisation implies new skills
Control			Fraud Detection means alignment with control activities
Creation	Knowledge management of customers, produce better services or products		
Communication			-From physical to virtual integration

Inner-Structure

This component represents the structure of the organisation that set up the position of each person in the organisation, defining their skills, responsibilities, level of power and physical space. Additionally, the technology structure is mentioned as capability enabler, which can automate the process, break physical constraints, integrating the whole organisation. The information technology is one of the key mechanisms to provide these benefits.

Table A1.4 Inner-Structures' Codes

Component	Key concepts	Mechanism
Personnel	Position Skills Leadership Diversity Commitment/Responsibility	HHRR Management Competence and skills management Rotation of functions Contract Outlines Team diversity
Technology Infrastructure	Capability Enabler New capabilities Automation of process Physical constraints Enterprise Integration Performance integration Reporting	Technology management Business capabilities Standards Strategic alignment Reusability
Hierarchy of Power	Functional Division Team Structure System architecture	Authority Structure Reward System Empowerment
Physical Infrastructure	Management of Plants and Offices	

In general, each sub-component shows a mechanism to maintain it such as the management of skills, rotation of personnel, reward systems and the technology's alignment. The exception of this rule can be a physical structure, which did not present any evidence from the data (journals in appendix A). Inner-structure is one of the components that affect a wide range of components in case of change.

Table A1.5 illustrates the impact of the other five components.

Table A1.5 Effect Matrix of Inner-Structure

Effects on	Direct effects	Meta effects	Side Effects
Production	-Technology can affect work practices (new processes or interference)	-Enable/constrain organisational capability - Technology changes can affect personnel and functions	-Technology can affect the cost -New capabilities mean new tasks and skills
Control	IT structure helps auditing functions	-IT provides the leverage to implement policies, work processes, and certification requirements	Changes in IT affect the power, so the forms of control
Communication	-Technology can help coordination -Changes in power affect the form of communication	-Technology can open new channels, making available new forms of communication	
Interfaces	-Updated data can help the relationship with the customer -Technology standards can help the coordination with stakeholders -The lack of personnel can mean a concern for interface activities	-The lack of personnel means a personnel/skill management to obtain or maintain human resource	
Creation		-Technology (IT) can be essential support of the strategy	-The data in IT can derive in customer's strategies

In summary, technology is one of the sub-components that affect every component in the case of change as enabler or constrained. Personnel is the second, affecting production and interfaces components of the organisation.

Creation

Creation potentially can affect every part of the organisation, because they represent a kind of meta-norms. From the data, it is possible to see that creation is represented in the form of strategy, which is coded as decisions. For instance, the method of production is a decision about the know-how of production, providing some limitations and guidelines. Enterprise organisations put more effort into financial decision and control, where the low-cost strategy is one of the most common strategies. However, the decision about the behaviour follows

strategies of autonomy, providing more power to the personnel. The multirole mechanism means that the autonomy can be achieved by a strategy of personnel rotation that learns more than one role, providing some flexibility in the personnel.

Table A1.6 Creation Components' Codes

Component	Key concepts	Mechanism
Production Decision	Method of production	Blueprints of Production
Financial Decisions	Strategies for Financial Decisions Low-cost strategy Money Allocation Profits Risk	Financial Control Annual Report Board
Inner-Structure Decisions	Autonomy Power Function Technology Standards	Multirole
Interface Decision	Product or service Supplier standards	Customer Strategy Innovation User data The low dependency of suppliers
Knowledge	Process Knowledge Management (KM) Input/output Performance Person in charge Consequences Learning Process Operational Learning Patterned interactions Supervision Business benefit	KM of Best Practices Standards Practices Key Knowledge Externalization of Knowledge Manual Description Documentation Learning Plan Induction New practices New policies

Interface decisions represent the decisions related to interfaces components such as customers and suppliers. From the data derives that the strategy of organisations is the customisation of product/service using data from the user or innovations. Standardization of suppliers shows a reduction of dependency because opens the possibility for new suppliers.

In the case of knowledge, it is considered a part of creation, because the data mentioned the formal knowledge, which can be found in manuals, models and documents.

Table A1.7 Effect Matrix of Creation Components

Effects on	Direct effects	Meta effects	Side Effects
Inner-Structure	-Changes in the line of business can change the functional structure	-Strategic Alignment with IT can improve its development	
Interfaces	-The pursuing of consumer preferences can affect the product or service in the interface -Innovation can produce new product or service	-Updated knowledge can help the relationship with the customer	-New product or service affects the whole organisation
Production	-Goal Alignment can reduce goals between teams, improving productivity -KM of processes can help the efficiency, effectiveness and learning		Any change in a financial can or behavioural control affect the norm of production
Control	Financial decisions affect the control of activities		-KM can help the definition of the performance index
Communication	-KM reduces dependency on groups, setting common knowledge		

The effect matrix shows that changes in strategy can affect almost every component, where financial decisions affect goals and impacts production activities and control. New forms of interaction with the environment such as new product/service and supplier's strategy can affect the whole organisation.

Control

Control activities are related to the activities and sub-components that trigger any action into the organisation. Financial controls are the main source of corrective actions, which are focussing on the financial state of the organisation. Their main mechanisms of controls are the management of budget and scope from external requirements. Self-regulation is the set of activities that use some feedback to implement a corrective action. The understanding of external forces can be made with the mechanism of complaints. Internal forces can be understood using contradictions, among an activity and other components

Table A1.8 Control Components' Codes

Control Activity	Key concepts	Mechanism
Financial Control	Budget management Project, product or service scope	Financial State or Balance
Self-regulation	Management of Feedbacks Evaluation of Complains Evaluation of Contradiction	Feedback Management Complains

The effect matrix shows the impact of inner-structure, interfaces, production and communication. The financial control constrains the use of technology, the flexibility of customers' requirements and production activities. Any change in production can affect the control of coordination, where financial control and self-regulation are parts of these effects.

Table A1.9 Effect Matrix of Control Components

Effects on	Direct effects	Meta effects	Side Effects
Inner-Structure	-Financial Control can affect the use of technology		-A close relationship between technology and financial control can provide more access to resources
Interfaces	-Financial control can change the flexibility in customers' requirements		-Self-regulation can affect the feedback mechanism from customers
Production	-The financial control can affect the cost and time of production		-Self-regulation can affect the coherence of production activities
Communication			-Self-regulation can affect the coherence of coordination of production activities

Self-regulation can be a complex definition that may imply more sub-components. However, in this case, it is represented by the activities related to the feedbacks in a centralised form.

Communication

Communication activities are mainly coordination among people. The coordination is the kind of interaction that makes possible a collective task. Part of the coordination is the decision welfare that protects the welfare of the whole organisation instead of particular. Currently, the technology allows virtual coordination, which helps in the process of decision making.

Table A1.10 Communication Components' Codes

Component	Key concepts	Mechanism
Coordination	Management of Dependencies Collective task Level of connection (high or low) Cooperation Physical or virtual	Hierarchy of power Functional division

The effects of changes in coordination are the impact of the integration, the communication with stakeholders and the control.

Table A1.11 Effect Matrix of Communication Components

Effects on	Direct effects	Meta effects	Side Effects
Inner-Structure	-Changes in coordination can affect the integration in IT		
Interfaces	-changes in coordination can affect the communication with stakeholders		-Coordination with stakeholders can affect its control
Production	Coordination is related to production activities		
Control	Coordination activities can help the control, using indicators as coordinators		

Appendix A2

List of Journals and Codes

This appendix shows the list of journals analysed in the improvement of the organisational model showed in the chapter 4, and the tables with the codes and sources. This research attempted to define and organisational model and the relationship among the components, using historical data of changes that affected IS. The following list of journals where selected because they include testimonial data, speaking about changes in the organisation and the information systems. These journals were analysed with thematic analysis to code and group the information in themes, proposed in the Tables A1 to A6.

List of Journals used as cases

1. Allen D, Kern T and Mattison D (2002) Culture, power and politics in ICT outsourcing in higher education institutions. European Journal of Information Systems 11(2), 159–173.
2. Allen Dk, Brown A, Karanasios S and Norman A (2013) How Should Technology-Mediated Organizational Change Be Explained? a Comparison of the Contributions of Critical Realism and Activity Theory. MIS Quarterly 37(3), 835–854.
3. Dery K, Kolb D and Maccormick J (2014) Working with Connective Flow: How Smartphone Use is Evolving in Practice. European Journal of Information Systems in press(5), 558–570.
4. Gal U, Lyytinen K and Yoo Y (2008) The dynamics of IT boundary objects, information infrastructures, and organisational identities: The introduction of 3D modelling technologies into the architecture, engineering, and construction industry. European Journal of Information Systems 17(3), 290–304.
5. Habjan a, Andriopoulos C and Gotsi M (2014) The role of GPS-enabled information in transforming operational decision making: an exploratory study. European Journal of Information Systems 23(4), 481–502.
6. Karsten H, Lyytinen K, Hurskainen M and Koskelainen T (2001) Crossing boundaries and conscripting participation: representing and integrating knowledge in a paper machinery project. European Journal of Information Systems 10(2), 89–98.
7. Kotlarsky J, Scarbrough H and Oshri I (2014) Coordinating Expertise Across Knowledge Boundaries in Offshore-outsourcing Projects: The Role Of Codification. MIS Quarterly 38(2), 607.
8. Leclercq-Vandelannoitte A (2014) Interrelationships of identity and technology in IT assimilation. European Journal of Information Systems 23(1), 51–68.
9. Lee G and Xia W (2010) Toward agile: An integrated analysis of quantitative and qualitative field data on software development agility. MIS Quarterly 34(1), 87–114.
10. Leonardi Pm (2011) When flexible routines meet flexible technologies: Affordance, constraint, and the imbrication of human and material agencies. MIS Quarterly 35(1), 147–167.
11. Lyytinen, K., and Rose Gm (2003) The Disruptive Nature of Internet Information Technology Innovations: The Case of Computing in Systems Development Organizations. MIS Quarterly 27(4), 557–595.
12. Lyytinen K and Rose Gm (2006) Information system development agility as organizational

learning. European Journal of Information Systems 15(2), 183–199.
13. Marble Rp (2004) Technological Switchbacks: The Transition to Western Information Systems in Privatised Firms of the Former East Germany. European Journal of Information Systems 13(2), 115–132.
14. Massey Ap, Montoya-weiss Mm and O'driscoll Tm (2002) Knowledge management in pursuit of performance: Insights from Nortel Networks. MIS Quarterly 26(3), 269–289.
15. Molla a, Heeks R and Tjia P (2006) Adding Clicks to Bricks: A Case Study of E-Commerce Adoption by a Catalan Small Retailer. European Journal of Information Systems 15(4), 424–438.
16. Porra J, Hirschheim R and Parks Ms (2005) The History of Texaco ' s Corporate Information Technology Function : A General Systems Theoretical Interpretation. MIS Quarterly 29(4), 721–746.
17. Roepke R, Agarwal R and Ferratt Tw (2000) Aligning the IT human resource with business vision: The leadership initiative at 3M. MIS Quarterly 24(2), 327–353.
18. Sherif K, Zmud Rw and Browne Gj (2013) Managing Peer-To-Peer Conflicts in Disruptive Information Technology Innovations: the Case of Software Reuse. MIS Quarterly 30(2), 339–356.
19. Singh R, Mathiassen L and Mishra A (2015) Organizational Path Constitution in Technological Innovation: Evidenece from Rural Telehealth. MIS Quarterly 39(3), 643–666.
20. Tan Cw and Pan Sl (2003) Managing e-transformation in the public sector: an e-government study of the Inland Revenue Authority of Singapore (IRAS). European Journal of Information Systems 12(4), 269–281.
21. Teo Tsh, Srivastava Sc, Ranganathan C and Loo Jwk (2011) A framework for stakeholder oriented mindfulness: case of RFID implementation at YCH Group, Singapore. European Journal of Information Systems 20(2), 201–220.
22. Tillquist J, King Jl and Woo C (2002) A Representational Scheme for Analyzing Information Technology and Organizational Dependency. MIS Quarterly 26(2), 91–118.
23. Volkoff O and Strong D (2013) Critical realism and affordances: theorizing IT-associated organizational change processes. MIS Quarterly 37(3), 819–834.
24. Xiao J, Xie K and Hu Q (2012) Inter-firm IT governance in power-imbalanced buyer–supplier dyads: exploring how it works and why it lasts. European Journal of Information Systems 22(5), 512–528.
25. Zmud Rw (2000) Data Warehousing Supports Corporate Strategy at First American Corporation. MIS Quarterly 24(4), 547.

Tables A1 Interface Components and Effects

Definition: This component represents the border of the organisation, which is composed by the interactions with customers, suppliers, partners, personnel and stakeholders.

Case Reference: 25, 9, 14, 2, 22, 11, 23, 7, 17, 21, 15, 1, 12, 20, 13, 4, 24, 6

Example:

- "Existing process was found to be primarily customer-driven. In fact, customer requests were mostly for extensions in functionality to existing products and services"
- "We considered their customers' as well as how the product could be marketed very early on"

- “New systems built by these firms included business-to-consumer (B2C) applications that extended existing products from traditional telephone and person-to-person sales channels for a financial company; middleware and front-end applications to link WAP-based B2C; business-to-business (B2B) services; and business-to-employee (B2E)”

Sub-codes of Interfaces

Sub-code	Reference	Articles
Customers	Customisation of product or service	25,9, 14, 2, 6
	Complains Policy and structure	22, 14
	New channels	11, 25, 15
	Transparency of operation	23, 13
	Customer knowledge (segment, sector, product and need)	25, 21, 20, 4
	Customisation by virtual delivery (remote drugs device)	2
Suppliers	Autonomy	22, 11, 24
	Outsourcing: Skills and Sharing knowledge policy	7, 11, 1
Personnel	Personnel sustainability	11, 17, 13
Stakeholders	Government Management	14, 25
	Community Management (awareness)	2
	Partner Management (Inter-organisational integration by means of Internet)	11

Effect Matrix of Interfaces

Affected component	Reference	Article
Production	Customer and supplier Integration can change product or service	11, 25
	Exploration of new customers affect the quality	12
Personnel	New products or specialization implies new skills	11
Creation	Knowledge management of customers, produce better services or products	14
IT structure	Complains: IT structure support claim resolution and requirements	22
Supplier-control	Control and standards of supplier (Fraud detection)	22

Tables A2 Inner-Structure

Definition: This component represents the structure of the organisation that set up the position of each person in the organisation, defining their skills, responsibilities, level of power and physical space

Case Reference: 2, 23, 10, 9, 22, 18, 16, 11, 14, 25, 19, 17, 21, 15, 1, 8, 20, 4, 5, 3

Example:

- “To support this major shift, a carefully conceived change management program (skills) was established before business processes and accompanying jobs were redesigned”
- “There is a sense of relationship to something bigger. Under this model, workers making a minimal effort at compliance feel dishonest”
- “After four months of using CrashLab in this way, engineers in the Strut Group were setting up their models in similar ways to one another and nearly all members of the group were using CrashLab”
- “rewards based on such performance, knowledge that enables richer employee contributions to performance, and the power to make decisions that influence performance”

Sub-Codes of Inner-Structure

Sub-code	Reference	Article
Personnel	Skills	11,17, 9, 25
	Position	11, 17
	Commitment/Responsibility	17
	Diversity	9
	Rotation	16
	Leadership Behaviour	17
Technology Infrastructure	Capability Enabler	11, 10, 16, 15, 5
	Automation of process	16, 2
	Reusability	18
	Enterprise Integration	11, 5
Hierarchy	Team structure	11
	Empowerment	14, 17, 9, 8
	Reward System	17, 2, 23, 14, 9, 21
	Functional Division	17, 20
Physical Structure	plant and office	16

Reference Matrix of Inner-Structure

Affected component	Reference	Article
Production	Technology can affect work practices.	11, 22, 18, 16, 21, 15, 4
	Enable/constrain capabilities	10, 16, 19, 1, 20
	Technological Interference (personnel and functions)	2, 16
	Technology can affect the cost of production.	16, 8, 5
Control	Auditing functions	10, 2, 21, 8, 3
	Changes in power affect forms of control	22, 11
Communication	Technology helps coordination	10, 22, 4, 3
	Changes in power affect forms of communication	22, 11,
Creation	Data from IT can be useful for strategies	23, 25, 17, 16, 20, 5
Interfaces	Technology standards can affect suppliers	22, 1
	Lack of personnel can affect the interface, which should obtain workers	11, 17

Tables A3 Creation Components

Definition: Creation potentially can affect every part of the organisation, because they represent a kind of meta-norms. From the data, it is possible to see that creation is represented in the form of strategy, which is coded as decisions

Case Reference: 7, 9, 18, 16, 11, 14, 17, 15, 1, 12, 20, 13

Example:

- “Mechanistic aspects operate toward an end according to the original blueprint of production.”
- “Texaco’s strategy changed to “low cost.”
- “Innovation is required and inextricably linked for success at 3M.”

Sub-Codes of Creation

Sub-code	Reference	Article
Production Decision	Method of production decision	11, 16
Financial Decisions	Low cost strategy	16, 15
	Money Allocation	16
Inner-Structure decision	Autonomy (power and function)	9
	Multirole	16
	Technology Standards	1, 13
Interface Decision	Definition of product and service	17, 14
Knowledge Management	Process Knowledge	14, 7
	Learning Process	18
	Pattern Interaction	7
	Externalization of Knowledge	7, 20

Reference Matrix of Creation Components

Affected component	Reference	Article
Hierarchy	Changes in the line of business can change the functional structure	14
Technology	Strategic Alignment	17, 16, 15, 1
Interfaces	The pursuing of consumer preferences can affect the product or service	17, 14, 12
Production	Strategic Alignment	18, 9
	Knowledge management can help the efficiency, effectiveness and learning	18, 14
Communication	KM reduces dependency on groups, setting common knowledge	7
Control	Knowledge management can help the definition of the performance index	18, 14

Tables A4 Control Components

Definition: Control activities are related to the activities and sub-components that trigger any action into the organisation

Case Reference: 2, 23, 10, 9, 22, 16, 14, 17, 6

Example:

- The control of financial accounting is made from exploration to retail operations
- Any parameter in the pre or post-processing of the model that diverged from the best practices appeared in the journal

- “The notion of feedback entails that forces within and external to a system lead to balance or change, in intended or unintended ways.”

Sub-Codes of Control

Sub-code	Reference	Article
Financial Control	Budget Management	16, 17, 14
	Project, product or service scope	10, 6
Self-regulation	Evaluation of Contradictions	2, 16, 23
	Complains policies	22, 14

Reference Matrix of Control

Affected component	Reference	Article
Inner-Structure	Financial control can affect the use of technology	10, 16
Interfaces	Affect the flexibility in customers’ requirements	9
Production	The financial control can affect the cost and time of production	10, 2, 9
Communication	Self-regulation can affect the coherence of coordination of production activities	16, 23

Tables A5 Communication Components

Definition: Communication activities are mainly coordination among people.

Case Reference: 2, 7, 22, 18, 14, 17, 4

Example:

- “Coordination mechanisms are particularly suited for work environments characterised by goal conflict, task interdependence, and task uncertainty.”
- “Competitive and cooperative dependencies created as organisations contend for scarce resources, affect internal arrangements.”
- “A related key theme concerns our findings regarding the inscription of particular social and cultural relations within IS technology and their effect on organisational power relations.”

Sub-Codes of Communication's Components

Sub-code	Reference	Article
Coordination	Cooperative dependencies created as organisations contend for scarce resource	22
	Level of connection	7
	Dissolution of physical boundaries	18
	Collective task	18, 14, 4

Reference Matrix of Communication

Affected component	Reference	Article
control	Strategic Control by means of an index	14
Production	Coordination is related to production activities	14
Technology	Help Strategic Control and integration	17, 2
Interfaces	changes in coordination can affect the communication with stakeholders	17

Tables A6 Production Components

Definition: Production activities are the routine and protocols that can be done by the imbrications of human and material.

Case Reference: 23, 10, 7, 9, 22, 18, 11, 14, 19, 12

Example:

- "If we are ever going to have math [simulations] lead the design and reduce our reliance on physical testing, we had to standardise the way we do the simulation work."
- "CrashLab did not afford engineers the ability to plot results from multiple iterations in a single chart for the sake of comparison—what engineer is called "cross-plots."
- "Extensive responses are likely to cause work overload and lack of software team focus and require the time-consuming involvement of upper management."

Sub-Codes of Production Components

Sub-code	Reference	Article
Capability	Organisational Affordance	23, 9, 14
Path	Set of Actions (variety of possible actions)	19
Production Activity	Roles, routine and protocols, using human-material imbrications	7, 10, 19
Standards	best practices and policy	10, 23, 14, 22
	Standards Methodologies or guideline	9, 18, 11, 12
Mechanism	Reuse	18
	Improvement	11

Reference Matrix of Production

Affected component	Reference	Article
Control	Changes in the methodology imply changes in the control	11
	Changes in the capabilities affect the control	23
Communication	Changes in the methodology imply changes in the coordination	11
Inner structure	New capabilities require more technology	10
	Contradictions requires changes in technology:	2
Interfaces	Changes in production can change some attributes in products or services	10

Appendix B

Data Collection Protocols

Data Collection of Rolls-Royce Case

This study is focused on the servitisation of Rolls-Royce but in the concept of an hour per fly, which is in the aeronautic scope. Rolls-Royce was the keywords in the search process, but it was focused on the understanding of the servitisation process and how their Information Systems help it. The data collection methodology followed these steps:

1. The following sources of data were considered
    a. The top then journals from Information Systems field such as MIS Quarterly and European Journal of Information System in the Association of Business Schools (ABS) list (The Association of Business Schools, 2015)
    b. Journals related to the servitisation process (Lightfoot et al., 2013)
    c. Books that considers the process of servitisation of Rolls-Royce
    d. Official documents of Rolls-Royce such as financial results and Annual Reports
    e. Public interviews from news
2. The second stage is the selection of the material, using abstracts or searching the word “Rolls-Royce” into the source of information.
3. Journals papers were coded by the criteria explained in the following section.

The following table shows the universe of the data sources and the selected papers in each source.

Table B.1 Data Collection of Rolls-Royce's Case

Source Name	Found	Selected
Information Systems according to ABS list		
Information Systems Research	2	0
MIS Quarterly	2	1
Journal of Management Information Systems	0	0
JAIS-Journal of the Association of Information Systems	2	1
Computers in Human Behaviour	0	0
Decision Support Systems	0	0
EJIS - European Journal of Information Systems	2	1
ESA - Expert Systems with Applications	4	3
GIC - Government Information Quarterly	1	1
Information and Management	0	0
Service Papers according to Lightfoor, Baines and Smart (2013)		
IMM – International Marketing Management	40	4
JM – Journal of Marketing	10	0
HBR – Harvard Business Review	2	1
JBIM – Journal of Business & Industrial Marketing	13	2
MIT Sloan (Management Review)	12	6
JSR – Journal of Service Research	3	0
IJSIM – International Journal of Service Industry Management	4	0
IJOPM – International Journal of Operations & Production Management	41	7
JOM – Journal of Operations Management	0	0
EMJ – European Management Journal	26	1
EurOMA – European Operations Management Association	0	0
JCP – Journal of Cleaner Production	4	1
JSSSE – Journal of systems Science & Service Engineering	1	0
CACM – Communications of the Association for Computing Machinery	7	0
JMTM - Journal of Manufacturing Technology Management	34	2
JME- Journal of Engineering Manufacture	94	4
Other		
Conferences (CFP)	5	5
Journals (OJ)	12	12
Thesis (THS)	2	2
Report (REP)	11	11
News (NW)	7	7
Books (BK)	6	6
Total	**347**	**78**

Table B.1 shows that the initial universe was 347 papers and documents, where search tools for text help into the second stage. In the second stage was discarded the documents, using the following criteria:

- It was selected the documents where Rolls-Royce is using as an example, but using primary or secondary sources (For instance, several of the documents mentioned Rolls-Royce as an example, but without references)
- It was selected the documents that mention aeronautic division (The documents that only speak about automotive industry were discarded)
- It was discarded critics of books related to Rolls-Royce or servitisation. However, some of these books were obtained and added as a part of the data.

Additionally, the keywords “Rolls-Royce” and “servitisation” were searched with Google Scholar to select books, news, papers and reports. It was used the same criteria in the journals, but no useful resources were found after the third page of Google Scholar.

Analytical Method of Rolls-Royce Case

The analysis of the data was made with the software NVivo 11. It was classified in the following form:

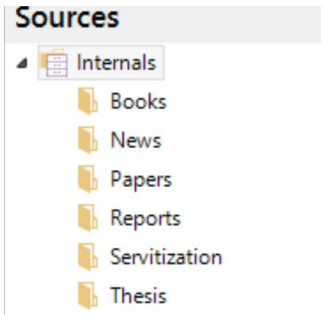

Figure B1 Classification of Data for Rolls-Royce Case

The codes proposed in table 5.1 were added as Nodes to NVivo. The Figure B2 shows an example of the nodes and their structure. For instance, it was identified an agent named “customer”, and it was included some affordances.

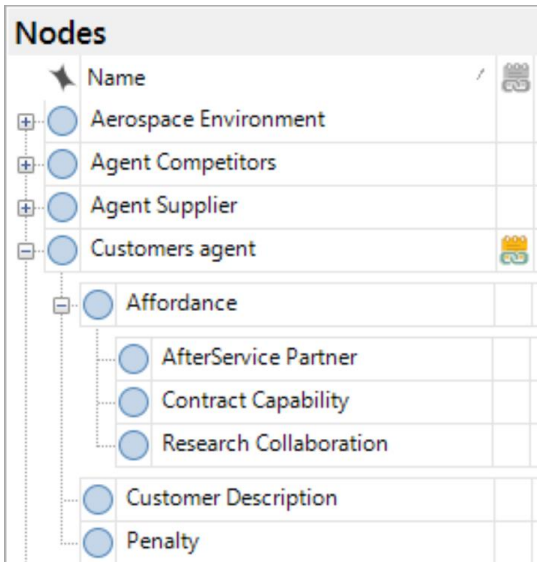

Figure B2 example of the nodes and their structure

The nodes were used to classify the references to the documents, where it was attempted to identify at least three references to a node. Figure B3 shows an example.

Figure B3 Example of a node (affordance)

Data Collection of Location System for Underground Mine Case

This study is focused on the proposition of a Location System for Underground Mine, using Visible Light Communication Technology. In this case, the researcher had access to the Management of Information and Communication Technologies Laboratory ("Laboratorio de Gestión en Tecnología de Información y Comunicación (Getic)") located in the University of Santiago of Chile. They have implemented a prototype for the VLC to register the access to a specific door in an underground mine. They are working on new prototypes to develop a network-based in VLC. The data was collected following the methodology proposed in chapter 6 in the following form:

1. The context of the case was understood by means of interviews with the Getic Lab.
2. It was tested in the current prototypes to understand the capability of them.
    a. It sent information from a sender to a receiver.
    b. It was measured the distance between the sender and receiver to check the feasibility to use this technology
3. From the result of the interviews, it was decided to focus on the safety of the miners as the main aim of the system, which needs control of their location.
    a. The main law of the government related to the safety of people in mines was identified[1]
    b. It was found the Safety norms of the company[2]
    c. It was taken notes from the meetings with the Getic Lab

[1] The current law of Safety in underground mines is named "Ley de Seguridad Minera", and It can be accessed in http://bcn.cl/1v2p2 (Last Access 25/06/2018, the source is in Spanish)
[2] The company policy of safety and occupational health (This resource is in spanish with the name "Reglamento Especial de Seguridad y Salud Ocupacional" and can be found in this link) https://www.codelco.com/prontus_codelco/site/artic/20110719/asocfile/20110719102746/resso.pdf (Last access 25/06/2018)

Analytical Method of Location System for Underground Mine Case

A similar method of the Rolls-Royce case was used to analyse the data. Initially, it was classified the information by sources in the software NVivo 11.

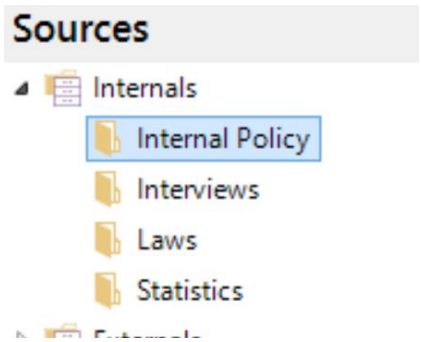

Figure B4 Classification of Data for Location System for Underground Mine Case

It was identified agents, affordances, Norms, and some context description. It was coded the data found in the previous section, repeating the same process of the previous case. Figure B5 shows an example of the codes and their references. This case was worked in the original language (Spanish) because the research is a native Spanish speaker

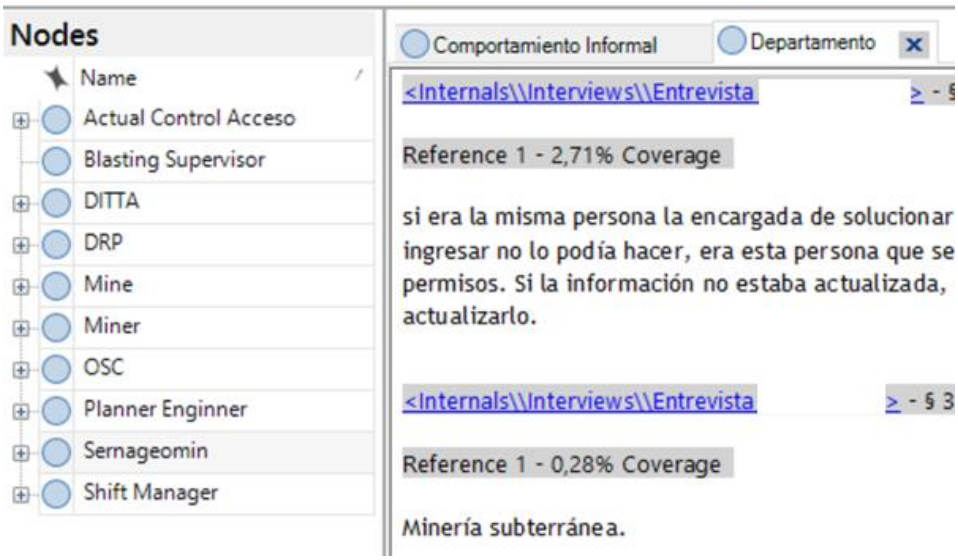

Figure B5 Example of a node and the codes

Appendix C

Evaluation Questionnaire and Interview

This Appendix shows the documents needed as a part of the ethics protocol, with the questions of the interview, and evaluation questionnaire.

Dear Participants,

INFORMATION SHEET

I am a doctoral research student at BISA (Business, Informatics, Systems and Accounting) at The University of Reading, UK. My research is Flexibility of Information Systems, and it is inspired by the study of the organisational semiotics and living systems. This project named "Smart Mining from an Autopoietic Lens" has a purpose the proposition of a Smart Mining Framework based on the principles of autopoiesis of organisations to support the safety of people in underground mines. A copper mine is viewed as an information system where information is seen as a sign, and norms govern the use of information. This Smart Mining Framework is considered as an artefact that can lead a process of analysis and design, enabling the information flows from the activities that interact with the external environment of the organisation and its internal components. Your participation is entirely voluntary, and you have the right to withdraw from the project at any time. This project has been subject to ethical review by the School Ethics and Research Committee and has been allowed to proceed. All data collected will be treated confidentially and of the participants is secured. If you have any queries, wish to clarify anything about the study, or wish to receive the results of the research, please do not hesitate to contact me by email at d.a.fuentealbacid@pgr.reading.ac.uk

Kind Regards,
Diego Fuentealba

DOCTORAL RESEARCHER

Business Informatics, Systems and Accounting (BISA)

Email: D.A.FuentealbaCid@pgr.reading.ac.uk

Henley Business School

Research Ethics Committee

I have read and had explained to me by **Mr Diego Fuentealba** the accompanying Information Sheet relating to the project on:

Smart Mining from an Autopoietic Lens

I have had explained to me the purposes of the project and what will be required of me, and any questions I had have been answered to my satisfaction. I agree to the arrangements described in the Information Sheet in so far as they relate to my participation. I understand that participation is entirely voluntary and that I have the right to withdraw from the project at any time, and that this will be without detriment. I understand that this application has been reviewed by the School Research Ethics Committee and has been given a favourable ethical opinion for conduct.

I have received a copy of this **Consent Form** and the accompanying **Information Sheet**.

Signature .....

Date .....

Email .....

Interview

Spanish	English
¿Por qué crees tú que se necesita hacer un control de acceso en la minería?	Why do you think that a control access is needed in a underground mine?
¿Qué tipo de control de acceso existen?	Is there any control access to the tunnels?
¿Sabes si han habido accidentes relacionados a la falta de control de acceso?	Do you know about any accident related to the lack of control access?
¿Sábes que factores consideran para dar permiso a los túneles?	Do you know the requirements needed to give access to the tunnels?
¿Tú sabes si existe alguna especie de mecanismo informal de seguridad que ocupen los trabajadores?	Do you know if there are any informal mechanism of control inside the tunnels?
¿Sabes si existe alguna normativa chilena que hable del control de acceso?	Do you know the current regulation related to the control access?
¿tú sabes qué parte de la empresa se encargaba de el control de acceso?	Do you know which part of the organisation is in charge of the access to the tunnels?
¿sabes si existe una persona encargada del control de acceso?	Do you know who is the person in charge to give access to the tunnels?
¿recuerdas si te hicieron firmar algún documento al momento de ingresar?	Do you remember the requirement or procedure to enter to the tunnels?

Evaluation Questionnaire

The following questions were asked, where the first question where changed in the second case.

A1. Do you think that this method can be useful for the identification of boundaries and activities and its dependencies?

A2. Do you think that this method can be useful for the identification of boundaries of the organisation and potential changes in the development of an information system?

B. Do you think that potential users (professionals and academics) can understand this artefact?
C. Do you think that this method is ease to use?
D. Do you think that this method is performed ethically right?
E. Do you think that this method can have any side effect?
F. Do you think that this method is complete?
G. Do you think that this method is detailed?
H. Do you think that this method is consistent with the main aim?
I. Do you think that this method is consistent with every stage?
J. Can this method be defined as simple?
K. Do you think that this method is efficient?
L. Do you think that this method can be adapted to another case?
M. Do you think that this method can be improved? How?