

MESG
MESTRADO EM ENGENHARIA
DE SERVIÇOS E GESTÃO

Product-Service Systems in production and maintenance planning

Elder Alexandre de Sousa Hernández

Master Thesis

Supervisor FEUP: Professor Jorge Pinho de Sousa

Co-supervisor INESC TEC: Doctor Samuel de Oliveira Moniz



2018-09-24

To my parents, Mayra Hernández de Sousa and António Saraiva de Sousa, for the support and love they give me.

To my sister, Miriam Nayelli de Sousa Hernández, for always being there to make me achieve my objectives.

Acknowledgments

Thanks to my Thesis Supervisor, Professor Jorge Pinho de Sousa, for the advices and counselling that helped me organize my ideas and work.

Thanks to my Thesis Co-Supervisor, Doctor Samuel de Oliveira Moniz, for always being there providing support and guidance on the thesis and project meetings. Also, for endorsing and trusting my abilities and skills as a Service Engineer (and Mechanical Engineer).

Thank you, to all collaborators and students in INESC TEC – CESE, who have contributed to create a good working environment.

Thank you, to my colleagues and professors of MESG, making these 2 years a landmark in my personal and professional growth.

Thank you, family and friends.

Key Words

Product-Service Systems, PSS Design framework, Design Science Research Methodology, Production, Maintenance Services

Abstract

The challenge in the transformation of current business into a Product-Service System (PSS) business model reside in the PSS Design process. As many authors point out, there is not one solution guideline to promote PSS Design and existing methodological approaches over simplify key aspects of the business.

Based on the Design Science Research Methodology (DSRM), a framework proposal was developed within this work to support the PSS Design. The intent of the framework was to provide a collaborative, flexible and iterative approach to support businesses in designing their PSS business model. The framework integrates components of PSS design literature with components of business literature.

This work applies the proposed framework in a real case of an Elevator Company in order to validate the approach.

Sumário

O desafio de transformar empresas actuais em um modelo de negócios Product-Service System (PSS) reside no processo de desenho do PSS (PSS Design). Como muitos autores apontam, não há uma linha guia de solução para promover o Design PSS, e abordagens metodológicas existentes simplificam os principais aspetos do negócio.

Com base no *Design Science Research Methodology* (DSRM), foi desenvolvida uma proposta de *framework* dentro deste trabalho para apoiar o *PSS Design*. A intenção do *framework* é fornecer uma abordagem colaborativa, flexível e iterativa para empresas desenvolverem o seu modelo de negócios PSS. O *framework* integra componentes da literatura de *PSS Design* com componentes da literatura de negócios.

Este trabalho aplica o *framework* proposto em um caso real de uma empresa de elevadores para validar a sua abordagem.

Abbreviations

PSS – Product-Service Systems

DSRM – Design Science Research Methodology

MS – Maintenance Services

BMC – Business Model Canvas

CRM – Customer Relationship Management

MIFA – Material and Information Flow Analysis

Contents

1. Introduction	1
1.1. Background	1
1.2. Purpose, Motivations, Objectives and Limitations	2
1.3. Thesis Structure	3
2. Theoretical Background	5
2.1. Product-Service Systems (PSS)	5
2.2. Maintenance Services (MS) and PSS	11
2.3. Gaps in Research	13
3. Design Science Research Methodology (DSRM)	14
3.1. PSS Design Framework proposal	16
4. Problem Identification	19
4.1. Step 1: Case Study Definition	19
4.2. Step 2: Problem Discovery	21
4.2.1. Firm Background	21
4.2.2. Product-Service Characterization	23
4.2.3. Strategic planning	27
4.2.4. Partner Stakeholder FASTEN Project	29
4.3. Step 3: Artifact development	32
4.3.1. Material and Information Flow Analysis (MIFA)	32
4.3.2. Elevator Maintenance Service Stakeholder Map	34
4.3.3. Business Model Canvas (BMC)	36
4.3.4. Maintenance Service characterization	40
5. Solution Design	51
5.1. Identifying Contributing Stakeholders	51
5.2. Solution	52
5.3. BMC Revision	55
5.4. Event Storming	57
5.5. Process Design	61
6. Evaluation	64
6.1. Behaviour Driven Development (BDD) Story	64
6.1.1. Corrective Maintenance BDD story	65
6.1.2. Preventive Maintenance BDD story	68
6.2. Interviews with Customers and End Users	69
7. Results	73

8. Conclusion and Future Works.....	75
References	76
APPENDIX A: meetings	81
APPENDIX B: Additional information.....	83
APPENDIX C: Key References Classification	90
APPENDIX D: Interviews.....	1

Figure List

Figure 1, evolution of PSS concept (Baines, et al., 2007).....	8
Figure 2, maintenance paradigm (Parida & Kumar, 2003).....	12
Figure 3, overview of a circular economy driven manufacturing and maintenance positioning (Takata, 2013)	12
Figure 4, Framework proposal based on the DSRM.....	18
Figure 5, Elevator Company A Brazil Organisational Chart.....	21
Figure 6, Elevator Company A product life-cycle	25
Figure 7, Elevator Company A Maintenance Service	26
Figure 8, maintenance service packages proposed by Elevator Company A.....	26
Figure 9, Elevator Company A maintenance modernization packages.....	27
Figure 10, FASTEN technological framework.....	30
Figure 11 – AS-IS MIFA of Maintenance Service and Production Planning	33
Figure 12, Elevator Company A business and project stakeholders.....	36
Figure 13, Business Model Canvas for Elevator Company A.....	37
Figure 14, firm and customers exchange framework	38
Figure 15, Elevator Company A maintenance methods.....	41
Figure 16, Preventive Maintenance Process Mapping	44
Figure 17, Corrective Maintenance Process Mapping.....	46
Figure 18, Modernization process mapping.....	48
Figure 19, panel of stakeholder chosen to contribute on the 1st design proposal.....	51
Figure 20, To-Be maintenance PSS frame	53
Figure 21, Result-Oriented PSS phases	55
Figure 22, Revised BMC according to a PSS elevator system solution provider	56
Figure 23, Collaborative Maintenance and Self Maintenance Service events	58
Figure 24, spare parts Production and Logistics services events	59
Figure 25, Maintenance Service events	60
Figure 26, Preventive Maintenance Service 1st redesigned process flowchart.....	62
Figure 27, Corrective Maintenance Service 1st redesigned process flowchart.....	63
Figure 28, cyber-physical industry 4.0 framework (Lee, Kao, & Yang, 2014)	83
Figure 29, interaction between production and maintenance (Al-Turki, 2011).....	84
Figure 30, MESA model of maintenance (Murray, et al., 1995)	85
Figure 31, the maintenance planning as part of the corporate planning system (Al-Turki, 2011).....	86
Figure 32, Taxonomy of maintenance philosophies (Kothamasu, Huang, & VerDuin, 2006).....	87

Figure 33 – Elevator Company A MIFA issue analysis.....	89
---	----

Table List

Table 1, proposed PSS business model types (Tukker, 2004).....	7
Table 2, DSRM adapted (Peffer, Tuunanen, Rothenberger, & Chatterjee, 2008)	15
Table 3, PESTEL analysis for the maintenance elevator services in the Brazilian market	28
Table 4, SWOT analysis for the Elevator Company A maintenance service.....	29
Table 5, Value Proposition within the firm infrastructure.....	39
Table 6, Elevator Company A ServQUAL dimensions	42
Table 7, Elevator Company A services integration in product life-cycle	49
Table 8 - Issues in Maintenance Service and Supply Chain.....	50
Table 9, Gains for the To-Be Preventive Maintenance	61
Table 10, Gains for the To-Be Corrective Maintenance	63
Table 11, Interviews topic evaluation.....	70
Table 12, project stakeholders means of contact and information collection	81
Table 13, attended meeting FASTEN project	82

1. Introduction

1.1. Background

In the modern economy businesses have major gains on combining product and services. From a revenue point of view, reaching new levels of customer interaction and ensuring, in some cases, a prolonged product life cycle, allows companies to continue engaging customer after the product sale (Meier, 2010). Companies can no longer rely on the existing product-focused business models and ensure the competitive dimensions of time, cost, quality, flexibility or environment (Dimache, Mitchell, & O'Dowd, 2010). Making a shift from product-focused business model towards a service oriented one, can be the means to achieve competitive advantage over the dimensions described before (Kindström & Kowalkowski, 2014), especially in terms of environmental sustainability (Tukker & Tischner, 2006). PSS is a business approach that combines products to a set of associated services that together bring perceivable value to the customer (Tukker & Tischner, 2006).

The Product-Service Systems and Servitization¹ concepts are linked to service-driven approaches dating back from the 90's, where a revolution from economy of products towards an economy of services takes place in companies (Ducq, Chen, & Alix, 2012). Before this, companies added to their products, product-related service extension merely as means to prolong product lifecycle and utility through time while providing customers a more satisfactory experience, worthy of extra revenue (Annarelli, Battistella, & Nonino, 2016). As more service extensions were added to the products, companies experienced organic and cultural restructuring to comply with these services, bringing new levels of added value to the customer. This induced a shift of perspective, where companies now see this service extensions as an integral part of their revenue-generating value proposition (Wise, 1999). From technological improvements, intellectual property, product image and brand names, aesthetic design, and styling, all these services are means to the company differentiate from their competition and diversify their products, ensuring company competitiveness in a dynamic market (Thoben, Eschenbächer, & Jagdev, 1999); (Mont K., 2002). Companies soon started to change their offerings, from mass production towards more customized approach where more personalization and more customer contact is required (Mont K., 2002).

The Product-Service System (PSS) approach is seen as a game-changer to support business reshape their business models fostering service-oriented perspectives whilst ensuring environmental sustainability (Wallin, Chirumalla, & Thompson, 2013). The combination

¹ Although PSS and Servitization are similar in nature, as their proposition is to add core corporate offering through services (Vandermerwe & Rada, 1988), they differ on the context on which they are applied. PSS are normally applied when there is a major interest in the environmentally sustainable potential of the offering, whilst Servitization is employed when there is a purely economic context (Annarelli, Battistella, & Nonino, 2016).

of a service oriented perspective with the environmental sustainability can support companies cope with opportunities and threats originated from the changes of external factors: from markets, such as more client focus, higher customization, or shrinking markets (Michelinia, Moraesa, Cunha, Costa, & Ometto, 2017), from environmental concerns, legislation and new economic perspectives, as the circular economy (Comission, 2011).

However, little is still understood on how the transition from existing business models into a PSS approach business model takes place (Wallin, Chirumalla, & Thompson, 2013). According to (Johnstone, 2008) this problem occurs due to available PSS models oversimplify sector specific dynamics and strategies which in turn reduces the understanding of emergent realities and manifestations of the PSS on these sectors. There is still a research gap to bring in a broader view from different disciplines, industries, supply-chain actors to support on the development of a profitable and viable PSS offer (Clayton, Backhouse, & Dani, 2012).

To help lessen the gap, this work will develop and propose a framework for an integrative PSS Business approach solution. Based on a real business case study, this work will propose a possible framework that will be implemented to support the business transformation of an elevator company with production and maintenance service.

1.2.Purpose, Motivations, Objectives and Limitations

This work was developed within the FASTEN European-Brazilian project. This project aim is to work with real companies, that provide case studies to be solved under the project premises of technological innovation and business development.

Based on the case study from an Elevator Company A partnered to the FASTEN project, a PSS business model proposal will be developed considering the production and maintenance planning perspectives. This proposal will integrate potential new technology innovations from the FASTEN project in a PSS solution.

This work will utilize a Design Science Research Methodology with models from different domains to aid on the redesign of a PSS with an integrative approach of the technological innovation introduced by FASTEN project.

To shift from product centred perspectives to service (human) centred perspectives, it is interesting for the organisations to know what the most suitable technologies are, how to adapt their manufacturing and maintenance programs, how to adapt their Human Resources, how to put in place the right services, and how to perceive the levels of interaction with the customer.

Working with a project such as FASTEN from INESC TEC, an innovation centre focused in technological and process innovation and in collaboration with a stablished company is of great value. This combination will allow to put in the perspective what are the challenges

ahead for the adoption of the Product Service Systems view point towards the required artifacts to support and characterize this shift.

The objectives of this work are:

1. Propose a framework to support the PSS design.
2. Apply and validate the framework in a real case

There are three major limitations for this work, by which can cause lack in depth study of the PSS Design on the case study in question:

Timeline: The master thesis has a timeframe of 5 months, the FASTEN project is a 3-year project with its own pace. The complete usage of the Service Design methodology will be conducted under timeframe constraints.

Dislocation: The studied use case company is established in Brazil and this research is being conducted in Portugal. The physical dislocation will unable to have regular and in person contacts with the stakeholders, and to have in-loco knowledge situation. Alternative channels have to be used to acquire information.

Confidential information: Although the company of the use case is partnered with the FASTEN project, some information cannot be traded by the company to the project. Information have to be acquired by public channels, and other in-house trade information must be validated by the company.

1.3.Thesis Structure

The thesis is structured in ten chapters containing different research and work aspects conducted to support the master thesis theme.

Chapter 1, concerns the master thesis overview, a scope to the research and work parameters. This chapter includes introduction, background, purpose, motivation, work objectives, scope and limitations, and thesis structure.

Chapter 2, concerns the Theoretical Background supporting the work. PSS concept, potential, obstacles, Maintenance Service, and Gaps in Research. This chapter is important as it will allow to understand what the best approaches are, what has been done, and what are the existing gaps in the field of transforming existing services into the PSS scope.

Chapter 3, concerns an overview of the utilized methodological approach and the framework proposal. The utilized methodology will be based on the Design Science Research Methodology approach with a framework proposal, adapted to the case study problem.

Chapter 4, concerns Problem Identification phase. Step 1 of the methodological approach - Problem identification: Problem Scope. This chapter introduces the initial information of the case study and contextualizes the problem at hand. This chapter will provide the

baseline to promote the work and drive the service design approach. Step 2 of the methodological approach - Problem identification: Problem Discovery. In this chapter a more detailed overview of the firm is conducted, internally and externally. And Step 3 of the methodological approach - Problem identification: artifact Development. This Chapter will create the required artifacts that will support on the PSS design.

Chapter 5, concerns the Solution Design. In this chapter, based on the artifacts created prior will create a first iterative approach towards a PSS Design.

Chapter 6, concerns the Evaluation. Tools of evaluation will be utilized to validate aspects of the PSS solution design.

Chapter 7, concerns the Result discussion. Concerns a critical analysis of the performed work.

Chapter 8, concerns the Conclusion and Future Works. A wrap up of the conducted work, and key aspects that the research enabled. Also, will propose new paths to be followed to further the research.

2. Theoretical Background

In this chapter a theoretical review overview will be conducted for the Product-Service Systems (PSS) in terms of concept, potential, obstacles, and the support of Maintenance Service. In the end research gaps will be presented as key aspects this thesis will focus on.

2.1. Product-Service Systems (PSS)

In 1999, Goedkoop in his report “Product Service systems, Ecological and Economic Basics” makes a broad overview of the potential behind Product Service Systems (PSS), taking the first steps towards a concept consolidation. Considering (Goedkoop M. J., 1999) terminology analysis, PSS is composed by:

- a Product component, “a tangible commodity manufactured to be sold;
- a Service component, “an activity done for others with an economic value and often done in commercial basis”;
- a System, “a collection of elements (material and immaterial) including their relations”.

Goedkoop integrative perspective will translate into,

- Product Service Systems is “a marketable set of products and services capable of jointly fulfilling a user need”.

We can relate this aspect of PSS to nowadays market demands. The potential customer seeks not the purchase of a product but rather a customized solution to a problem or need they have (Boehm & Thomas, 2013). The combination of Product and Service components in PSS, appear as a jointly offering of value or functional fulfilment that meet client satisfaction (Goedkoop M. J., 1999).

Since 1999, the concept and terminology of PSS has evolved due to the fact different domains have shown keen interest in researching from different perspectives (Boehm & Thomas, 2013). PSS has been approached in the light of different domains and perspectives, such as, Business Management, Information Systems and Engineering & Design² (Mahut, Daaboul, Bricogne, & Eynard, 2015).

Even though the PSS concept and terminology have evolved, the concept basis has remained the same (Mahut, Daaboul, Bricogne, & Eynard, 2015). An interesting approach to the PSS concept comes from (Mont K. , 2002), which states:

² **Business Management** domain have actively study PSS in the fields of marketing and consumer studies, with the goal to understand how the product-service bundle is offered to the customer. **Information Studies** domain plays an important role to study the development and integration of Information and Communication Technologies of PSS, by harnessing, developing and implementing new technology to be at the disposal of the new business’s requirements. **Engineering and Design** domain research preoccupies on designing, building and operating physical products of PSS. (Boehm & Thomas, 2013)

“PSS should be defined as a system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy the customer needs and have a lower environmental impact than traditional business models”.

So, in summary, based on Mont K. perspective, the PSS dimension according to Chirumalla et al. (Chirumalla, Bertoni, Ericson, & Isaksson, 2012) is composed by:

$$\text{PSS} = \text{Product} + \text{Service} + \text{Network} + \text{Infrastructure}$$

The most recent concept for PSS in literature comes from Boehm and Thomas (Boehm & Thomas, 2013), defining PSS as:

“An integrated bundle of products and services which aims at creating customer utility and value.”

The term “integrated bundle” is an interesting addition, as it delivers the intent of different weights of product or service can compose the package of the offering. In a further chapter, we will explore the different types of PSS business model.

PSS types

The PSS business model transforms how companies operate to sell value to customers. The product/service ratio in this set can vary, either in terms of function fulfilment or economic value (Goedkoop, van Halen, te Riele, & Rommens, 1999).

As PSS perspective is to provide to the customer the means to achieve the value that he acquired rather than limiting to the sale of a product. According to Mont (Mont K. , 2002), this implies a shift of product utilisation that is going to be replaced by the possibility to fulfil consumers' needs through the provision of more dematerialised services, which are also often associated with changes in the ownership structure.

Tukker (Tukker, 2004) proposes 8 types of PSS business model that reach different weights of service and product component integration:

- Product-oriented Services, where the core of the business is still the selling of the product but with possible service extensions;
- Use Oriented Services, the business still has a product as central, but it is not core. Meaning that the ownership of the product is still under the provider, presented in numerous forms and can be shared among users;
- Result oriented services, provider and user agree on a result or outcome but there is no predetermined result. Meaning the provider can develop the appropriate system that will provide the result.

Tukker further identifies the categories can be decomposed into 8 types of PSS. Table 1 shows the types of PSS business model.

Table 1, proposed PSS business model types (Tukker, 2004)

Categories	Types	Description
Product-Oriented Services	Product Related	In this scheme the provider sells the product but also provide services that are required for each of the product use life. (e.g. maintenance contract, disposal contract)
	Advice and Consultancy	Provider gives advice in the best way to the product to be more efficiently used. (e.g. plant layout, logistics)
Use-Oriented Services	Product lease	The provider maintains ownership and is also responsible for maintenance, repair, and control. The customer pays a regular fee and has “most cases” unlimited and individual access to the leased product.
	Product renting/sharing	The provider maintains ownership and is also responsible for maintenance, repair, and control. The customer pays a regular fee and but does not have unlimited or individual access to the product. Other individuals can sequentially use the product.
	Product pooling	Similar to leasing or renting. But there is simultaneous use of the product.
Result-Oriented Services	Activity management	Outsourcing or 3 rd partying the services. Performance indicators ensure service quality of the outsourced service.
	Pay per service unit	Classical example of PSS example. There is still a product basis, but the customer is only buying the output of that product. (e.g. nr. Of copies in a photocopy machine)
	Functional result	The customer agrees and purchases terms of service from the provider - a condition or scenario. The provider is free to develop the means to comply and deliver the agreed terms. (e.g. ensure maximum crop production, with no pesticide)

The PSS business model has harnessed great attention by different domains (Boehm & Thomas, 2013), from a theoretical point of view, PSS business model may be an answer to a highly turbulent and competitive market and ensure environmental sustainability (Tukker, 2004).

Market dynamics and competitiveness

As the effects of turbulent markets, derived from new customer demands³, and increasing competitiveness puts pressure on traditional based model companies. Companies urge to find new forms of differentiation, ensure competitiveness and tap into new opportunities (Matthyssens & Vandenbempt, 2008) (Mont K. , 2002).

Product driven companies can initially gain some advantage through the addition of services to their value proposition, such as maintenance service, repair, overhaul and exchange of spare parts – a Servitization of the product offering (Tukker & Tischner, 2006). Further, companies need also to develop the network and infrastructures required to start engaging customers and partners, making them an integral part of the value creation process – a service-centred perspective (Kindström, 2010) (Vargo & Lusch, 2004).

As the PSS offering will translate in a product-service bundle, considering both product and service component as one offering (Mahut, Daaboul, Bricogne, & Eynard, 2015). The PSS model include these premises (Baines, et al., 2007), adding also a third layer of which is to consider a nature of PSS business model type, what are the weights of the product-service combination (Johnstone, 2008). In Figure 1, we can see a proposed structuring of businesses towards the PSS business model proposal (Baines, et al., 2007).

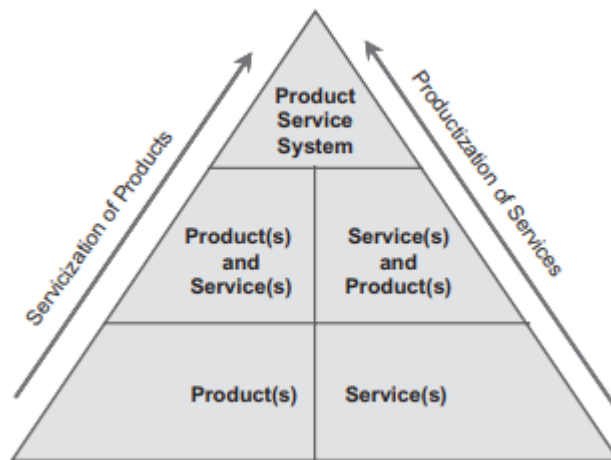


Figure 1, evolution of PSS concept (Baines, et al., 2007)

Due to service inherent characteristics, the PSS business model also changes the perspective of the business relations, from a traditional “*transaction-based*” into a “*long-term-based*” relationship with the customer (Chirumalla, Bertoni, Ericson, & Isaksson, 2012). As product and service have to provide functional fulfilment throughout every phase of the PSS life-cycle, the company has to allocate required infrastructures (resources, data

³ Companies are pressured to deliver with flexibility, quality, delivery dates and prices (Meier, 2010)

management) and deploy a network to ensure a proper service delivery (Baines, et al., 2007) (Mont K. , 2002).

Developing activities surrounding the PSS offering can also heighten the degree of knowledge the company has from its customer and environment (Matthyssens & Vandenbempt, 2008). The introduction of Information Systems discipline fosters the data management perspective (Boehm & Thomas, 2013). Companies can monitor its products⁴ during the PSS lifecycle, extrapolate information, strengthen their innovate aspect and accompany their consumer needs (Mahut, Daaboul, Bricogne, & Eynard, 2015) (Tukker, 2004).

For Month K. (Mont K. , 2002), the goal achieved by a product company transformation into a PSS business model include:

- create added-value to a product, through services;
- provide a base growth strategy on innovation;
- tap into customers preferences, through increase relationship and flow information between company and customers;
- improve total value to customers, as increased servicing and surrounding activities, prolonging product life, extending its functionality and managing its end of life cycle (re-purpose, recycle, the part or entire products);
- take advantage of environmental changes, example take-back legislation.

In this aspect, from the literature review, the requirements to supporting the design of the PSS should comprehend:

- assessment of the level of integration of Product and Service, and the several dimensions within the PSS offering (Andriankaja, Boucher, Medini, & Vaillant) (Mont K. , 2002);
- need to identify the right partners/stakeholders and include them during the development process, create new level of interactions considering their requirements, promote a collaborative PSS Design process (Morelli, 2006) (Baines, et al., 2007);
- access and develop new competences and infrastructure to ensure functional customer satisfaction during PSS lifecycle (Boehm & Thomas, 2013).

Environment

PSS business models are the ideal vehicle to transform businesses into environmentally sustainable (Tukker, 2004). In Goedkoop report (Goedkoop M. J., 1999), “Product Service systems, Ecological and Economic Basics”, it is perceivable the importance given to PSS

⁴ Information Systems can harvest, stock and process data related to the PSS (Mahut, Daaboul, Bricogne, & Eynard, 2015)

as means to restructure businesses into a sustainable economic approach, both in terms of environmental and economic growth.

The shift induced by PSS of a product-oriented business into a service-oriented, also shifts the cost and revenue streams from product (cost of producing) towards services (revenue margins) (Mont K. , 2002). Companies will then be incentivized to seek to maximize service life of products, and product availability, whilst ensuring customer satisfaction (Tukker, 2015).

PSS models are often associated to the circular economy proposal (Boons & Lüdeke-Freund, 2013). According to authors, due to its product and service integrative bundle offering, PSS can provide the grounds to increase re-use, repurpose, remanufacture and recycle of products life-cycle, thus increasing manufacturing efficiency and reducing material consumption (Mont K. , 2002) (Michelinia, Moraesa, Cunha, Costa, & Ometto, 2017).

Mont (Mont K. , 2002) considers that the environmental aspect, the goal of PSS should be:

- promote a closed product life-cycle;
- reduce consumption through alternative scenarios of product use;
- ensure resource productivity and dematerialization of PSSs;
- provide system solutions with total element integration, facilitating resource and function efficiency of elements;

However, the successful transformation into PSS businesses from the environmentally sustainable aspect it is not clear and forthcoming (Mont K. , 2002).

In the literature, several issues are raised to ensure the environmental aspect of a successful transformation. Some of these are:

- during the PSS Design process, the environmental aspect must be intentionally considered for all product life-cycle (Michelinia, Moraesa, Cunha, Costa, & Ometto, 2017);
- “result-oriented” PSS type has the higher potential to ensure circular economy model. As the company shifts from selling products to selling solutions and results, product ownership is transferred to the company. This transfer can allow the company, when the service finishes, to have product return, re-manage its components and module and re-offer the services (Michelinia, Moraesa, Cunha, Costa, & Ometto, 2017);
- a need to access the competitiveness and value added brought by PSS business models (Tukker, 2004);
- determine the factors by which the PSS business model generates less material flow and emission than competing business models (Tukker, 2004).

PSS obstacles

From the consulted literature several authors state that PSS Design implementation can suffer cultural and corporate challenges (Mont K. , 2002). These need to be considered when designing the PSS.

Corporate perspective

A company when conducting the business transformation into PSS, have to transform several layers of their business and re-integrate all stakeholders into a new PSS driven infrastructure and network (Mont K. , 2002). The costs of deployment⁵ and the required changes of revenue streams can impair companies to perform a successful PSS Design implementation (Baines, et al., 2007) (Johnstone, 2008).

Cultural perspective

In most product companies, in the Business to Customer scope, a customer paying for a product means that implicitly is also acquiring it. As the PSS business proposes the maintenance of product ownership to the company, the customer is just paying for functionality, this change of culture *status quo* may polarize customer to not fully embrace PSS (Mont K. , 2002) (Baines, et al., 2007).

2.2. Maintenance Services (MS) and PSS

As this project will focus in the particularities of a PSS implementation in production and maintenance planning of an existing company. As the production technology innovation of the project are dealt by other parties, we will not dwell on the theme of new production methodologies but will rather focus on the integration of the new Production Innovations and the Maintenance Service (MS) within the PSS Design.

A brief study of the current state of MS is required, to provide the grounds on how it can be articulated with production and integration within a PSS Design.

According to (EN:13306, 2010), MS can be defined as:

Maintenance Services are a set of technical, administrative, and managerial actions driven to ensure the life cycle of a product to perform the correctly the purpose and functions it was designed for.

Initially MS were only considered as a support service, nowadays MS is viewed as an integral part of the business and value generator enabler (Parida, 2006)(Figure 2). With the

⁵ (Johnstone, 2008) (Baines, et al., 2007) (Mont K. , 2002) demonstrate several aspects of the PSS implementation require the companies to invest resources to accommodate new infrastructures and networks.

development of new techniques, new and lower prices of acquisition of technology, it is now feasible for industries to integrate these technologies. A doorway to catapult new production, maintenance, products, and service optimization frameworks⁶ (Parida & Kumar, 2003).

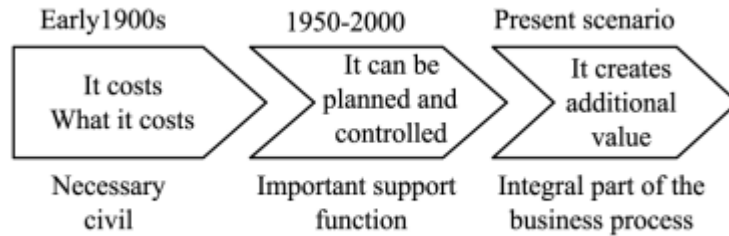


Figure 2, maintenance paradigm (Parida & Kumar, 2003)

As PSS business must ensure an environmental sustainability aspect, MS play an important role in PSS. (Iung & Levrat, 2014). In “result-oriented” PSS, the provider must ensure proper service levels to satisfy the customer needs, it must maximize equipment availability through the management and reduction of any unscheduled downtimes (Mont K. , 2002). So, this kind of business rely heavily in MS as the means to ensure product availability and reliability to the customer (Tukker, 2004).

Takata (Takata, 2013) illustrated the importance of MS as an active participant to ensure the implementation of PSS on an environmentally sustainable manufacturing (Figure 3).

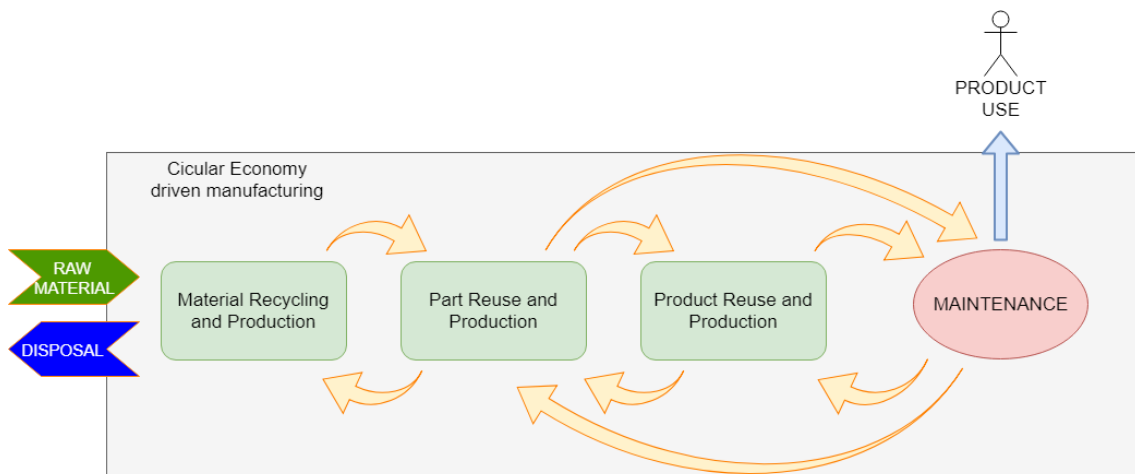


Figure 3, overview of a circular economy driven manufacturing and maintenance positioning (Takata, 2013)

⁶ (Parida, 2006) proposes a framework for modern MS based in three pillars: IT, organisational, methods. In APPENDIX B, page 83.

Based on the requirements to promote PSS, the MS must be reconfigured to accomplish new objectives. These are (Mont K. , 2002) (Takata, 2013):

- manage product life cycle maintenance;
- ensure item reliability, item performance must maintain or surpass customer expectation for quality;
- ensure item availability, item must be ready to use and avoid negative image by customers;
- promote costs optimization, achieve cost of maintenance must be lower than the production;
- acquire information to promote item redesign, easy to use by the customer, easy to produce, easy to maintain.

To achieve this profit vision for MS, the organisation must bring in the stakeholders who will contribute, influence, and be affected by this service (Baines, et al., 2007). These stakeholders are representative to what are the requirements or performance expected to the output of the maintenance service. And case by case the organisation should promote this to design an integrative solution of the maintenance service within a PSS driven business (Iung & Levrat, 2014).

For PSS Design, the Proactive Maintenance⁷ is beneficial as it tackles important maintenance objectives for this business specificities such as, reduction/prevention of outages, increase of safety, maximize equipment life, and a reduction of maintenance costs (Tukker, 2015).

2.3. Gaps in Research

Although there has been massive research regarding PSS unfortunately there are gaps that hinder the successful implementation of PSS on businesses. Companies struggle in transforming from the traditional existing product-based business into a service-product solution provider business (Exner, Schnürmacher, Adolphy, & Stark, 2017) (Kindström, 2010). Also, other point is regarding of how all the promises of high-services revenue PSS takes place (Johnstone, 2008) and how the *sustainability* happens (Mont O. , 2004). As PSS is still not fully understood, a definitive transformation roadmap unfortunately is still undisclosed (Johnstone, 2008).

⁷ In APPENDIX B, page 83, study performed for Maintenance types

3. Design Science Research Methodology (DSRM)

This work is based on the FASTEN project, that aims to deliver a technology integrated PSS solution. The Design Science Research Methodology (DSRM) seems the most suited methodological approach to support the design of the PSS with a technological integrative aspect.

PSS has gained more attention due to new business challenges and technology integration in the industry. As Business Management, Information Systems, and Engineering and Design propose different concepts and approaches of PSS (Boehm & Thomas, 2013), different methodological approaches to support in the development, design and implementation of PSS are also disseminated in PSS literature⁸.

DSRM is a methodological approach developed by Information Systems domain (Geerts, 2011). Peffers et als (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2008), authors who developed this methodological approach, imbued this methodology with three objectives:

- a) provide a nominal process for the conduct of Design Science Research;
- b) build upon prior literature about Design Science in Information Systems and reference disciplines;
- c) provide researchers with a mental model or template for a structure for research outputs.

DSRM purpose is to conduct a re-design of a current situation into situation that should be preferred one, with the creation of artifacts⁹ to achieve the desired goals (Herbert, 1996). However, we must differentiate the intent of DSRM from other design methodologies. DSRM intent is to address unsolved problems through unique and innovative technique or solve a problem in an effective or efficient manner (Hevner, March, Park, & Ram, 2004).

The DSR methodological proposal can be viewed in the following Table 2:

⁸ (Clayton, Backhouse, & DaniI, 2011) offer an interesting overview and evaluation of the existing methodologies to support PSS design.

⁹ An artifact can be a concept, model, method or an instantiation, created for a practical purpose. The created artefact should be relevant and present novelty to the design proposal (Herbert, 1996) (Geerts, 2011). In APPENDIX B, page 88, for further exploration on the theme.

Table 2, DSRM adapted (Peffer, Tuunanen, Rothenberger, & Chatterjee, 2008)

Activity	Activity description	Knowledge
Problem identification and motivation	<i>What is the problem?</i> Research problem definition and solution value justification	Problem in PSS Design (Literature Review)
Define the objectives of a solution	<i>How the problem should be solved?</i> The criteria's that the solution must meet.	Motivations, objectives for PSS Design
Design and development	<i>Create an artifact that solves the problem.</i> Create constructs, models, methods or instantiations in which a research contribution is embedded.	PSS Design framework proposal (Framework proposal) Identify a real case. (Elevator Company A)
Demonstration	<i>Demonstrate the use of the artifact.</i> Prove artefact works, by solving one or more instances of the problem	Apply the framework proposal in a real case. (tools/methods to enable PSS Design framework proposal)
Evaluation	<i>How well the artifact works?</i> Observe and measure the degree of adherence the artifact has with the solution. Compare objectives with results.	Results obtained from the framework application. (Results overview)
Communication	<i>Communicate the performed work.</i> Problem, solution (demonstrate the utility, novelty, and effectiveness of the solution to researchers and other relevant audiences)	Propose future works by which the PSS Design framework proposal can be applied and studied.

The DSRM is composed of 6 activities, in sequential order, that act as a methodological guideline basis – found in column 1.

Column 2 comprehends a brief description of what the each of the activity.

Column 3 binds each activity to the knowledge performed in this work. The knowledge base is a set of knowledge tools (foundational theories, frameworks, instruments, constructs, models, methods, and instantiations) that serve the DSRM as materials to

accomplish each activity (Geerts, 2011) (Hevner, March, Park, & Ram, 2004). Choosing the right knowledge tools, explaining the selection, and explaining the way they are used, is a principle to obtain a feasible and rigorous DSRM (Geerts, 2011).

The arrow in the left of the table demonstrates that DSRM is an iterative process and will suffer a build-and-evaluate loop (Hevner, March, Park, & Ram, 2004). The Evaluation and Communication activities are valuable sources of feedback information of the designed artifacts and provide a better understanding of the problem, triggering re-iteration(s) of the design process (Geerts, 2011).

Based on DSRM, this work will propose a framework that will support the PSS Design for a firm dedicated to Elevator production and maintenance service.

3.1.PSS Design Framework proposal

Within this work a framework proposal was developed, integrating tools/methods to support the PSS Design. A framework enables to establish a basis of how the research will be conducted and to contribute with the augmentation of knowledge base through a scientific process.

Based on the framework methodology proposed by Offermann et al. (Offermann, Levina, Schönherr, & Bub, 2009), an adapted version was designed considering the work objectives and limitations.

The proposed framework will consist in three main phases.

Phase 1 – Problem Identification

This phase is consistent to the activities: Problem Identification, Define the Objectives of a solution and Design and Development. A decision to consolidate the three activities into one phase, was to allow the identification of the information required to layout the current state of the problem. As this phase relies majorly in acquiring, organising and treating information from different sources, validation from key stakeholders is valuable and has to be constantly requested throughout the phase.

Three steps compose this phase which correspond to the accordingly to the first three activities.

Step 1: Case Study Definition – an initial “face-to-face” with the problem. This step is also used to have first-hand information from the Company Experts, and answering key questions such Problem definition, Problem Scope, Solution Objectives. Some initial Literature Review can also be performed to complement some key aspects.

Step 2: Problem Discovery – this step involves expanding the knowledge and seeking new sources of information. The baseline in this step is to create an overall overview of the firm from internal and external point of view.

Step 3: Artifact Development – this step translates in organising and treating the information acquired from past steps through the development of artifacts. The idea behind this step is to design the current situation of the firm. An important aspect is to create meaningful artifacts and in a common language with the stakeholders.

Phase II – Solution Design

In this phase, based on the artifacts developed in the phases before, will demonstrate that the artifacts can support the solution design process.

Having information on the current firm status and what are they objectives, the following phase is Solution Design:

Solution Design – Based on the artifacts developed beforehand and based from information acquired of the solution objectives. A first approach is taken together with chosen stakeholder, to co-design a possible solution. To achieve a faster and hand-on-approach kick-off, in this 1st iteration of the solution design only the firm and technology experts were included. This allowed flexibility in terms of time and complexity on reaching a starting possible solution proposal. In this phase some of the artifacts proposed in the past chapter can be utilized to translate the solution design. Or new artifacts can also be deployed to help provide support on evidencing key aspects of the solution proposal.

Phase III – Evaluation

The last phase of the methodological framework concerns evaluating the reached PSS Design solution.

Evaluation – The intent is to validate key aspects of the designed solution. The tools utilized for this phase can adjust according to type of evaluation is going to be conducted, at who is the evaluator. In this work it was chosen a qualitative evaluation, choosing a stakeholder who participated on the design process and a stakeholder who did not participate. The tools utilized were BDD stories (use case scenario) and unstructured interviews.

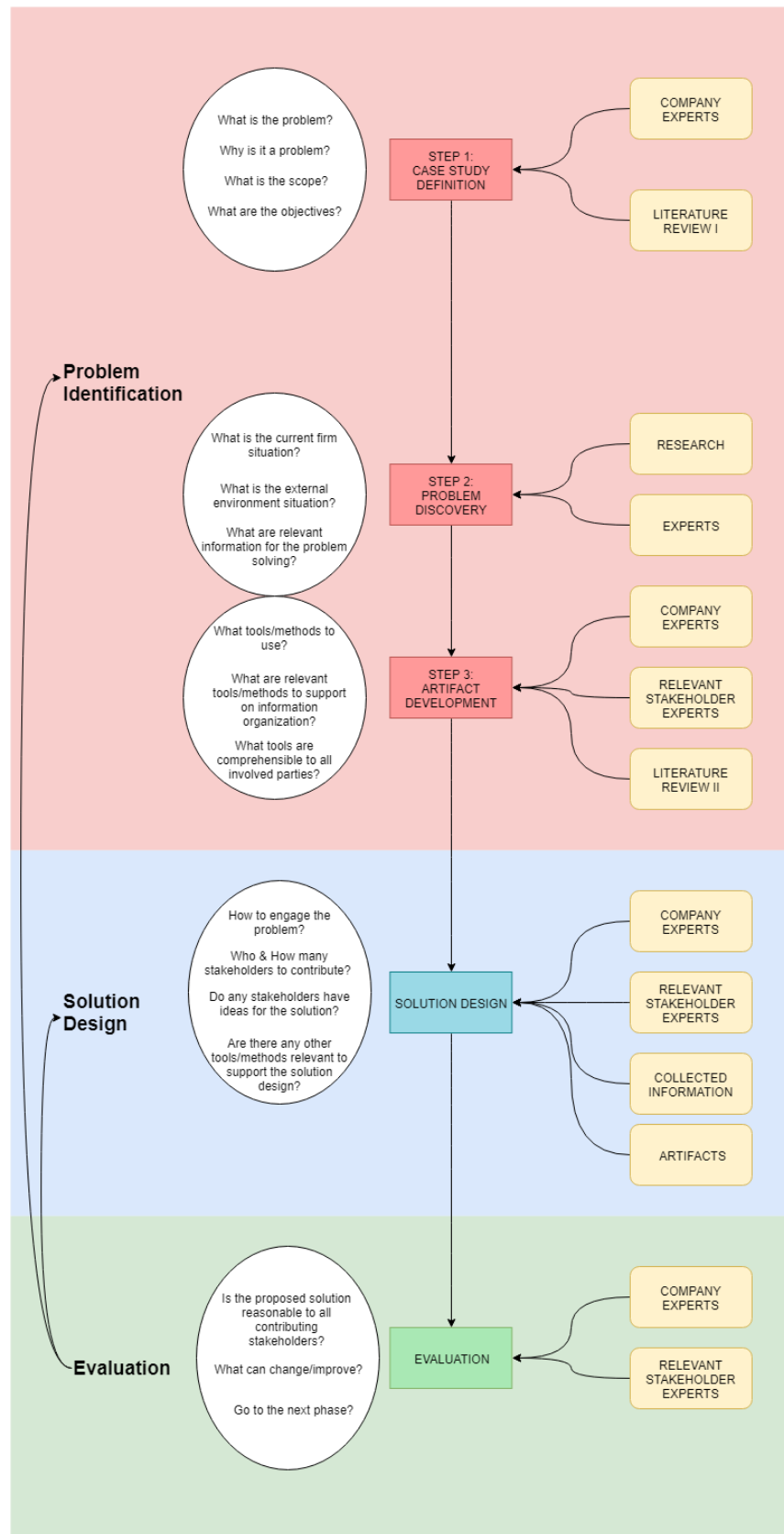


Figure 4, Framework proposal based on the DSRM

4. Problem Identification

This chapter scopes the two entities by which this work is linked to: the Company case study, focused on the production and maintenance case study and the FASTEN project, driven by INESC TEC, which provides the technologically innovative side.

Due to protection restrictions, the name of the company has been redacted and we will address it as Elevator Company A.

4.1.Step 1: Case Study Definition

The real case that serve basis is from a renowned Elevator Company A located in Brazil.

Through the information available in the project agreement, information gathered in company portal and meetings¹⁰ held with the company representatives and FASTEN project researchers, an initial problem framing was performed:

- Elevator Company A sells elevator system solutions in South America by a network of local agencies and representatives – Product provision.
- Elevator Company A also offers maintenance services to elevator systems (from their own brand and others) by contract, or requisition. This is also ensured by a network of local agencies and representatives – Service provision.
- Elevator Company A owns a production plant in south Brazil, supplying their own product component to all South America. These components will be used be available both for selling or the maintenance service of elevators – Manufacturing advantage.
- There are several types of active elevators all over South America, each with their own component type and specifications – high variability and dispersion of product pool.
- Elevator Company A contractualized maintenance service must ensure quality parameters such as elevator functionality and performance, on time fashion – ensure Service Quality.
- The Elevator Company A has active programs to reduce material and carbon footprint – commit to an environmentally sustainable business.
- Elevator Company A has invested in exploring technology potential as means to gain process advantage efficiency and efficacy – technology advantage.
- Elevator Company A is interested in the technology integration from the FASTEN project: additive manufacturing capabilities through the usage of IoT technology integrated in existing manufacturing capabilities (FASTEN, 2017).

Problem identification

¹⁰ In APPENDIX A, page 82, participation on FASTEN meetings

Based on the outputs of the problem framing and the FASTEN project agreement. The problem identification:

- How can we design a product-service system offering?
- How can we integrate the available technologies?

Objectives of the Solution

A re-design of Elevator Company A, production and maintenance businesses, by:

- support the (re) design of the firm Product-Service offering;
- conduct a technology driven transformation (based on the FASTEN project technologies).

4.2. Step 2: Problem Discovery

4.2.1. Firm Background

The Elevator Company A Brazil is a business segment of a major industrial multinational foreign company dedicated to three segments, steel production, industrially machinery and services. The Elevator Company A belongs to the service segment of the group.

The Elevator Company A was formed through the acquisition of local companies in Brazil, dedicated to the market of elevator maintenance, during the periods of 1999 and 2002.

Elevator Company A has a presence in Brazil through 10 Business Units that are responsible for the commercialization, installation, and maintenance services of elevators and other similar equipment's.

What distinguishes Elevator Company A from the regional market competitors is that it also owns a manufacturing plant, that support the business through the development, manufacturing, and assembly of its own elevators, relying little on equipment importation.

Firm Organisational Structure

The Elevator Company A is guided by a Mother Firm Headquarters. The Elevator Company A reports to a centralized Business Manager but has relative operational autonomy.

The firm organisational structure is portrayed in the following Figure 5.

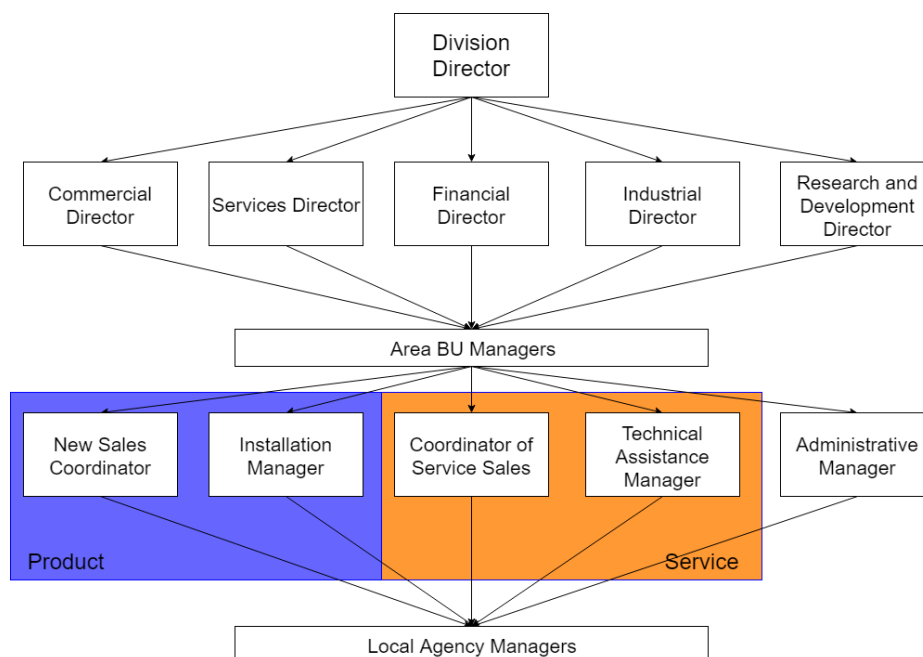


Figure 5, Elevator Company A Brazil Organisational Chart

Vision

The Mother Firm vision is “Engineering confidence with everything we do.”

On the Elevator maintenance level, the vision is: “To provide good services and quality products to reach total satisfaction, obtaining positive results for the customer, suppliers, and employees.”

Mission Statement

Both Mother Firm and Elevator Company A share the same mission statement. The following statements were taken from the Elevator Company A website:

A technological and materials company. Based on competence and diversity, global and traditional performance are key for global leadership.

We meet the challenges of tomorrow with our customers. We are customer-focused. We develop innovative products and services that create sustainable infrastructures and promote efficient use of resources.

We hold ourselves to the highest standards. We engage as entrepreneurs with confidence, a passion to perform and courage, aiming to be best in class. This is based on the dedication and performance of every team member. Employee development is especially important. Employee health and workplace safety have top priority.

We share common values. We serve the interests of the group. Our interactions are based on transparency and mutual respect. Integrity, credibility, reliability, and consistency define everything we do. Compliance is necessary. We are a responsible corporate citizen.

Organisational Objectives

The Elevator Company A in line with their mother company objectives, have delineated three objectives by which they should challenge their business:

Quality

- Develop, sell, and produce the best product and services with worldwide technology,
- Compromise with continuous improvement of the process with the aim to grow rentability, quality and productivity;

- Satisfy the customers, shareholders, collaborators, and communities to build and develop lasting relationships.

Environment

- Prevent pollution and control the negative impact on the environment;
 - o Reduce to 19% global gas emission goal;
 - o 100% of any CO2 emission is compensated by the purchase of carbon credit;
 - o Reduce logistic transportation, to reduce CO2 footprint;
 - o Implement 5R¹¹ program for residual management;
- Comply any legal environmental requirements and subscribed to others;
- Ensure the necessary resources to achieve the continuous improvement of SGA.

Safety and Security

- Security as top priority;
- Prevent work accidents and occupational diseases;
- Comply any legal work requirements and subscribed to others;
- Ensure the necessary resources to achieve the continuous improvement of SGSSO;
- Bring awareness to the collaborators regarding the importance of Security and Occupational Health

4.2.2. Product-Service Characterization

This subchapter will consider the aspects compounding the firms value proposal, what are the customers' requirements and needs.

Products

Elevators, fingers (horizontal escalators), escalators, electronic or mechanical bridges, industrial automatic solutions, supporting equipment's and components.

Customer Type

The Elevator Company A customers come from a wide range to areas and with different kind of necessities. Based on the mother company website for the Elevator service business area the customers can be decomposed in:

¹¹ 5R – Organisational objectives towards Reduce consumption to avoid waste generation; Rethink attitudes with environmental attitude; Recycle everything that finished its purpose; Reuse to maximize product lifetime; Reject not environmentally friendly products.

Commercial - modern companies require to move constantly people through floors, the Elevator Company A provides a solution for the commercial buildings with a promise to deliver reliability, shorter ride times and less congestion.

Residential - the Elevator Company A, understand residential client elevators require them to be running efficiently, reliable and safe is of the utmost importance for the client and their tenants. The Elevator Company A offer the ability to design around the aesthetics of the customer unique building, provide tenant security and improve energy efficiency.

Industrial - beyond just moving people, the Elevator Company A offer solutions that help move heavy machinery, vehicles or any other load types, promising large capacity or unique projects can be attained.

Transportation – the Elevator Company A can design solutions that keep the customer passengers on the move. They support their selling pitch on their expertise that can enable to can coordinate together with public transportation schedules allowing their passengers to not be delayed.

Healthcare – this area demands the utmost in reliability and health safety; for example, concerns like poor indoor air quality and space limitations are not an option. The Elevator Company elevators are designed to offer customizable features to meet the unique operational requirements of medical facilities.

Government - the ability to work within the detailed criteria that accompanies government contracts is a key remark for the company and is familiar with.

Hospitality – the company offers a full range of equipment to meet the all kind of needs from different size, and type of hospitality organisations. The company promises durability and reliability of the equipment.

Education – concerning the needs of the customers to ensure students health and building security and safety.

The customer who recurs the Elevator Company A business, is looking for accessibility solutions for buildings and spaces, for persons or cargo. And by contracting the maintenance service the customer wants to ensure equipment reliability, and availability.

Product Life Cycle

Elevator Company A is dedicated to representing the Multinational Group in South America. The firm is responsible for all product lifecycle stages, from development, production, acquisition (commercialization, importation, exportation), installation, maintenance of the company's equipment's. There are last steps dedicated to the disposal and destructions of pass due equipment. A representation of the different areas on which the company specializes can be seen in Figure 6.

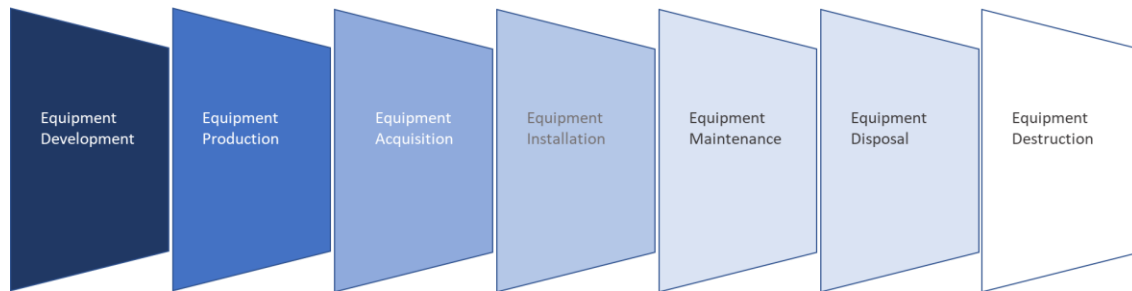


Figure 6, Elevator Company A product life-cycle

Firm Service Distribution

The company is present in 22 Brazilian states and in 15 Latin American countries, Uruguay, Paraguay, Chile, Argentina, Mexico, Porto Rico, Peru, Costa Rica, Ecuador e Colombia.

The structure in Brazil, 10 Business Units¹² represent the Elevator Company, each of them with its own autonomy to manage day-to-day business. These Business Units are responsible to conduct commercial business, service provision and equipment maintenance within their area. Further the company covers 510 Brazilian cities through a network of branches and affiliated stores who report to their area Business Unit.

Elevator Maintenance Service

For this research we will pay attention to the Maintenance Service of the Elevator Company A (Figure 7).

¹² The Elevator Company Business Units in Brazil are Rio Grande do Sul, Santa Catarina, Paraná, São Paulo (Mato Grosso e Mato Grosso do Sul), Rio de Janeiro (Espírito Santo), Minas Gerais, Distrito Federal (Amazonas, Goiás e Pará), Bahia, Pernambuco (Sergipe, Rio Grande do Norte, Alagoas e Paraíba) e Ceará (Maranhão).

The reason is according to the proposed case study the maintenance service is responsible for most of the activities involving – product installation, equipment functionality assessment, equipment maintenance methods – and are in direct contact with the customer.

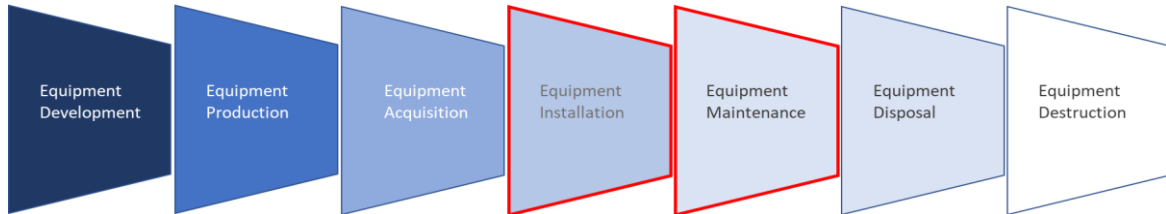


Figure 7, Elevator Company A Maintenance Service

The Equipment Installation and Maintenance Service is carried out by the local representation agencies of Elevator Company A. This representation agencies have a team of mechanics and technicians that perform the installation and provide the maintenance services of the equipment within their service area.

Maintenance Service portfolio

The Elevator Company A proposes different kind of packages for maintenance service provision.

The contemplated maintenance packages are directed for residential and commercial buildings. The packages vary according to provided services at different price range.

Express	Service	Plus	Premium	Performance
For residential buildings up to 20 floors with low or medium traffic. - Preventive + Corrective Maintenance - Team availability 24h/7 days per week. - Call costs included - Component warranty: 6 months.	For commercial and residential buildings. - Preventive + Corrective Maintenance - Team availability 24h/7 days per week. - Call costs included - Component warranty: 12 months.	For commercial and residential buildings. - Preventive + Corrective Maintenance - Coverage on components with higher probability of degradation (acc. Contract) - Team availability 24h/7 days per week. - Call costs included - Component warranty: 12 months.	For commercial and residential buildings. - Preventive + Corrective Maintenance - Coverage on components (acc. Contract) - Team availability 24h/7 days per week. - Call costs included - Component warranty: 12 months.	For commercial and residential buildings with high traffic. - Preventive + Corrective Maintenance - Performance of availability - Coverage on components (acc. Contract) - Team availability 24h/7 days per week. - Call costs included - Component warranty: 12 months.

Figure 8, maintenance service packages proposed by Elevator Company A

As we can see in Figure 8, the common maintenance services provided by the packages is the offering of preventive and corrective maintenance, ensuring a team availability of 24/7, and component warranty (with a wider gap in the highest cost packages).

A second type of service is also offered by the Maintenance Service, the equipment modernization. At this option, the customer who wishes to refurbish, update components or make a total replacement of their existing equipment, can have the Elevator Company A maintenance team to evaluate and propose available options (Figure 9).

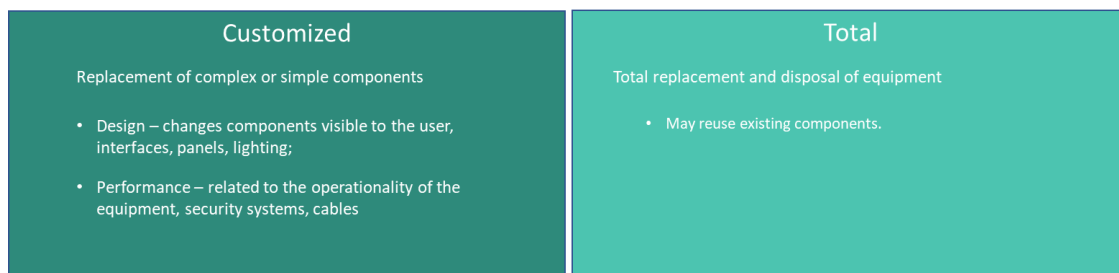


Figure 9, Elevator Company A maintenance modernization packages

4.2.3. Strategic planning

Strategic planning has the aim is to keep in check the balance of the organisational side with the external environment. Ensuring this balance requires a constant evaluation of the organisational products and services as means to maximize the organisational performance.

PESTEL

The PESTEL analysis provides of the external market factors that influences the business. For the Elevator Company A, the market focused on is the Brazilian market. By which we saw in the previous is where most of the company's agencies are distributed in the South American continent. For this analysis, we are also going to consider the FASTEN project technological basis as a promoter of the existing technological trends for this market.

In Table 3 the PESTEL analysis for the Brazilian market is detailed.

Table 3, PESTEL analysis for the maintenance elevator services in the Brazilian market

Political	• Political crisis can affect company businesses; • Promotion of more environmentally sustainable businesses;
Economic	• Brazil is the 6th largest elevator market worldwide, with an estimated 400.000 installed elevators; • Due to economic instability, purchase power has become lower and variable by state;
Social	• In Brazil, commercial Elevators are viewed as not only a transport but a means to interact – example given on an interview of elevator boots with adverts; • Habitational and commercial building management have different level of actors with different roles;
Technological	• Pilot projects with new technologies such as IoT, Big Data are starting to provide viable solutions to access in real time equipment information to support maintenance routines; • Composite solution can replace steel, providing lighter and more durable equipment; • 3D printing technology has developed, providing an accessible and cheaper solution to support a more flexible production;
Environmental	• Concerns regarding environmentally sustainable businesses; • Promotion of circular economy and component reusability; • Emission and waste control;
Legal	• Data acquisition and protection status; • Federal Safety and regulatory norms for elevators can impact how, when maintenance services are performed; • State Safety and regulatory norms for elevators can impact how, when maintenance services are performed; • Certification and tax payment to perform installation and maintenance duties.

SWOT

SWOT matrix analysis is a strategic planning technique which foster the internal examination of the organisation, strengths, and weaknesses, versus the external examination, of the threats and opportunities that will enable the organisation survivability, chances to grow and improve (Harrison, 2010).

In this section a SWOT analysis will be performed to analyse the current situation of the Elevator Company A Maintenance Service in Brazil. The information was obtained through the access of websites about elevators, meetings with company managers and through semi-structured interviews with users (Table 5).

Table 4, SWOT analysis for the Elevator Company A maintenance service

Internal Environment	Strengths	Opportunities	External Environment
	• Own a production centre which can directly provide the service components without importation; • Good network and coverage of affiliated stores provides a direct contact with customer; • Development and research department.	• Provide maintenance to other equipment brands; • Integration of new technologies to support and provide maintenance; • Equipment modernization;	
Internal Environment	Weaknesses	Threats	External Environment
	• A wide range of elevator pool; • Elevators (due to old series) with no available spare parts; • Limited HR for maintenance teams;	• Mature market, with high competition and other big elevator brands; • Economic downsize, customer seek cheaper maintenance providers; • Data protection and handling	

4.2.4. Partner Stakeholder FASTEN Project

An important aspect concerning the PSS design is the technology integration. The partner stakeholder FASTEN project, promotes several new technologies that can enable gains to support the PSS design.

The FASTEN project aim is to design and develop the architecture of connected additive manufacturing systems that will enable to harness the potential brought by IoT platforms, modern automation, and predictive and prescriptive software, with the objective in reducing the unit cost of custom designed products. This features of the FASTEN framework will be translated into the development and implementation of a FASTEN Industrial Analytics Suite on two real case studies, that will help demonstrate this application potential (FASTEN, 2017).

FASTEN technology framework (Figure 10) provides the means to assess productivity, efficiency, and global performance of the business.

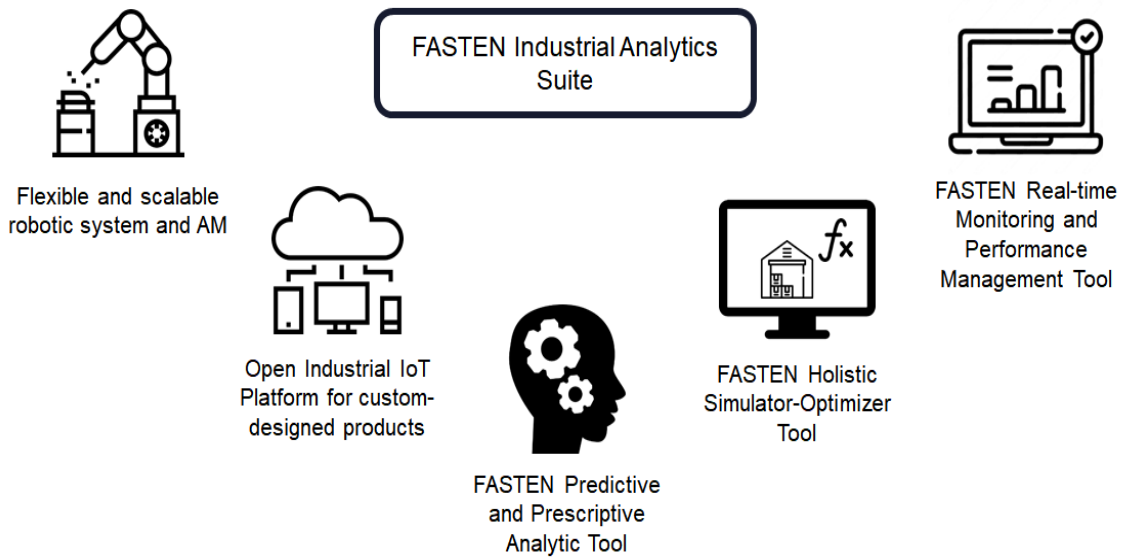


Figure 10, FASTEN technological framework

FASTEN framework (FASTEN, 2017) is constituted by:

- Automatization and Additive manufacturing¹³ layer:
 - *Objective:* Flexibilization of the industrial operations.
 - *Technology:* Additive manufacturing consist in a combination of CAD/CAM software and 3-D printers designated to perform manufacturing tasks. The automatization consists in the use of a flexible and scalable mobile robotic system. This system is integrated with the industrial environment in order to perform specific tasks and navigate through the industrial floor.
 - *Gains:* Cover the industry gaps in terms of small and customized production, faster and more efficient system reconfiguration, and cost reduction and lead-times. Advanced perception of the path planning and object localization, recognition, and handling.
- Open-industrial IoT platforms layer:
 - *Objective:* ensure continuous data flow from different business parameters.
 - *Technology:* Develop and deploy a FASTEN platform that will allow crossing between Physical Manufacturing System (PMS) and Cyber Manufacturing System (CMS).

¹³ Additive manufacturing is the process of utilizing digital 3-D model data to produce a physical part through material layering (FASTEN, 2017).

- *Gains*: horizontal and vertical integration within the manufacturing system. Vertical integration ensures the flow of data, events, and information from real world to digital, and vice-versa, through sensing-actuation loop. Horizontal integration will provide the means to interact (access and manipulate) with the heterogenous data originated from multiple resources of the manufacturing system, this is done through open standard APIs.
- Predictive real-time simulation and optimization:
 - *Objective*: transform data into knowledge (data acquisition, management and treatment).
 - *Technology*: Machine learning algorithm techniques.
 - *Gains*: Gained knowledge will allow to have a precious insight on the current and forecasted state of various functional areas within the organisation such as manufacturing, operations, supply chain, quality. Having this input will allow the organisation to achieve, in terms of manufacturing, fast and reliable decision making, supporting a higher production flexibility and approach towards the customer demands. By also, applying machine learning algorithm techniques, will allow the system to predict system failures, demands of material or infer material useful life. For maintenance, this information is of great use as it will allow to implement a more customized proactive maintenance approach, by planning in advance suitable and customized service it will allow to reduce unscheduled system downtime and manage the lifetime, durability, of the assets (FASTEN, 2017).

4.3. Step 3: Artifact development

This chapter considers the information gathered from the different sources, an analysis is performed to transform the information into artifacts to be utilized in further development of the PSS solution proposal. Each subchapter contemplates a PSS Design artifact.

4.3.1. Material and Information Flow Analysis (MIFA)

It is necessary to understand the process of how value (Product and Service) is delivered to the customer – the supporting value chain. To achieve this, a Material and Information Flow (MIFA) diagram seemed an appropriate tool to have a common ground with the Elevator Company A representatives to discuss the matter in question.

MIFA is a lean management tool, that is based on Value Stream Mapping (VSM). The main intent of this tool is to identify value and non-value-added activities. Also, it is used to understand material and information flows within the supply chain of the firm, from suppliers towards customers (Kurilova-Palisaitiene & Sundin, 2014).

MIFA tool was chosen due to:

- allows to have key insight on (Rother & Shook, 1999):
 - Current state (sequence) of operation is processed within the firm;
 - Possible optimization opportunities;
 - Simplify operations, reduce or eliminate activities that bring no value to customers;
- it is a pictorial diagram, making an easy tool to communicate with the involved stakeholders;
- it is widely utilized in the industry.

An adapted version of MIFA will be used to perceive also in terms of Service Chain – this customer interaction information flow and its utilization within the company maintenance and production planning.

To understand the current overall material and information flow in the company, a scenario of material request by the maintenance service towards the organization supply chain is used for this purpose. An assumption of MIFA for the scenario of the overall organization supply chain with the maintenance service provision can be viewed on Figure 11.

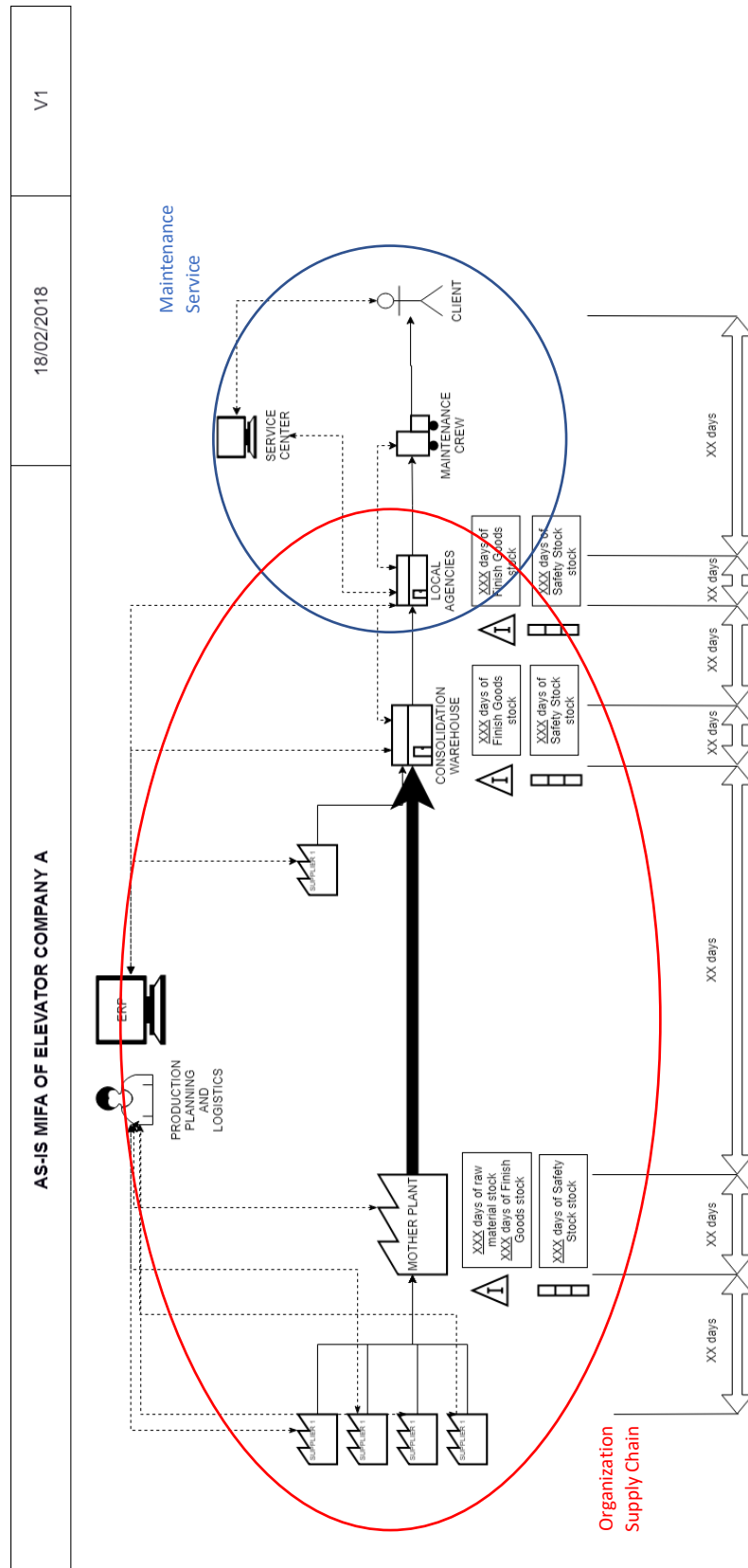


Figure 11 – AS-IS MIFA of Maintenance Service and Production Planning

4.3.2. Elevator Maintenance Service Stakeholder Map

Based on the information acquired from the company from the tool MIFA, and other sources of information. A Stakeholder Mapping tool is done to help perceive the interested parties for the PSS design. As the Company is located in Brazil, the majority of stakeholders are from South America.

In a macro level, four groups compose the stakeholders that interact through material and information flow. In (Figure 12), are identified:

- *The Customer (Firm perspective):*
 - direct customers of the maintenance service identified target customers of the company, who pays directly to the firm the equipment activities (elevator).
- *The End-users (Equipment users):*
 - the elevators systems are means of transport, to reach from point A to B;
 - the elevators systems are an element that compose the environment ¹⁴ of the (Elevator Company A) Customers;
 - customers of the (Elevator Company A) Customers are End-users of the elevator system. Although not directly associated to the Elevator Company, they influence the service requisition through the demand of the equipment availability and operability.
- *Company Alignment (Firm perspective):*
 - the Elevator Company A, production and the maintenance service, is the Brazilian subsidiary to a broader multinational company sharing common principles, mission and vision, and aligning its business strategy according to these –Mother Company;
 - the Elevator Company A is composed by a production side and a maintenance service;
 - concerning the elevator production:
 - manufactures complete elevator systems and components;
 - develops and customizes elevator systems;

¹⁴ Based on the Servicescape model by Booms and Bitner, service elements are non-human elements that compose the physical environment on which a service process occurs.

- product supply chain, warehouses, consolidation points, transportation;
 - requires information from the elevator maintenance service to know what to produce, information for development;
- concerning the elevator maintenance service:
 - manages the clients;
 - commercializes elevators;
 - installs the elevators systems;
 - performs elevator maintenance;
 - needs an influx of material from the production side.
- *External Stakeholders:*
 - suppliers – Material suppliers for the production;
 - partners – Logistics (example: trucking/shipping companies), Local Agencies (independent local representatives,), Technology providers (ERP, CRM, productive systems), Other services (some case maintenance teams);
 - government – Legislation (state/federal, example: “federal requirement for all elevators must have maintenance performed in regular basis); Safety Inspection (equipment’s must ensure safety and regulatory standards).

The following Figure 12 provides more insight about the different level of stakeholders that exist around the firm.

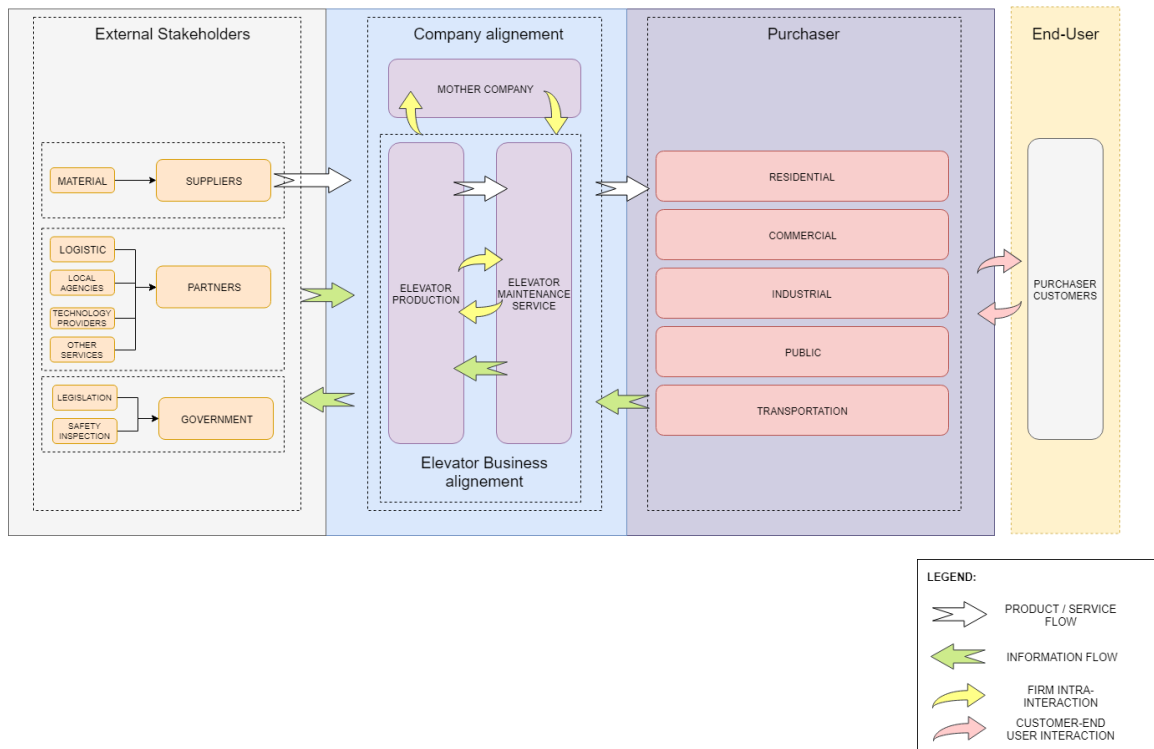


Figure 12, Elevator Company A business and project stakeholders

4.3.3. Business Model Canvas (BMC)

Based on the findings of the current state of the Elevator Company A, a Business Model Canvas of the firm service provision was drafted.

BMC tool that enables the description, visualization, and organization of the firm current business model state or develop new business model proposal, all in a shared language (Osterwald & Pigneur, 2010). The BMC covers the four core components of the business, customers, offer, infrastructure and financial viability, through nine basic business elements (Wallin, Chirumalla, & Thompson, 2013) (Osterwald & Pigneur, 2010).

- Value proposition – validate the bundle of products and services that create value for a specific customer segment.
- Customers – identify the different groups of people or organizations a firm aims to reach and serve.
- Channels – describes the stage that the firms utilize to reach and interact with its customer segments to deliver a value proposition.
- Customer Relationship Management (CRM) – describes how the firm will attain and establish a relationship with specific customer segments.
- Key Activities – describes the most actions/tasks a company must do to ensure its business model work.
- Key Resources - describes the most important assets needed to make a business model work.

- Partners – describes the network of suppliers and partners that make the business model work.
- Revenue Streams – represents the cash a company generates from each customer segment.
- Cost Streams – describes all costs incurred to operate a business model.

Authors (Wallin, Chirumalla, & Thompson, 2013) appoint BMC tool can be a valuable artefact to support on the PSS design, as it covers the 4 core elements of PSS models, namely:

- concerns on Network and Infrastructure – points of contact, enhancing CRM - customer, supplier participation, data collection;
- choosing the Product-Service offering – requirements, capabilities, flexibility;
- revenue models and costs – shift on the perspectives implied of transaction-based business towards long term relationship;
- strategic positioning – enhance firm disposition for further innovations and improvements.

The current business BMC presented in Figure 13 is drafted using elements collected from STEP 1.

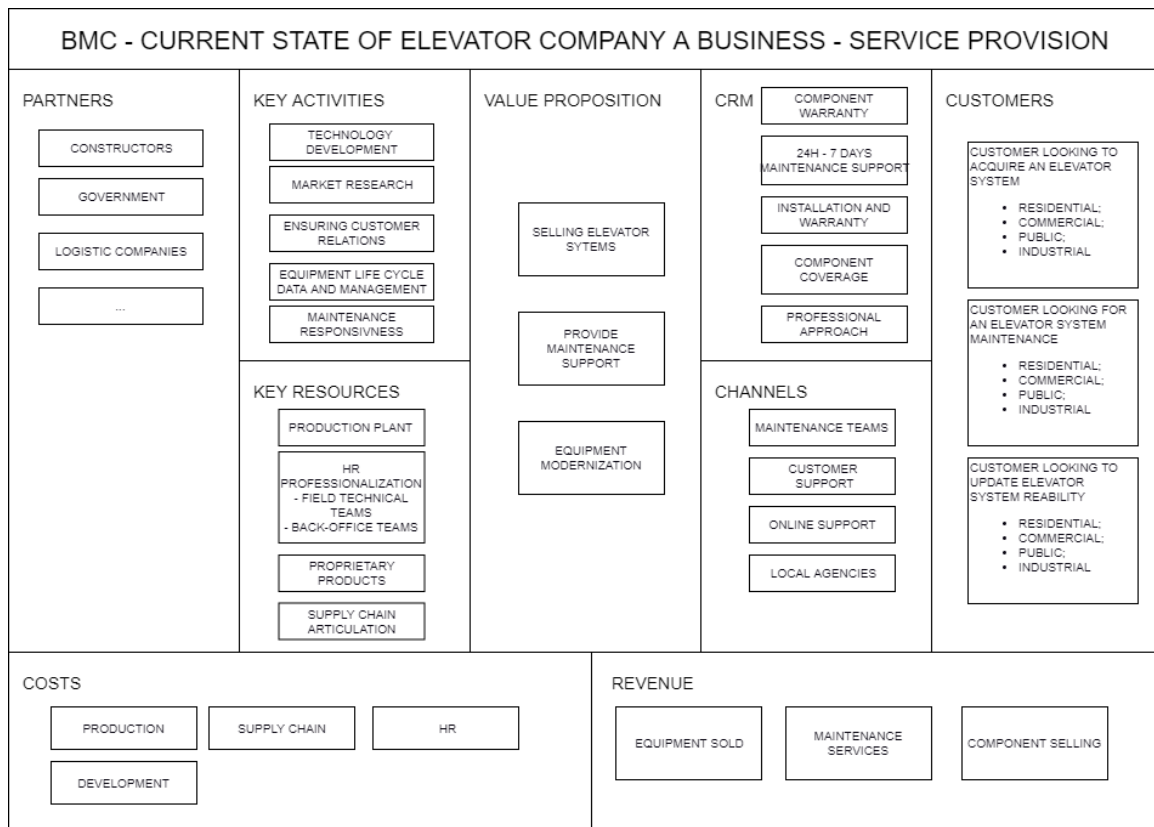


Figure 13, Business Model Canvas for Elevator Company A

Customer Definition

Although on the research to understand who the firm aims their products, the company defines as their customer segments Residential, Commercial, Public (Public Services, Hospitals, Educational buildings), and Industrial. In terms of available offering the firm must characterize in a broader sense what these segments need from their value proposition (Figure 14).

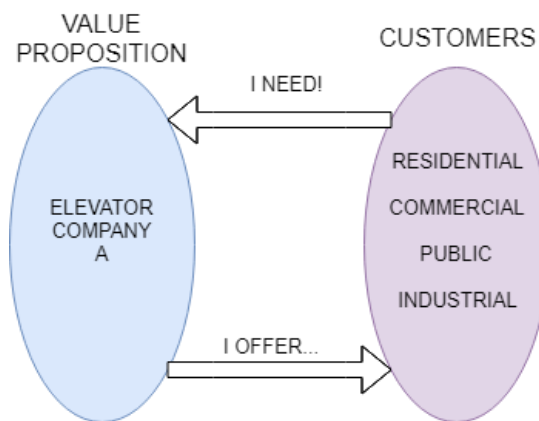


Figure 14, firm and customers exchange framework

Having Figure 14 as basis, it was feasible to characterize three macro-customer types for the Elevator Company A:

- customers looking to acquire (purchase) an elevator system;
- customers looking for an elevator system maintenance;
- customer looking to update elevator system reliability.

A micro-segmentation of the macro-segmentation can be done, subdividing the macro-segments into Residential, Commercial, Public (Public Services, Hospitals, Educational buildings), and Industrial. Enabling to characterize further and adjust the value-offering according to the each of these micro-segments.

In this work we will not go in further detail and will work with the customer macro-segments.

Value Proposition and Business structure

The Elevator Company A has three value propositions, associated to the three macro-customer segments. On the following Table 5 we can see how the value proposition is structured.

Table 5, Value Proposition within the firm infrastructure

Value Proposition	Description	Customer	Channels	Added services	Revenue Streams
Selling Elevator System	Product commercialization process. Purchased equipment is expedited to a local agency. Local agencies manage the process. Customer or installation team pick equipment.	Looking to acquire an elevator system.	Online. Phone. Local agencies. Maintenance Teams.	Product-driven: equipment customization (based on available portfolio), installation (optional) and warranty (by law).	Selling equipment.
Maintenance Services	Elevators are required by law to have contracted maintenance. Can be contracted or single-service-request. Maintenance teams are based in local agencies to serve within a service area. Local agencies manage the process.	Looking to ensure equipment system availability.	Online. Phone. Local agencies. Maintenance Teams.	Service-driven: equipment functional verification (base, required by law), maintenance support availability	Providing Maintenance Services (according to contract). Selling components, (according to contract).
Value Proposition	Description	Customer	Channels	Added services	Revenue Streams
Equipment Modernization	Equipment needs tuning. Customer needs to purchase components or update system. (Optional) Maintenance teams can access in loco the needs. Customer purchases components and/or service. Maintenance teams are based in local agencies to serve within a service area. Local agencies manage the process.	Looking to update elevator system reliability.	Online. Phone. Local agencies. Maintenance Teams.	Service driven: Assessment of the equipment. Selling. Installation. Product driven: components selling.	Providing Maintenance Services (Evaluation/ Installation) Selling components.

Production – a Key Resource

Although the Elevator Company A primes to be also a product manufacturing company, this aspect is only seen as a key resource, and advantage for the company (Social, 2003).

The Manufacturing can be seen as a Key Resource as it provides the firm a source of product availability (inhouse production, not relying in third parties or imports), ensuring proprietary designs and also product quality.

As a downside, the manufacturing carries other issues/costs related to manufacturing and logistics.

Overview

From the BMC we determine:

- service activities are key for the Elevator Company A success in delivering their value proposition – sell their products, provide maintenance service, and ensure customer satisfaction;
- local agencies, customer support and maintenance teams represent the structure of the firm recognizable to the customer;
- manufacturing is perceived as a Key Resource of the firm Business – and advantage;
- the PSS design should focus on reshaping the Maintenance Service aspect of the business.

4.3.4. Maintenance Service characterization

Having defined the participation of the Maintenance Service (MS) in the Elevator Company A value proposition.

From the BMC we could extract that from the activities of MS within the firm, the equipment maintenance service is most service-directed offering and therefore more complex in nature.

Through the study performed regarding MS methods¹⁵, and the Elevator Company A service proposal, three types of maintenance service compose this offering: Preventive Maintenance, Corrective Maintenance, and Modernization (Figure 15).

¹⁵ In APPENDIX B, page 83, Maintenance Engineering Methods

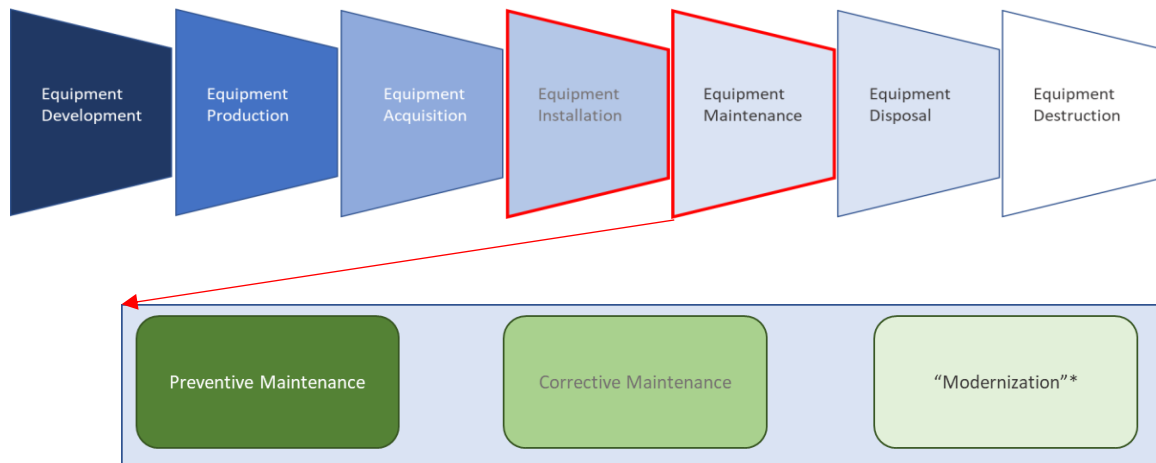


Figure 15, Elevator Company A maintenance methods

As seen in the Theoretical Background, these three maintenance methods are process manifestations by which the MS is provided to the customer. Although we present these three processes we must split them into two groups of processes with different goals.

Preventive and Corrective maintenance processes, as previously researched, have the goal to ensure to the customer the equipment is available and performing correctly. The situation on which they are utilized is based on how the company drives their maintenance strategy and the level of service established to be provided.

Modernization process is different service offering to the customer. Rather than an operational process for ensuring equipment functionality, this process has the characteristic that is made upon customer requests. Customers wishing to update or tune their equipment can have a personalized consultation by the Maintenance Service, and/or purchase the components per request.

To have a better perception of the processes behind the MS, an adapted process mapping of swim lanes was driven for each of the processes.

The core objective is to identify inefficiencies within such as bottlenecks, repetitions, or delays, define actors in terms of process ownership or responsibilities.

As mentioned the chosen mapping is the swim lane where we can clearly distinguish the different level of actors and their contributions on the process. To support the PSS design, an adaptation was included on the swim lane mapping, an independent lane was included under the process lane. This new lane scope enhances the product perspective in terms of availability during the maintenance process. As the idea behind the PSS is to provide a service to the customer in terms of equipment usage, the company must ensure maximum equipment availability. So, this mapping of the product availability can support with the design of future PSS.

Having the PSS in mind, together with the Elevator Company A managers, a AS-IS process design was conducted for the Preventive maintenance, Corrective Maintenance and Modernization of the Elevator Company A.

Service Requirements

Utilizing the research conducted in the previous chapters, the information acquired will be utilized to identify the levels of quality proposed by the Maintenance Service.

By utilizing the ServQUAL proposed by Parasuraman et al., (Parasuraman, Zeithaml, & Berry, 1988), is a tool that enables to identify the five dimensions by which service offering can be qualified.

As the Maintenance Service is the main trigger for the company to perform their product selling and add value, the ServQUAL tool was applied to characterize the offerings of the Elevator Maintenance Service (Table 6).

Table 6, Elevator Company A ServQUAL dimensions

Tangible	- Local physical agencies or representatives; - Maintenance teams belonging to the company; - Maintenance teams, vehicles are identified, equipped and with appropriate attire;
Reliability	- Maintenance team's qualification; - Ensures total maintenance from corrective to preventive maintenance;
Responsiveness	- Commitment to respond in 24/7;
Assurance	- Component warranty (varies in contract type);
Empathy	- Customer can choose a wide range of service packages, but also can customize their contracts and requirements;

Preventive Maintenance Process

To perform this type of maintenance the customer must be already contractual linked to the maintenance service through a service package. Preventive Maintenance situations are deployed due to several factors. The most common factors are:

- routine maintenance;
- component replacement;
- legislated maintenance;

The process is composed by the following actions, which can be viewed in Figure 16:

- Based on these factors the Elevator Company maintenance system will trigger the preventive maintenance process.
- The trigger affects the Backoffice, who will then take point by planning the required maintenance activities based on the triggered factor and then assign a maintenance team.
- The maintenance team will then receive their work order, prepare accordingly tools and necessary replacement components (if the case is such) and dislocate to the customer premises.
- The customer will receive the service, meaning will shut down the equipment and warn the users to avoid using while is being maintained.
- The maintenance team will then make a check-up if the equipment is performing correctly:
 - Case is, the equipment is certified of correct operability;
 - Case not, the maintenance team will perform the required maintenance:
 - Case is, the team has parts available to complete the maintenance it will fix the elevator;
 - Case not, the team will maintain the elevator shutdown and order the required pieces and schedule a future Corrective Maintenance in the system;
- After the validation of the equipment correct operability, the maintenance team will report the maintenance performed and input to the system this information.
- The system will then store and register the fixing under the equipment historic information.

Regarding the product side:

- In preventive maintenance, usually, the equipment is still available and operational. But not up until the maintenance team checks it, there is insurance regarding its performance;
- During the brief time the maintenance is being performed in loco the elevator is shut down;
- Depending on the result from the check-up.
 - In an extreme case the maintenance team verifies there is need to replace a component, if it affects the correct performance of the elevator and they need to order from the warehouse the elevator is shutdown up until the next maintenance

Conclusion: there is low credibility regarding the elevator correct performance, up until the maintenance team performs the check-up.

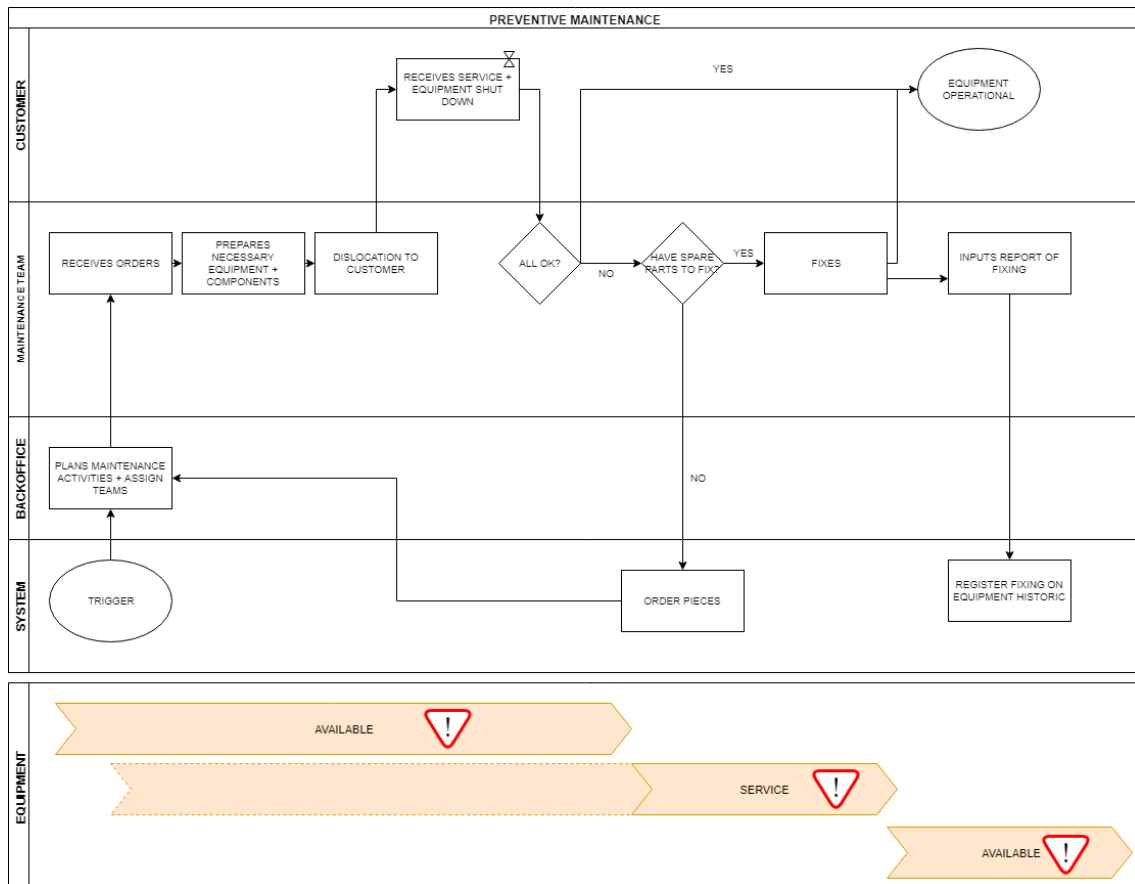


Figure 16, Preventive Maintenance Process Mapping

Corrective Maintenance Process

To perform this type of maintenance the customer must be already contractual linked to the maintenance service through a service package. Corrective maintenance is an extreme type of maintenance, where it is conducted only when the equipment breaks and stops operating correctly. In this process the service is operating over a situation that already occurred driven the elevator to be unavailable.

The process is composed by the following actions, which can be viewed in Figure 17:

- The equipment is broken or inoperable, this is the trigger for the process;
- The customer reacts to the broken equipment, and reports to the maintenance company the problem;
 - This problem reporting can be done through email or telephone;
 - In this case we contemplated the email process;

- The system registers the maintenance, and re-orders according to importance and other factors;
- The information of the system is seen by the Backoffice, who are tasked to allocate a maintenance team to the service order
- The maintenance team will then receive their work order, prepare accordingly tools and most common replacement components, and dislocate to the customer premises.
- The customer will receive the service.
- The maintenance team will then make a check-up of the equipment and identify the needed component to replace:
 - Case is, the team has parts available to complete the maintenance it will fix the elevator;
 - Case not, the team will maintain the elevator shutdown and order the required pieces and re-schedule a future Corrective Maintenance in the system;
- After the validation of the equipment correct operability, the maintenance team will report the maintenance performed and input to the system this information.
- The system will then store and register the fixing under the equipment historic information.

Regarding the product side:

- In corrective maintenance, the equipment is unavailable and in operational.
- Depending on the result from the check-up.
 - If there is need to replace a component, and they need to order from the warehouse the elevator is shutdown up until the next maintenance

Conclusion: there is a huge risk to have a wide period of elevator unavailability.

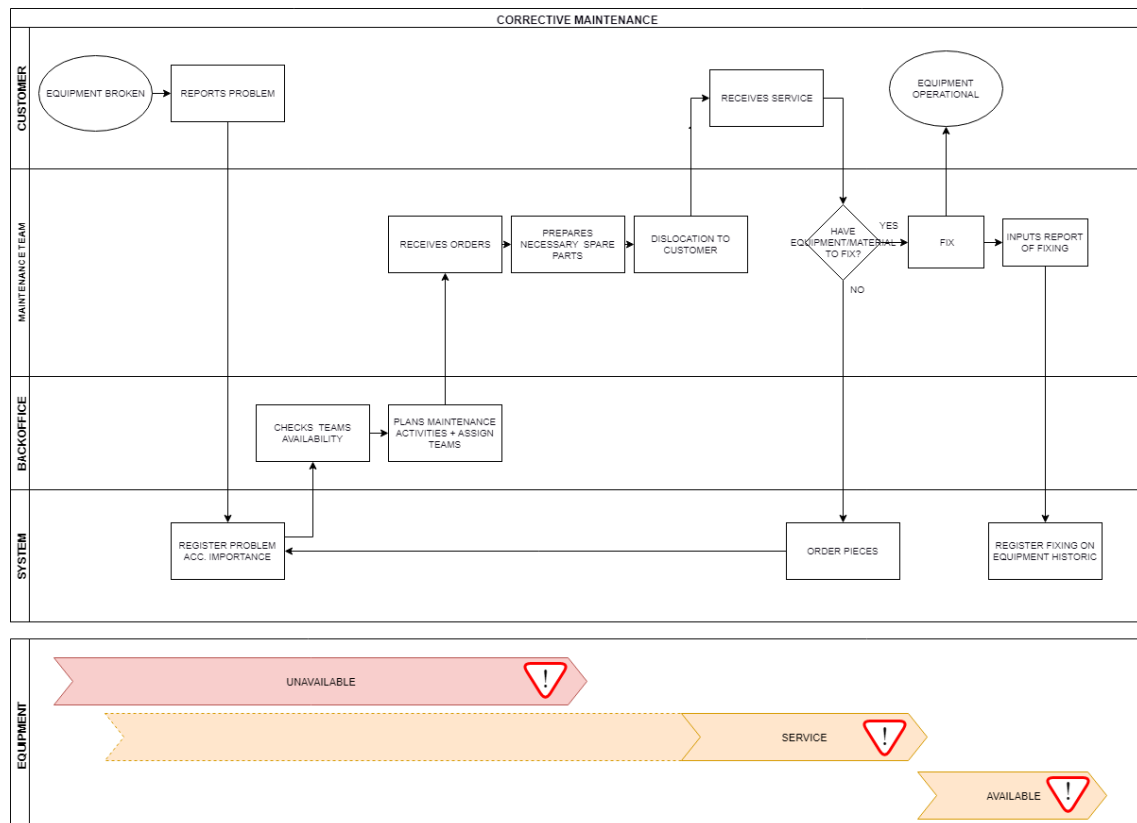


Figure 17, Corrective Maintenance Process Mapping

Modernization Process

Differently from what happens on the other maintenance, in this service offering the customer does not need to be contractually linked to the maintenance service. The customer engages directly with the service to have a consultation to refurbish and upgrade its already installed elevator. The designed process can be viewed in Figure 18.

- The trigger to deploy this service comes from the customer side. As seen in the customer analysis the factors that lead to trigger this service can come from different motivations, such as:
 - Wish to update the technology of old elevator – complete update or specific update;
 - Wish to refurbish the outside of the elevator;
 - Wish to have an opinion regarding their elevator;
- The customer proceeds to contact the Elevator Company Contact Points, and requires the maintenance service;
 - The contact can be through telephone or face-to-face on an agency, the contact person will register the request and schedules with the client the best date and registers on the system;

- The contact can be through email or online platform proposing a date, the System will register the occurrence. The Backoffice will contact the customer to confirm the scheduling of the visit.
- The Backoffice will assign a maintenance team to perform the consultancy;
- The Maintenance Team receives the request orders;
- The Maintenance Team dislocates to customer premises on the schedule date;
- The Customer receives the service and provides more info regarding their service expectations;
- The Maintenance Team checks the feasibility of the request;
- The Maintenance Team informs the customer the possible available solution;
- The Customer provides feedback on their options;
- The Maintenance team provides a feedback to the Backoffice based on the request and customer feedback in the available solutions;
- The Backoffice checks the available material in the warehouse and makes a quotation of the service and forwards through email to the customer;
- The Customer receives the quotation and decides;
 - Confirms the service, and contacts the Backoffice;
 - Rejects service;
- Upon confirmation, the Backoffice books the intervention and assigns a Maintenance team;
 - The Information System books the required material;
- The Maintenance Team will collect the necessary equipment and spare parts;
- The Maintenance Team dislocates to the customer premises;
- The Customer receives service;
- The Maintenance Team performs the intervention;
- The Intervention is performed and registered in the Information System.

Conclusion: in terms of equipment unavailability, this is a low risk maintenance activity.

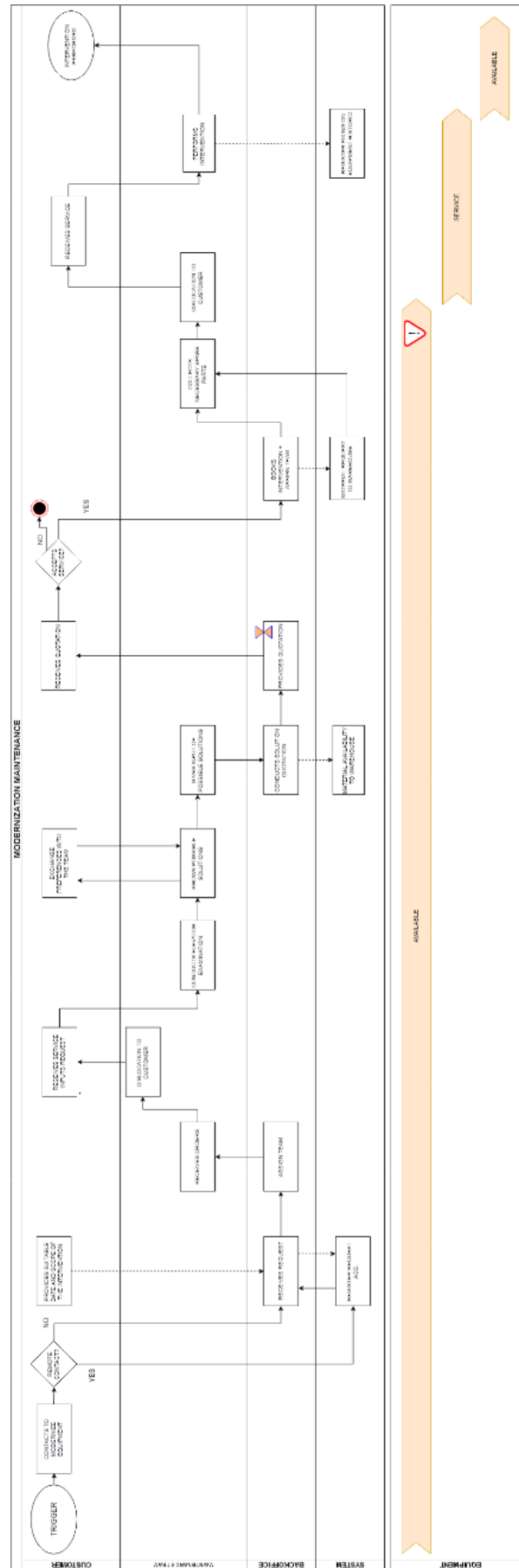


Figure 18, Modernization process mapping

Overview

From the input given, and according to Baines (Baines, et al., 2007) classification, the Elevator Company A has incrementally evolved through the Servicization of the Products. The firm currently can be considered a Product-Service System type.

The findings to confirm that Elevator Company A is a PSS driven business:

- During all product value lifecycle, the firm participates through services, Table 7.

Table 7, Elevator Company A services integration in product life-cycle

Product value Lifecycle	Services	Impact
Equipment Development	Local Agencies/ Customer Support	Collect and report on customer preferences/issues encountered in current equipment's
Equipment Production	Local Agencies/ Customer Support	Gives input on local equipment demands to be produced.
Equipment Acquisition	Local Agencies/ Customer Support	Provide Support on the purchase – details/ information/ customization/ booking/ warranty (required by law)
Equipment Installation	Local Agencies – Maintenance Teams	Perform equipment installation (product) on customers site
Equipment Maintenance	Local Agencies/ Customer Support – Maintenance Teams	Contractualized or singular service. Ensure equipment's performance or asses and update equipment
Equipment Disposal	Local Agencies/ Customer Support – Maintenance Teams	Dismantle elevator systems (product) at the customers site
Equipment Destruction	Local Agencies/ Customer Support – 3 rd party (?)	Dismantle/Scrap material from elevator systems

- Maintenance Service provision represent an important asset for the company to ensure a continuous engagement with the customer. The maintenance teams are in direct contact with the customer and are key to ensure customer satisfaction. To do this, they must maintain equipment functionality and availability to customer by abiding the service quality levels promised by the firm (Chapter 6.6).
- Based on Tukker (Tukker, 2004) PSS classification scheme. The described offering of Elevator Company A is of Product-Oriented Services, Product Related – In this scheme the provider sells *the product but also provide services that are required for each of the product use life. (e.g. maintenance contract, disposal contract).*

Also, it was possible to lay down the existing problems of the current business structure:

- Utilizing the MIFA done, Figure 18, and based on the organisation distribution and requirements we can detect issues present on the material and information flow within the supply chain. A set of encountered issues can be checked in Table 8.

Table 8 - Issues in Maintenance Service and Supply Chain

	Reason	Example
Service requirements	Type of contract – customer segment	Different segments have different contracted requirements by which the company has to cover and ensure equipment reliability.
	Type of contract – components coverage	A particularity of the contract is to cover and replace components. The basic maintenance contract does not cover this but the advanced versions do cover.
Huge Demand variability	Equipment variety	Escalators, elevators, sea-elevators, handicap elevators.
	Equipment versions	According to period of installation, type of usage.
	Service type	Preventive, corrective, modernization each with different level of requirements.
	Huge equipment pool	Only in Brazil, accounts 300.000 operational elevators.
	Components have different lifecycles than original designed.	Due to different usages, environmental conditions.
Huge stock level	Safety stock to compensate production + transport large lead-times.	The maintenance service must provide service provision fast and efficiently and cannot wait lead-times to have a component.
Transportation	Huge lead time for transports.	Transport lead-time from the Brazilian plant located in the south to the north part of the country or external.
	Transport frequency and volume	To ensure consolidation centres have acceptable stock levels, safety stock + stock.
Extra costs	Import and export of material	The plant import material from overseas. The plant export FG (more valuable) material to external south America market.

5. Solution Design

Based on the case study objectives, the literature review, developed artefacts and research about the company A, a starting solution was developed together with target stakeholders.

In this chapter, contemplates:

- *identify Contributing Stakeholders;*
- *Proposal (1st iteration);*
- *artefact design towards a PSS design (1st iteration);*
- *evaluation of the PSS design proposal.*

5.1. Identifying Contributing Stakeholders

From the Stakeholder Mapping, performed in chapter 4, an identification of possible contributors/experts for the solution design is put in evidence.

Following the strategy of the methodological framework, choosing the right quantity/quality of stakeholders is important to support on the 1st iteration of the solution design proposal. Also considering the limitations of this work a more direct approach was taken with the available stakeholders and sources of consultation.

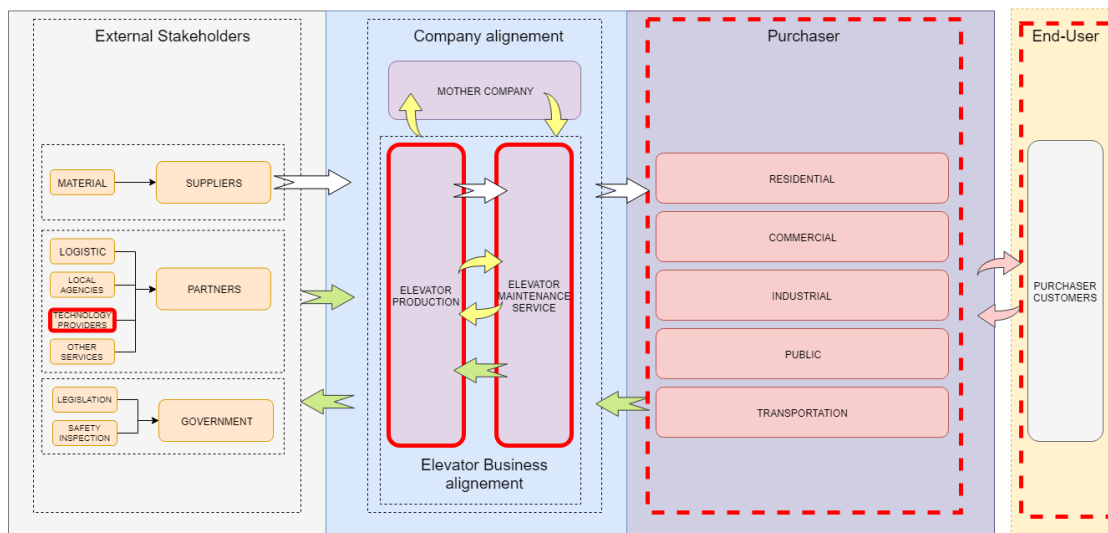


Figure 19, panel of stakeholder chosen to contribute on the 1st design proposal

In Figure 19 the chosen panel of stakeholders to contribute for the 1st iteration can be viewed. These are:

Elevator Company A Experts

As the problem is presented by the Elevator Company A, it was important to include them in the PSS design process. They are source of expert information regarding how elevator business work, and how the Elevator Company A Business works. Also, they are promoters and executers of the transformation, paving down the objectives of the design.

Experts: Three Improvement and Technology Managers from the Elevator company. Contacts made through the FASTEN meetings.

Technology Partners – INESC TEC (under FASTEN project)

As the PSS transformation is technology driven, through the FASTEN project association. The experts from the project can provide direction on how to integrate and exploit the technology developed.

Experts: Four FASTEN project experts including project manager. Contacts made through the FASTEN meetings¹⁶.

Customer

The purchasers are the solution acquirers. Making a business shift into PSS will directly affect the access of how the purchaser will obtain the solution. Having a feedback/evaluation of the 1st iteration ideas from purchaser viewpoint can be beneficial to arrange the impact of ideas.

Experts: One residential building manager.

End-Users

End-user will be the stakeholder who will experience the product and be affected by the services (example: elevator downtime). In the case of residential buildings will also be a purchaser of the elevator solution.

Experts: Four elevator users, from commercial and residential.

5.2. Solution

Based on the on the conducted research on PSS and maintenance services and combining the knowledge acquired about the company, a proposal of TO-BE redesign of their services with an integrative technologic solution proposed by the FASTEN project.

On the conducted study regarding the organisational aspect of the Elevator Company A, the company is concerned regarding environmentally sustainable organisation with a

¹⁶ In APPENDIX A, page 81, attended meetings

concern in turning their elevator more environmentally friendly. The second aspect is that the company also has a strong development and innovation department that integrates the sustainable solution on their elevators.

Starting with the proposal for this thesis, to conduct a research regarding a shift of an existing maintenance service into a PSS. Based on (Tukker, 2004) PSS classification and considering that the current maintenance service has been driven by the environmentally sustainable values of the organisation, and circular economy proposal. The target transformation will be from a Product Oriented PSS towards a Result-Oriented PSS.

On a meeting held with the Elevator Company A managers and technicians, and the FASTEN project collaborators an overview of the PSS Design solution framing for the production and maintenance service was presented, Figure 20.

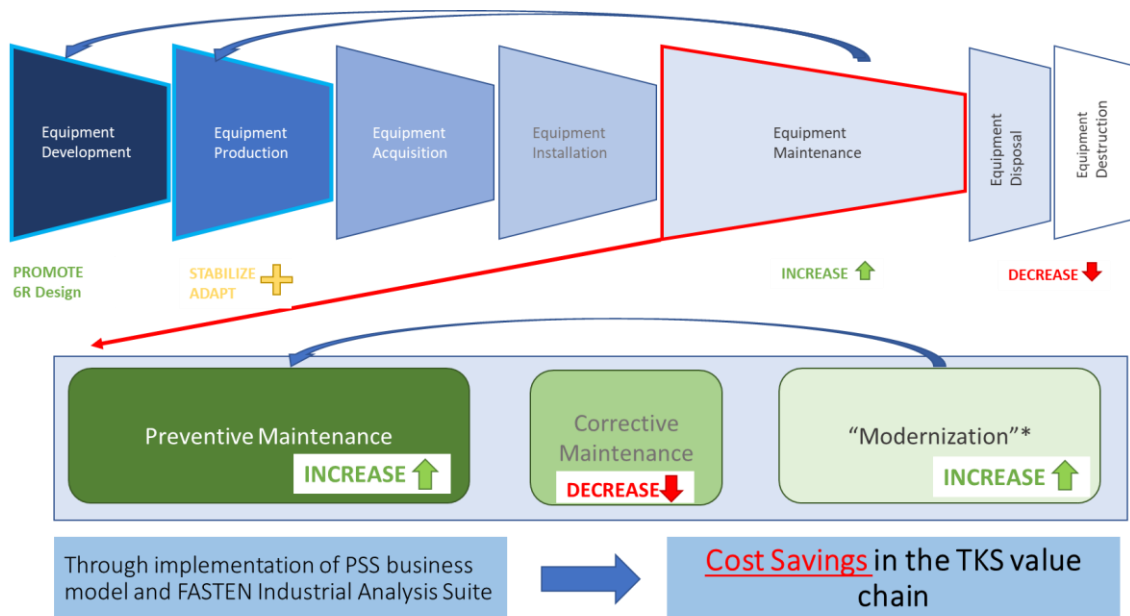


Figure 20, To-Be maintenance PSS frame

The new solution, increases the weight of Equipment Maintenance as a driver for the organisation. In theory and according to the literature review, by shifting the perspective towards a more service maintenance provider, will allow the organisation to:

1. Ensure equipment operability;
2. Promote re-use or recycling of components;
3. Reduce equipment disposal and destruction;

To ensure the promotion of Maintenance Services as key enablers to promote the PSS business model, measures must be taken in terms of promoting the correct maintenance

methods. Together with the firm responsible, for each of the maintenance services offerings a to-be solution were delineated out:

- *Increase of Preventive Maintenance*

The integration of technologies such as equipment Sensorization with a Big Data analysis will allow the organisation to be more responsive and flexible to issues. Equipment sensorization can allow to collect real-time data of the equipment working status, the proper management of this data through Big Data cloud can allow the Maintenance Service conduct focused preventive maintenance by knowing ahead which components are bound to fail or analyse the most common issues encountered in elevators through a number of variables.

- *Decrease of Corrective Maintenance*

Through promoting a higher preventive maintenance can result in lower corrective maintenance approach and can lessen the impact on customers of equipment unavailability that result on a negative impact on service quality.

- *Promoting Modernization*

As the organisation faces problem of having huge equipment variability, faces problem of finding spare components for older elevators and needs to have sensorization equipment installed. The maintenance service must seek forms to enhance this service provision to the customers. A discussed possible solution is to promote the shift of equipment ownership to the company to mitigate the costs of equipment modernization.

Having a strong maintenance service will allow the organisation to consolidate their equipment production and enhance equipment development towards firm's service quality requirements and environmentally sustainable policies.

- *Promote Equipment Development*

The Elevator Company A has currently a strong department towards researching and implementing new design and technologies for their equipment's. The consolidation of know-how collected and acquired on the maintenance and production side of the organisation. From the maintenance side information of what are the most common issues identified on elevators, what are the components with higher replacement rate, what issues are harder to correct or require more specialization from the maintenance teams. From the production side considerations of what are the components harder to produce, consume more resources or have higher number of references for the same functionality. A proposal considered is to promote 6R design methodologies.

- *Stabilize and adapt Equipment Production*

The case study proposed by the Elevator Company was finding a solution to solve their manufacturing side which was affecting performance on the service side due to components unavailability. From the technology solution proposed on the FASTEN project a flexible production with 3D printing can allow to produce near the sites the required components. By linking this solution with the beforementioned proposition will allow the organisation to reach a more customized and flexible manufacturing.

5.3. BMC Revision

Considering the transformation will be from a Product-oriented PSS towards a Result-oriented PSS, changes within the business scope must be applied.

The artifact BMC can support on transforming the business scope according to the requirements of a Result-oriented PSS. From the literature review, a relation was established from the basic requirements of a Result-Oriented PSS with the fields of the BMC (Figure 21).

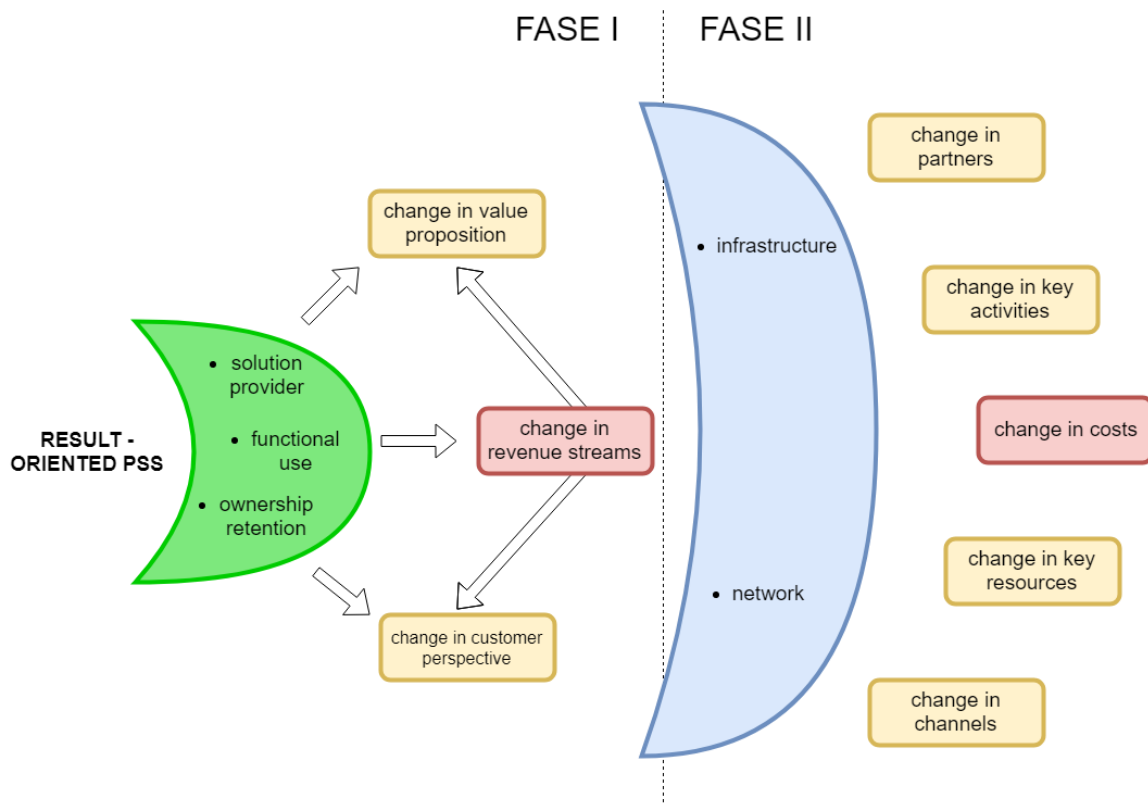


Figure 21, Result-Oriented PSS phases

From the firm perspective, and for this work, the portrayed Phase I was interesting as it allows to have a starting design and evaluation of the core PSS Design solution.

Based on the BMC designed of the current state of the business, the BMC for Result Oriented Elevator firm PSS was designed. At this stage, and based on the firm perspectives

at this stage, the focused fields were the Value Proposition, Customer and Revenue Stream (Figure 22).

Customer – as the “raw” customer perspective is to have a reliable and functional elevator system that enables him to reach from point A to B. The company promise should tackle this core customer need.

Value Proposition – to tackle the customer “core need”, the value proposition should translate this. Providing a reliable and functional Elevator System Solution, is how the Product-Service System is delivered. Having the Service aspect as enabler to provide and ensure the customer fulfils its needs (example: replacing components, committing to product availability, meeting inspection and maintenance needs).

Revenue Stream – this aspect should consider the value proposition of the firm. As the offering is composed of both Product-Service integration, quantifying and determining a price tag for this type of offering should be carefully studied and analysed by the firm. For this case a broader approach was taken, based on the literature review. A Pay-per-use approach was considered as an example, when the customer pays based on the number of trips performed/month. In this work we will not determine the pricing but just evaluate the proposal.

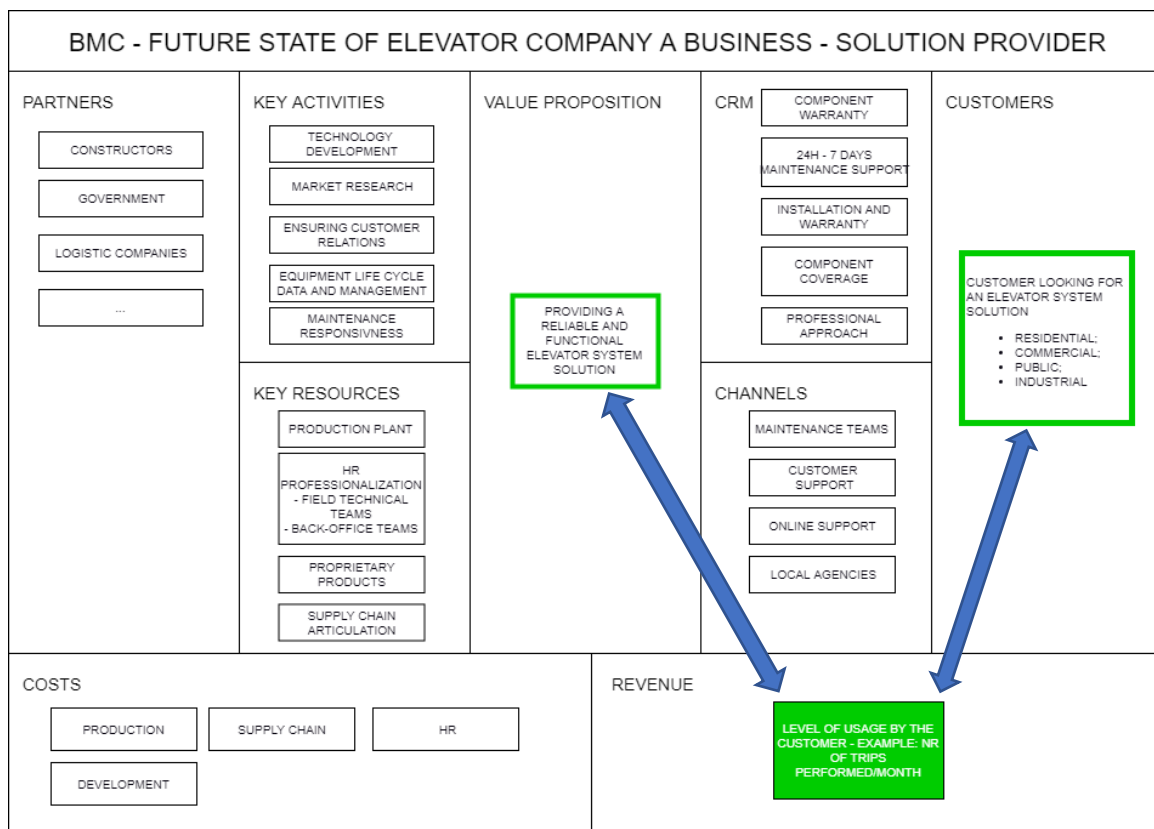


Figure 22, Revised BMC according to a PSS elevator system solution provider

5.4. Event Storming

Based on the PSS business model, the BMC, the artefact Process Mapping must be adapted to the new reality. As the PSS Design involves a technology integration aspect, the method Event Storming was proposed by the project manager to support this design stage. The benefits to consider this tool were:

- Method developed from Software domain;
- domain-driven design involves a quick and collaborative storming of ideas to evolve complex design towards a model of the domain;
- allows the interaction of different stakeholders – Elevator Company A representatives (business) and FASTEN project collaborators (developers) – fostering knowledge production and sharing;
- the Event Storming can promote information models that help define the types of events that occur that trigger, plans, deploy, supervise, and end manufacturing systems.

The baseline of the Event Storming starts from the Maintenance Service (MS), the Corrective Maintenance and Preventive Maintenance. The goal was to understand from these two MS methods, what was the information escalation upstream to the Spare Part (Component) production.

Corrective Maintenance

For the Corrective Maintenance Service, is composed by five service steps:

- Collaborative Maintenance Service.
- Self-Maintenance.
- Spare Parts Production Service.
- Spare Parts Logistic Service [Optional].
- Maintenance Service.

Preventive Maintenance

For an Elevator Preventive Maintenance Service, is composed by four services steps:

1. Self-maintenance
2. Spare parts production planning
3. Spare parts logistic service
4. Maintenance service

Event Storming diagram

The Event Storming, Figure 23, for the Corrective Maintenance service: Collaborative Maintenance Service and a Self-Maintenance steps, highlights how the equipment issue detection and assessment is performed.

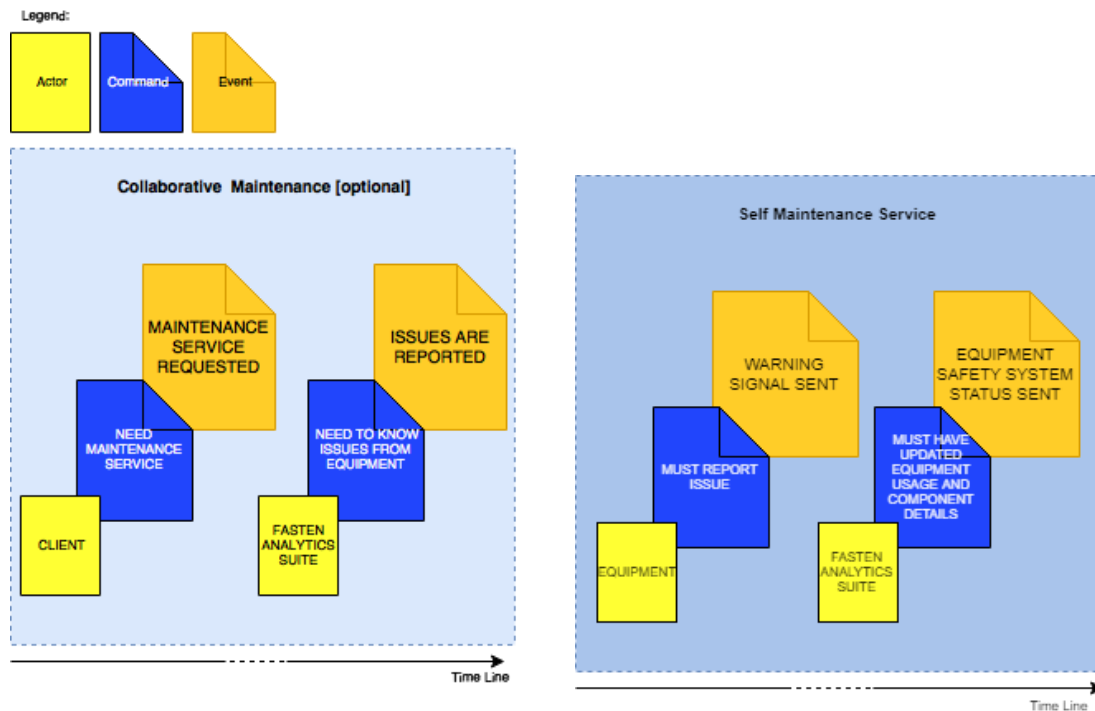


Figure 23, Collaborative Maintenance and Self Maintenance Service events

- The customer will interact with the System (FASTEN), providing an overview of the problem/issue with the equipment.
- This step is only considered on the case of the Corrective Maintenance Service.
- In this step the equipment self-diagnosis an existing issue (corrective maintenance) or an impending issue (preventive issue);
- The equipment sends an alert signal to the system (FASTEN).
- The alert system will trigger the deployment of a request of “equipment report status” from the System to the equipment, who will then send an overall status report of all its systems, components, and other values (please check chapter of the JSON files for an example of the kind of report).

Regarding the equipment Spare Part Production decision and Logistics are composed by: Spare Part Production Service and Spare Part Logistic Service (Figure 24).

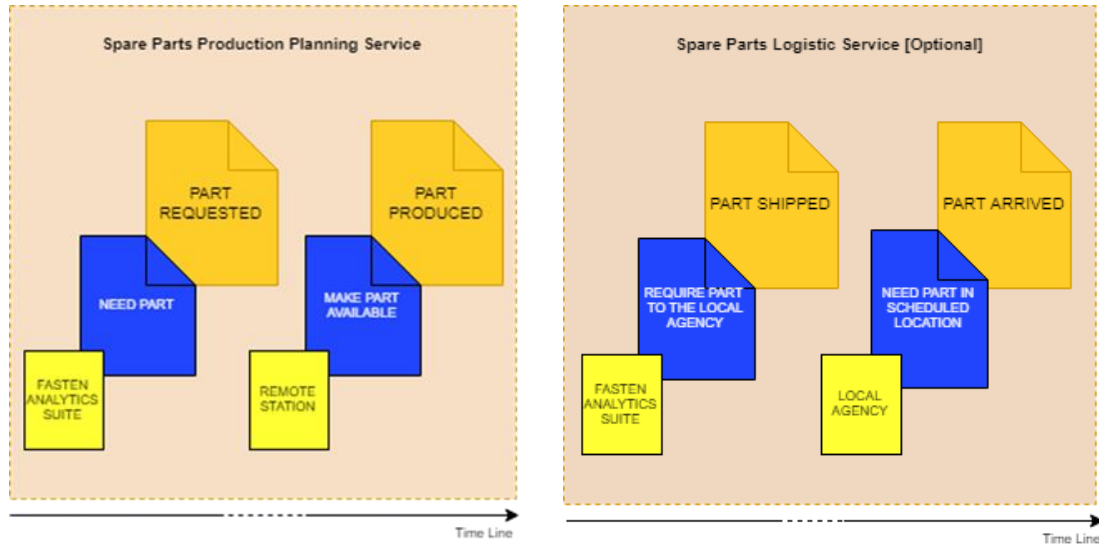


Figure 24, spare parts Production and Logistics services events

- Having the system acquired all the required information, the System will analyse and evaluate the course of action to be taken .
- A request for spare part production is done by the System to the remote and production centres.
- The remote and production centres will ensure the part will be produced and available under predetermined constraints to ensure proper service quality levels.
- The Spare Parts Logistic Service concerns the transportation of the requested spare part to near the agency who will perform the Maintenance Service step.
- This step is optional as it is related to the distance from the remote and production centres are located from the Local Maintenance Service Agency.
- In this step the System will require for the produced spare part to be near to where the maintenance will be performed. This will comprehend the logistic service the remote station will perform to ship out the part to the nearest Local Maintenance Service Agency.
- Afterwards, the Local Maintenance Service Agency will confirm to the

System the spare part arrives on its premises.

The Equipment Physical Maintenance Service is composed by: Maintenance Service (Figure 25).

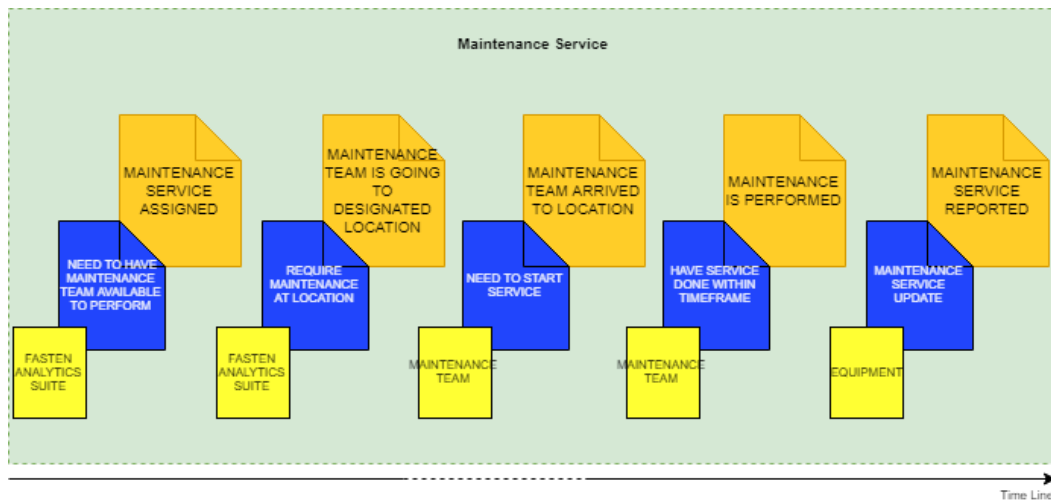


Figure 25, Maintenance Service events

- The Maintenance Service is the final step and comprehends the actions that the company takes to ensure the equipment availability and thus consolidating value with the customer through ensure of service quality levels.
- In the Maintenance Service the company will interact directly with the equipment and end user (equipment customer).
- The Maintenance Service will be triggered by the System, who acknowledging that the spare part is available near to the Local Maintenance Agency, will assign a Maintenance Team to perform the service and take the spare part.
- The System will then input the destination of service to the Maintenance team.
- The Maintenance team after arriving to the designated location will then input its arrival to the location into the System.
- The Maintenance team will perform the designated maintenance service.
- After job completion, the Maintenance team will report to the equipment that the job was performed, the degree of service and update any spare part changes.
- The equipment will then send a report to the System of all the new updated systems, spare parts, and information of the maintenance service.

5.5. Process Design

This first iteration of the PSS design with technology integration, was done together with FASTEN (technology stakeholders) and Elevator Company A members.

Preventive Maintenance

Pre-requirements: Customer must be already contractual linked to the maintenance service through a service package.

Description: To ensure the correct functioning of the PSS model, preventive maintenance methods must be “heavily” employed. This to ensure a continuous equipment availability to the customer and avoid equipment stoppages.

Gains:

Table 9, Gains for the To-Be Preventive Maintenance

Scenario	Leads	Gains	Affects
Acquiring and managing equipment information through IoT	Ensure correct equipment performance;	Equipment reliability and tracking	Service Quality;
Predictive Maintenance	Maintenance planning / Production planning Save equipment status and conditions	Receive warnings before failures/ equipment stoppage	Service Quality/ Production Side
Maintenance planning	Increase maintenance team's availability and predisposal	Reduce team stress;	Service Quality;
Production planning	Component availability	Reduce inventory/ unnecessary logistic flows	Production Side / Service Quality

Process Mapping reconfiguration (Figure 26):

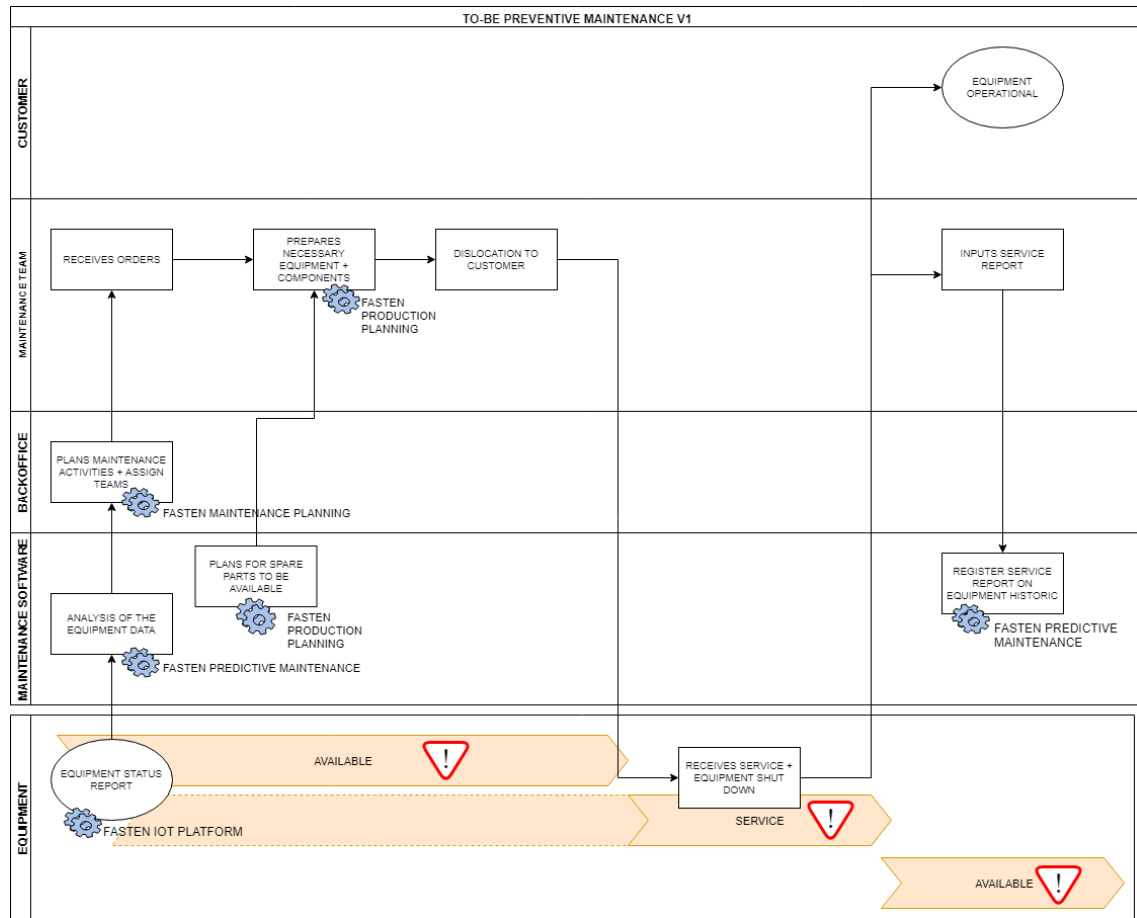


Figure 26, Preventive Maintenance Service 1st redesigned process flowchart

Corrective Maintenance

Pre-requirements: Customer must be already contractual linked to the maintenance service through a service package.

Description: Even though having preventive maintenance as a means to avoid corrective maintenance, situations where an unplanned equipment repair can occur (example: button switch replacement).

Gains:

Table 10, Gains for the To-Be Corrective Maintenance

Scenario	Leads	Gains	Affects
Acquiring information of type of component/ or maintenance	Reduce transport time to assess problem on site.	Reduce transport consumption + emissions; Reduce teams overscheduling.	Service Quality
	Ensure component availability	Reduce waiting time;	Production Side Service Quality
Additive manufacturing	Production per-order and near-site;	Reduce inventory; Reduce logistic movement.	Production Side
Maintenance planning	Increase maintenance team's availability and	Reduce team stress;	Service Quality;

Process Mapping reconfiguration (Figure 27):

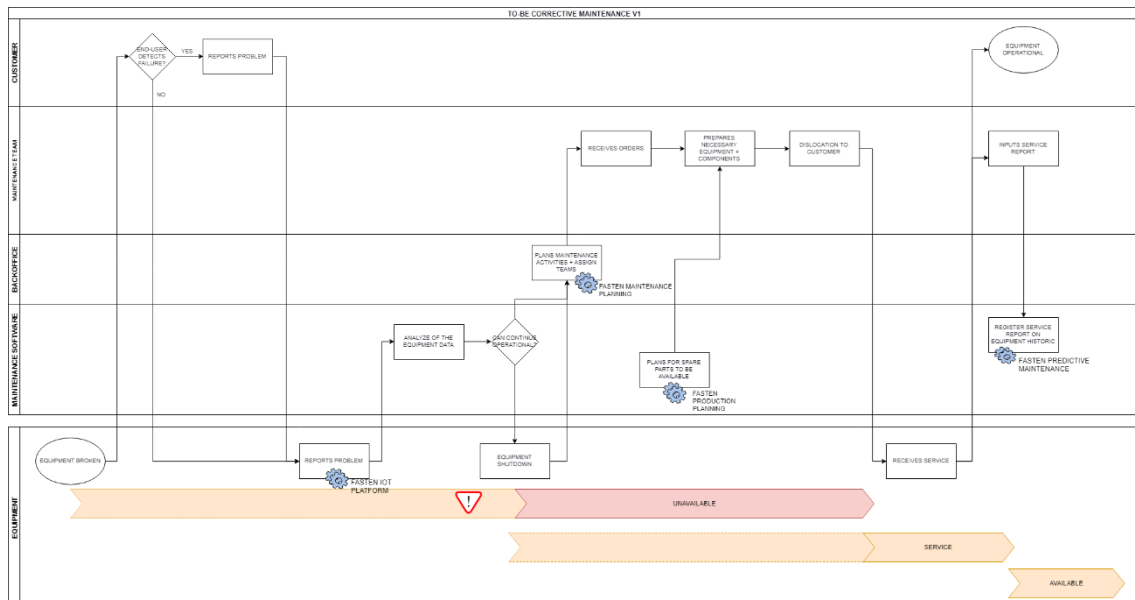


Figure 27, Corrective Maintenance Service 1st redesigned process flowchart

6. Evaluation

Following the proposed framework approach in this chapter the outputs of the Design process will be evaluated.

Considering this is a 1st iteration of the possible PSS design, two tools were selected: A BDD story and a brief interview with potential users. BDD Story, is a tool that can help develop probable use-scenarios for the technology integration and can be done together with the technology developers and Elevator Company A. Unstructured interviews is other tool which we can have a direct contact with the customers and end-users and have them evaluate the proposed solutions.

6.1. Behaviour Driven Development (BDD) Story

The Behaviour Driven Development (BDD) Story is a tool that considers the business nature and its requirements and translates them into features that will aid in the development of business-related software (Frank, 2017). The features translation is key for this methodology, as it must come in a clear, comprehensive, accurate, and simple language. Also, the features outcomes play an important role on the methodology as it must be ready to use and understandable for all involved entities – business entities, analysts, developers, testers – this will allow to know what is going on (traceability) and how it works (trackability).

The BDD Story is composed by:

```
Title (one line describing the story)
Narrative:
As a [role]
I want [feature]
So that [benefit]
Acceptance Criteria: (presented as Scenarios)
Scenario 1: Title
Given [context]
    And [some more context] ...
When [event]
Then [outcome]
    And [another outcome] ...
```

Based on the BDD story approach we can draw possible scenarios on how the PSS with the technology integration can interact with the different steps of the production and maintenance service.

To support the BDD story evaluation, it was decided to weight the changes required to turn the ideated solutions feasible. The following qualitative metrics were used:

Technology driven – necessary to implement technology not currently available on equipment's or firm to support the ideated solution;

Process driven – necessary to change or create new processes on the firm to support the ideated solution;

Social driven – necessary to promote a shift in how customers and end-user's utilization habits to support the ideated solution.

6.1.1. Corrective Maintenance BDD story

Story 1:

Title: CORRECTIVE COLLABORATIVE Maintenance Service, End-User wants equipment failure correction
Narrative:
As an End-User
I want to report the failure
So that the failure is corrected, and the equipment is functional

Story 1, Scenario 1:

Scenario 1: The Elevator door cannot open properly
Given the End-User detects the failure
And has an account on the company's customer service portal
And has the company's maintenance app installed on its mobile phone
And has a mobile phone with a camera
When the End-User sees the door is not opening properly
Then the End-User takes a photo of the failure
And the End-User reports the maintenance issue through the maintenance app
And FASTEN receives the photo
And FASTEN should say if the Elevator is safe or not
And FASTEN confirms the maintenance service

Story 1, Scenario 2:

Scenario 2: The Elevator is making "metallic" sounds when stopping
Given that the End-User cannot visually see the failure
And has an account on the company's customer service portal
And has the company's maintenance app installed on its mobile phone
When the End-User hear the sound often
Then the End-User access the maintenance app
And the End-User write a brief report of the situation on the maintenance app
And the End-User sends the report
And FASTEN receives the report
And FASTEN should say if the Elevator is safe or not
And FASTEN confirms the maintenance service

Story 1 Evaluation:

Technology driven – need to develop technology (app) to support information trade.

Process driven – firm require internal process to manage and give answer to all the requests.

Social driven – end user collaborates directly with the firm.

Story 2:

Title: CORRECTIVE SELF MAINTENANCE, the Equipment detects an equipment failure
Narrative:
As an Equipment
I want to report the failure
So that the failure is corrected, and the equipment is functional

Story 2, Scenario 1:

Scenario 1: The door cannot open properly
Given that the Equipment door sensors identify that the door is not making a complete slide when opening
 And the Equipment has its own server and external sensors
 And the Equipment is connected to a cloud server
 And the Equipment has installed a server capable to receive and compile external sensors data
When the Equipment detects the failure
Then the Equipment compile a brief report with the type of failure
 And the Equipment sends to FASTEN through the cloud server
 And FASTEN receives the report
 And FASTEN should determines if the Elevator is safe or not

Story 2 Evaluation:

Technology driven – need to develop and implement required technology on equipment and Information Systems to support information collection, management and deploy actions.

Process driven – firm require internal process to manage and follow all the requests.

Social driven – purchase the solution? Firm takes the cost? (check if required according to Business plan).

Story 3:

Title: CORRECTIVE SELF MAINTENANCE, FASTEN received a report from the Equipment and wishes to know more about the reported failure
Narrative:
As FASTEN
I want to know more about the equipment status
So that FASTEN takes the appropriate measures to correct the Equipment failure and the Equipment is functional

Story 3, Scenario 1:

Scenario 1: The System wishes to understand the failure
 Given that there is a failure report on FASTEN from the Equipment
 And the Equipment has its own server and external sensors
 The equipment is connected to a cloud server
 The equipment has installed a server capable to receive and compile external sensors data
 When FASTEN receives the report
 Then FASTEN queries the Equipment what is its overall system status operability
 And the Equipment performs an overall system check
 And the Equipment compiles the data into a overall status report
 And the Equipment send to the System the overall status report
 And FASTEN receives the status report of the equipment

Story 3 Evaluation:

Technology driven – need to develop and implement required technology on equipment and Information Systems to support information collection, management and deploy actions.

Process driven – firm require internal process to manage and follow all the requests.

Social driven – purchase the solution? Firm takes the cost? (check if required according to Business plan).

6.1.2. Preventive Maintenance BDD story

Story 4:

Title: PREVENTIVE SELF MAINTENANCE Service, technology requires a periodic overall system status report from the Equipment
 Narrative:
 As FASTEN
 I want to know the current overall system status of the Equipment
 So that FASTEN can have data to book the next preventive

Story 4, Scenario 1:

```

Scenario 1: Equipment receives request
Given that FASTEN requires periodic update from the
Equipment's
    And the Equipment has its own server and external
    sensors
    The equipment is connected to a cloud server
    The equipment has installed a server capable to
    receive and compile external sensors data
When the scheduled periodic self-maintenance happens
Then FASTEN queries the Equipment to give its overall
system status report
    And the Equipment performs an overall system check
    And the Equipment compiles the data into an overall
    status report
    And the Equipment send to the System the overall
    status report
    And FASTEN receives the status report of the equipment
  
```

Story 4 Evaluation:

Technology driven – need to develop and implement required technology on equipment and Information Systems to support information collection, management and deploy actions.

Process driven – firm require internal process to manage and follow all the requests.

Social driven – purchase the solution? Firm takes the cost? (check if required according to Business plan).

Session output

The BDD story tool is useful to align the output from the solution design and translate it into a use case scenario. By using this tool, it enabled to have a common ground with the technology developers, designing with them possible situations on how the technology could be applied (based on the previous event storming). Also, this tool allowed the Elevator Company A managers to perceive the provided technology integration, but also how new processes can happen (based on the process mapping from the solution proposal).

6.2. Interviews with Customers and End Users

Interviews were conducted with a small group of customers and end-users from Brazilian origin. The idea behind this was to source and verify information with persons who know the Brazilian reality in terms of utilizing elevators.

The chosen interview type was unstructured but was segmented into topics based on what was studied in terms of PSS businesses and the ideated solutions. The interviews can be found in this work appendix.

A quality evaluation was conducted afterwards with key findings from topic related. The quality evaluation was as follows:

Positive – findings that support the ideated solution. This should be preserved in future solution design iterations.

Develop – findings that support the ideated solution, but still need further development to answer further requirements. In future iterations these ideas must be consolidated within the solution design.

Negative – findings that may hinder or will create attrition towards the ideated solution application. These findings should be further developed and integrated in the solution design.

The following Table 11 portrays for each topic the key findings from the interviews.

Table 11, Interviews topic evaluation

Business	Equipment belonging to Provider (Elevator Company A)	(Develop) “Could possibly be interesting, if there are gains in terms of price, ensuring maintenance or component availability.” (Negative) “Some more traditional Brazilian people are used to buying is acquiring. And have a deep sense of proprietary. Changing their minds could be hard.” (Negative) “I just have a doubt regarding, if I want to change the service provider, if the equipment belongs to them they will take it?”
	Purchase shift towards solution provision. (Pay-per service example)	(Develop) “If the price will not be unbearable to the customers and also the contract contemplates the acquisition of spare parts in case of breakdown. I see no problem” (Negative) “My experience as building manager is that Elevator companies nowadays have huge margins in selling spare parts. My question is are these companies able to commit in this shift of perspective?”

	Remote maintenance	(Develop) “I see no harm. However, the Maintenance Company must respect the minimum maintenance requirements required by law”
	Environmental awareness	(Positive) “Having technology as means to improve environmentally sustainable business seems to me an important indicator of the company modern and (possibly) with a quality service.” (Develop) “I am all forth this type of ideas, but do not want to pay extra for it.” (Negative) “I feel that the environmental impact does not condition my purchase. For me price is the most important aspect when choosing the maintenance service.”
Technology	Price of installation	(Negative) “Nowadays the cost of refurbishing an existing equipment can cost the same as buying one. Which is very expensive. So, most tenant associations do not wish to purchase new or refurbish.” (Develop) “If there is a way to decrease installation costs, it could facilitate the refurbishment and implementation of new technologies on existing equipment’s.”
	Collaborative Maintenance	(Develop) “Could be interesting, but the users shouldn’t have to download an app to contribute. Probably the building doorman or building managers should have it” (Develop) “Probably not an app, but other means of dialling and reporting problems could be interesting. For example, the elevator interface.” (Negative) “I (as user) do not wish to install applications on my mobile or deal with reporting maintenance issues”

Sessions output

The interviews provided key findings for the most prominent topics of the PSS business and its technology integration aspect.

For this 1st iteration evaluation output, several of the ideas behind the ideated solution need to be further developed and others need to be revised (Negative evaluation). This tool allowed to have a quick overlook on how the customers and end-users could react to the different aspects of the solution proposal.

7. Results

The proposed methodological Design Science Research based framework allowed to prepare, organise, collaborate and evaluate design solutions towards a Product-Service Systems design.

The prior Literature Review supported the comprehension the pre-requirements of PSS businesses, what has been done until now, identify gaps and perceive the importance of Maintenance Service, as not only a means to support businesses but as a value provider. This pre-research was of great value to acquire background knowledge in terms of concepts, and work done until now regarding PSS. This allowed the PSS Designer to become an expert on the domain, and also a key promoter and enabler of the PSS design.

Regarding the proposed DSRM based framework.

In the Problem Identification Phase, the Problem Discovery Step involved a deep research regarding the environment, firm structure and technology potential allowed to collect the required amount of information to conduct an exhaustive analysis of the current state of the firm service provision.

The Artifact Step, required to create tools that allowed to define the current AS-IS state of the firm business organisation. The importance of this step was to choose the right tools, to have a common “language” with the stakeholders of the project.

- Utilizing the MIFA tool allowed to design the whole levels of interaction required to create value for the firm, and then provide it to the customer.
- Utilizing the Stakeholder Mapping, allowed to pinpoint what are business influencers, the value providers (support, co-create value), the Value Requirers.
- The BMC tool was a keypoint tool that allowed to define the business: Value proposals, Customers, Channels, CRM, Key Activities, Key Resources, Partners, Value Streams, Cost Streams.
- Process Mapping tool. Allowed to explore in detail the mechanisms behind MS provision. How different actors interact. Also, by adapting the Process Mapping tool, it was also able to understand the product situation during all the process – this is of extreme importance for PSS.

The Solution Design Proposal Step, is where together with the identified key stakeholders is to formulate a first proposal to “solve” the initial problem. Promoting the utilization of collaborative problem-solving tools as Event Storming fostered an approximation of stakeholders and increased knowledge sharing. Other particularity was the utilization of already designed artifacts to enable new solution proposal. The usage of the BMC and process mapping promoted and demonstrated how the integration and design of processes could happen.

Evaluation Step, utilize methods to bring together the involved stakeholders to validate the reached proposal. For this work two tools were utilized in different phases, a DSS story tool that allowed to create scenarios together with the stakeholders associated with the business. Interviews for the stakeholders who receive value from the business. After acquiring feedback, crosscheck the validated aspects of the proposal. Pinpoint and save the unvalidated, and questionable aspects.

As we can see throughout all the design process different stakeholders participated on providing key information on the current state of the firm, provided ideas towards a solution, validated artifacts, and evaluated solutions.

A valuable remark for this work came from the Elevator Company A and FASTEN project members. In their perspective the proposed artifacts, were good platforms of acquiring and diffuse information, allowed to stablish and organise the information into a comprehensive structure and were simple and straightforward to use. These characteristics maximized the artifacts usability, fostering a widespread utilization between the firm and key stakeholders.

In terms of evaluation tools, the deployed tools provided some feedback regarding the ideated solution design. As two evaluation tools was utilized different levels of feedback was obtained. The BDD story, which involved the firm and FASTEN project developers, allowed to perceive the different levels of technology, process and social integration that the ideated solutions required in order to accomplish a scenario output.

8. Conclusion and Future Works

As stated by (Johnstone, 2008), there is not a clear universal key roadmap to help firms transform businesses into PSS.

This work intent was to demonstrate that by utilizing the methodological approach, DSRM, a framework could be devised that could promote PSS Design within a firm. Based in the usage of domain related tools and methods, the proposed structured approach allows an iterative PSS Design approach.

Prior to starting, conducting a brief research regarding the industry and the firm organisational structuring allows to start contemplating the required tools and methods necessary.

A key aspect for this methodology framework, is to identify and involve key stakeholders that can contribute and support in the PSS design. Key stakeholders can be knowledge retainers of the firm's business and operation or domain experts related to key drivers for the PSS design.

Defining the composition of the working PSS design team is also of importance. Working with only a small and manageable team of key stakeholders at the start allowed swiftly to create, consolidate and validate information structures (artifacts), and simplified the solution design and evaluation process. They won't cover all the aspects, but probably key aspects of the PSS transformation can be assessed.

In the portrayed case study, by utilizing tools common to the sector of the case study, allowed to have a simple, common language with the participant stakeholders. This particularity allowed to collect and consolidate information faster and acquire a clear portray of the business.

In terms of future works, further iterations should be considered to review and restructure the unvalidated and questionable aspects of the first iteration proposal. The following iterations should bring in new aspects for the PSS design, namely:

- adding more layers of tools that enable a broader understanding of the problem.
- adding more stakeholder sources. A key aspect should reside in bringing more inputs from different backgrounds;
- choosing and adding different key-stakeholders, to deepen knowledge acquisition, idea generation and proposal evaluation;
- defining revenue and cost evaluation methods, are key to guide the design solution throughout the iterative process.

Other interesting proposal for future works, should consider the utilization of the proposed framework into other case studies of firms from different background. The intent should consider in bringing new tools and methods to foster the PSS design in firms of different backgrounds.

References

- Akkermans, H., & Vos, G. (2002). Amplification in service supply chains : an exploratory case study from the telecom industry. *Eindhoven: Technische Universiteit Eindhoven*.
- Al-Turki, U. M. (2011). A framework for strategic planning in maintenance. *Journal of Quality in Maintenance Engineering*, 150-162.
- Andriankaja, H., Boucher, X., Medini, K., & Vaillant, H. (n.d.). A Framework to Design Integrated Product-Service Systems based on the Extended Functional Analysis Approach. *Procedia CIRP* 47, 323-328.
- Annarelli, A., Battistella, C., & Nonino, F. (2016). Product service system: A conceptual framework from a systematic review. *Journal of Cleaner Production* 139, 1011-1032.
- Baines, T. S., Lightfoot, H., Steve, E., Neely, A., Greenough, R., Peppard, J., . . . Wilson, H. (2007). State-of-the-art in product service-systems. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 221(10), pp. 1543–1552.
- Boehm, M., & Thomas, O. (2013). Looking beyond the rim of one's teacup: a multidisciplinary literature review of Product-Service Systems in Information Systems, Business Management, and Engineering & Design. *Journal of Cleaner Production*, 245-260.
- Boons, F., & Lüdeke-Freund, F. (2013). Business models for sustainable innovation: state-of-the-art and steps towards a research agenda. *Journal of Cleaner Production*, 9-19.
- Chirumalla, K., Bertoni, A., Ericson, Å., & Isaksson, O. (2012). Knowledge-Sharing Network for Product-Service System Development: Is it atypical? *CIRP IPS2 Conference*, (pp. pp. 109-114). Japan.
- Clayton, R., Backhouse, C., & Dani, S. (2012). Product-Service System (PSS) design: using Design Thinking and Business. *Journal of Manufacturing Technology Management*, Vol. 23, No. 3, pp. 272–298.
- Clayton, R., Backhouse, C., & Danil, S. (2011). Evaluating existing approaches to product-service system design: a comparison with industrial practice. *Journal of Manufacturing Technology Management*, 23 (3), pp. 272 - 298.
- Comission, E. (2011). *Communication from the comission to the European Parliament, the council, the european economic and social comitee and the comitee of the regions. Roadmap to a Resource Efficient Europe*. Eur Comm 2011.
- Costa, N., Patricio, L., Morelli, N., & Magee, C. L. (2017). Bringing Service Design to manufacturing companies: Integrating PSS and Service Design approaches. *Design Studies*. doi:<https://doi.org/10.1016/j.destud.2017.09.002>
- Dimache, A., Mitchell, S., & O'Dowd, P. (2010). TRAPSS methodology – A smart solution for manufacturing SMES. *Research THEA*.
- Ducq, Y., Chen, D., & Alix, T. (2012). Principles of Servitization and Definition. (pp. 117-128). Enterprise Interoperability.

- EN:13306. (2010). *Maintenance - Maintenance Terminology*. BSI Standards Publication.
- EU-Comission. (2011). *Communication from the comission to the European Parliament, the council, the european economic and social comitee and the comitee of the regions. Roadmap to a Resource Efficient Europe*. Eur Comm 2011.
- Exner, K., Schnürmacher, C., Adolphy, S., & Stark, R. (2017). Proactive maintenance as success factor for use-oriented Product-Service Systems. *The 9th CIRP IPSS Conference: Circular Perspectives on Product/Service-Systems* (pp. 330-335). CIRP.
- Exnera, K., Schnürmachera, C., Adolphyb, S., & Starka, R. (2017, 03 24). Proactive maintenance as success factor for use-oriented Product-Service Systems . *ELSEVIER*, pp. 330-335.
- FASTEN. (2017). Flexible and Autonomous Manufacturing Systems for Custom-Designed Products. RIA Research and Innovation action.
- Frank, J. (2017, June 09). *Why Behavior Driven Development (BDD) Makes User Stories Even Better*. Retrieved from Revelry: <https://revelry.co/behavior-driven-development-bdd/>
- Gacenga, F., Cater-Steel, A., Toleman, M., & Tan, W.-G. (2012). A Proposal and Evaluation of a Design Method in Design Science Research. *The Electronic Journal of Business Research Methods Volume 10*, pp. 89-100.
- Geerts, G. L. (2011). A design science research methodology and its application to accounting information systems research. *International Journal of Accounting Information Systems*, 12, pp. 142-151.
- Goedkoop, M. J. (1999). *Product Service systems, Ecological and Economic Basics*. PRé consultants.
- Goedkoop, M., van Halen, C., te Riele, H., & Rommens, P. (1999). *Product service systems, ecological and economic basis*. PricewaterhouseCoopers.
- Harrison, J. P. (2010). Strategic Planning and Swot Analysis. In J. P. Harrison, *Essentials of Strategic Planning in Healthcare*. Health Administration Press.
- Herbert, S. (1996). *The Sciences of the Artificial 3rd edition*. MIT Press.
- Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly Vol. 28 No. 1*, pp. 75-105.
- Hipkin, I., & Cock, C. D. (2000). TQM and BPR: lessons for maintenance management. *OMEGA, The international Journal of Management Science, ISS 28*, pp. 277-292.
- lung, B., & Levrat, E. (2014). Advanced Maintenance Services for Promoting Sustainability. *3rd International Conference on Through-life Engineering Services* (pp. 15-22). CIRP.
- Johnstone, S. D. (2008). In search of 'product-service': evidence from aerospace, construction, and engineering. *The Services Industries Journal, Vol.28*.
- Kindström, D. (2010). Towards a service-based business model – Key aspects for future competitive. *European Management Journal, 28(6)*, 479–490.
- Kindström, D., & Kowalkowski, C. (2014). Service innovation in product centric firms: A multidimensional business model perspective. *Journal of Business & Industrial Marketing, Vol. 29, Issue 2* .

- Kothamasu, R., Huang, S. H., & VerDuin, W. H. (2006, March 15). System health monitoring and prognostics — a review of current paradigms and practices. *International Journal of Advanced Manufacturing Technology*, pp. 1012-1024.
- Kurilova-Palisaitiene, J., & Sundin, E. (2014). Minimum Time for Material and Information Flow Analysis (MiniMIFA) - A Method to identify Challenges and Improvement Opportunities. *The 6TH Swedish Production Symposium*. Gothenburg.
- Lee, J., Kao, H.-A., & Yang, S. (2014). Service innovation and smart analytics for Industry 4.0 and big data environment. *Product Services Systems and Value Creation. Proceedings of the 6th CIRP Conference on Industrial Product-Service Systems* (pp. 3-8). CIRP.
- Lee, J., Lapira, E., Bagheri, B., & Kao, H.-a. (2013). Recent advances and trends in predictive manufacturing systems in big data environment. *Manufacturing Letters*, 38-41.
- Liyanage, J., Badurdeen, F., & Ratnayake, C. (2009). Adapting an effective asset maintenance practice for sustainability. In M. Ben-Daya, S. O. Duffuaa, A. Raouf, J. Knezevic, & D. Ait-Kadi, *Handbook of Maintenance Management and Engineering* (pp. 686-690). Springer Science & Business Media.
- MacArthur, E. (2013). *Towards the Circular Economy*. Ellen Macarthur Foundation.
- Mahut, F., Daaboul, J., Bricogne, M., & Eynard, B. (2015). Survey on Product-Service System applications in the automotive industry. *International Federation of Automatic Control* (pp. 840–847). Elsevier.
- Marquez, A. C., & Gupta, J. N. (2006). Contemporary maintenance management: process, framework and supporting pillars. *OMEGA, International Journal of Management Science, Issue 34*, pp. 313-326.
- Martinez, V., Bastl, M., Kingston, J., & Evans, S. (2010). Challenges in transforming manufacturing organisations into product-service providers. *Journal of Manufacturing Technology Management, Volume 21*, (pp. 449-469).
- Matthyssens, P., & Vandenbempt, K. (2008). Moving from basic offerings to value-added solutions: Strategies, barriers and alignment. *Industrial Marketing Management* 37, pp. 316–328.
- McAfee, A., & Brynjolfsson, E. (2012). Big data: the management. *Harvard business review*, 60-68.
- Meier, H. R. (2010). Industrial Product-Service Systems - IPS. *CIRP Annals Manufacturing Manufacturing Technology*, 59, pp. 607-627.
- Michelinia, G., Moraesa, R. N., Cunha, R. N., Costa, J. M., & Ometto, A. R. (2017, 03 12). From linear to circular economy: PSS conducting the transition. *ELSEVIER*, 64, pp. 2-6. doi:<https://doi.org/10.1016/j.procir.2017.03.012>
- Mont, K. (2002). Clarifying the concept of product–service system. *Elsevier*, 237-245.
- Mont, O. (2004, September). Product-service systems: panacea or myth? *PHD Dissertation*. Lund University.
- Morelli, N. (2006). Developing new product service systems (PSS): methodologies and operational tools. *Journal of Cleaner Production* 14 (pp. 1495-1501). Elsevier Ltd.

- Müller, P., & Stark, R. (2010). A generic PSS development process model based on theory and an empirical study. *International Design Conference*. Dubrovnik: Design 2010.
- Murray, M., Fletcher, K., Kennedy, J., Kohler, P., Chambers, J., & Ledwidge, r. T. (1995). Capability Assurance: a Generic Model of Maintenance. *Maintenance Engineering Society of Australia*.
- Offermann, P., Levina, O., Schönherr, M., & Bub, U. (2009). *Outline of a Design Science Research Process*. Malvern.
- Osterwald, A., & Pigneur, Y. (2010). *Business Model Generation*. New Jersey: John Wiley & Sons, Inc.
- Parasuraman, A. P., Zeithaml, V. A., & Berry, L. L. (1988, January). SERVQUAL: A multiple- Item Scale for measuring consumer perceptions of service quality. *Journal of Retailing Vol.64*, pp. 12-39.
- Parida, A. (2006, 10). Development of a Multi-criteria Hierarchical Framework for Maintenance Performance Measurement. *Luleå University of Technology*.
- Parida, A. (2006). Study and analysis of Maintenance Performance Indicators (MPIs) for LKAB: A case study.
- Parida, A., & Kumar, U. (2003). Maintenance performance measurement (MPM): issues and challenges. *Proceedings of the 16th International Congress* (pp. 53-59). Växjö: COMADEM 2003.
- Peffer, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2008, January). A design science research methodology for information systems research. *Journal of Management Information Systems Vol. 24 Issue 3*, pp. 45-78.
- Reim, W., Parida, V., & Ortqvist, D. (2015). ProductService Systems (PSS) business models and tactics e a systematic literature review. *Journal of Cleaner Production*, 61-75.
- Reim, W., Parida, V., & Ortqvist, D. (2015). Product–Service Systems (PSS) business models and tactics – a systematic literature review. *Journal of Cleaner Production*, 61-75.
- Rother, M., & Shook, J. (1999). *Learning to See - Value Stream Mapping to Add Value and Eliminate Muda*. Brookline: The Lean Enterprise Institute.
- Salonen, A., & Bengtsson, M. (2008, 10 13). Identification of Maintenance Performance Indicators through stakeholder involvement. *Mälardalen University*.
- Social, O. (2003, July). Elevator Company A, Comportamento Social e Trabalhista. *Obesrvatorio Social*.
- Swanson, L. (1997). An empirical study of the relationship between production technology and maintenance management. *Int. Journal Production Economics* 53, 191-207.
- Swanson, L. (2001). Linking maintenance strategies to performance. *Int. J. Production Economics* 70, 237-244.
- Takata, S. (2013). Maintenance-centered Circular Manufacturing. *2nd International Through-life Engineering Services Conference*, (pp. 23-31).

- Thoben, K.-D., Eschenbächer, J., & Jagdev, H. (1999). Extended Products: Evolving Traditional Product Concepts. *7th International Conference on Concurrent Enterprising*, (pp. 27-29). Bremen.
- Tsang, A. H. (1998). A strategic approach to managing maintenance performance. *Journal of Quality in Maintenance Engineering*, Vol. 4 Iss 2 , 87-94.
- Tukker, A. (2004). Eight Types of Product-Service System: Eight Ways to Sustainability? Experiences from Suspronet. *Business Strategy and Environment*, 246-260.
- Tukker, A. (2015). Product services for a resource-efficient and circular economy e a review. (pp. 76-91). *Journal of Cleaner Production* 97.
- Tukker, A., & Tischner, U. (2006). Product-services as a research field: past, present and future. Reflections from a decade of research. *Journal of Cleaner Production*, 1552-1556.
- Vandermerwe, S., & Rada, J. (1988). Servitization of business: Adding value by adding services. *European Management Journal*, 314-324.
- Vargo, S. L., & Lusch, R. F. (2004). Evolving to a New Dominant Logic for Marketing. *Journal of Marketing*, Vol. 68, No. 1, pp. 1-17.
- Voudaris, C., Owusu, G., Dorne, R., & Lesaint, D. (2008). Service Chain Management. In C. Voudaris, G. Owusu, R. Dorne, & D. Lesaint, *Technology Innovations for the Service Business*. Springer.
- Wallin, J., Chirumalla, K., & Thompson, A. (2013). Developing PSS Concepts from Traditional Product Sales Situation: The Use of Business Model Canvas. *Springer-Verlag*.
- Wise, R. B. (1999). Go Downstream: the New Profit Imperative in Manufacturing. *Harvard Business Review*, 77(5), 133-141. Retrieved from <https://hbr.org/1999/09/go-downstream-the-new-profit-imperative-in-manufacturing>

APPENDIX A: meetings

Channels and Resources

As presented before, there are some limitation to how to promote a co-creative atmosphere and have more close contact actions with the stakeholders.

The following Table 12 present a set of utilized channels to reach out each stakeholder to the project, and how information is acquired.

Table 12, project stakeholders means of contact and information collection

From	Country	Stakeholders	Channels	Information Sources
Company	Brazil	Company Managers	• Conference Call Meetings; • Telephone; • Email;	• Project meetings; • Online interviews; • Articles;
		Maintenance operators	• Conference Call Meetings; • Telephone; • Email;	• Online interviews; • Articles.
		Customers	• Conference Call Meetings; • Email;	• Interviews; • Online reviews; • Articles; • Company website;
FASTEN project	Portugal (INESC TEC)	FASTEN developers + experts	• Physical Meetings;	• Interviews; • Meetings; • Benchmarks;
	EU countries + Brazil	FASTEN developers + experts	• Conference Call Meetings; • Email;	• Meetings.

Attended Meetings

Table 13, attended meeting FASTEN project

Date	Participants	Scope	Output
01.02.2018 (not participant)	FASTEN project investigating members (conf-call)	Case Study Requirements from Elevator Company A	Problem framing. Solution objectives.
20.02.2018	FASTEN project leader (face-to-face)	Overview of the FASTEN project	Solution objectives. Designing study objectives.
26.02.2018	INESC TEC investigators (face-to-face)	Overview of the developed technology	Drawing the technology aspect objectives.
01.03.2018	FASTEN monthly meeting (conf-call)	Case requirements definition Company discovery	Validation of the problem framing and solution objectives. Confirmation of company current state.
14.03.2018	FASTEN project leader (face-to-face)	PSS Research Overview	Definition for the contemplated PSS. Defining stakeholders to be involved.
05.04.2018	FASTEN monthly meeting with Elevator Company A managers (conf-call)	Presentation of the Study Models – current state.	Validation of the study models' chapter by Elevator Company A.
11.04.2018	INESC TEC investigators (face-to-face)	Possible integration of new technologies within the current state	Event Storming.
03.05.2018	FASTEN monthly meeting with Elevator Company A managers (conf-call)	Discussion of possible future PSS objective.	Approach development. Validation.
05.05.2018	FASTEN monthly meeting with Elevator Company A managers (conf-call)	Discussion of the Solution Design models.	Validation of the solution design study models by Elevator Company A.

APPENDIX B: Additional information

Three pillars of the modern maintenance

(Marquez & Gupta, 2006) proposed the inclusion of the modern maintenance management framework, based in three pillars: IT pillar, Organisational (or behaviour) pillar, Maintenance Engineering Methods pillar. The following sections we extend the analysis of these three pillars:

IT pillar

In the physical aspect, the Internet of Things (IoT) framework together with sensorization technology, have bridged new pathways to connect systems and humans, enabling data collection and big data environment in the industry. The future of the industry will reside in fleet-wide information systems that will convert machines to be self-aware and self-maintained, detecting potential critical failures, collecting data, and making decision to avoid potential issues (Lee, Kao, & Yang, 2014).

On the cyber aspect of industry 4.0, a transformation from passive machines designed to only take commands and react, towards more intelligent machines, who can actively take part in the production and maintenance planning and adjust operational parameter to achieve maximum productivity and product quality. Other interesting achievement is the design of Prognostic and Health Management algorithms, that based on machine history and situational analyses can adapt the machine setting to their environment, providing the machines in the field to be capable of learning from flowing data and be more robust (Lee, Kao, & Yang, 2014). Figure 31 helps clarify the relation of cyber-physical.

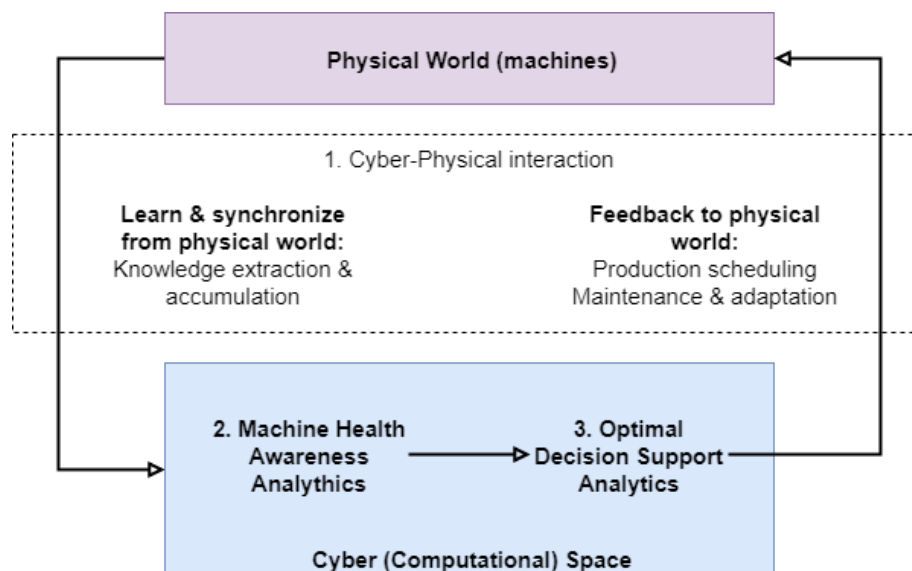


Figure 28, cyber-physical industry 4.0 framework (Lee, Kao, & Yang, 2014)

Organisational pillar

Maintenance systems management must be integrated in a broader perspective of the organisational structuring and strategy. As maintenance is entwined with other areas, for

its planning it must take into consideration the production planning, maintenance decisions, equipment inherited reliability and market and commercial requirements (Al-Turki, 2011).

Maintenance and production have close relationship, both have cooperative objectives in their planning, based upon each other's plans and viewpoints. As the main goal for the organisation is to produce in order to satisfy demand through the maximum utilization of available resources, maintenance enters into this perspective as to maximize asset value and availability. So, to function perfectly this cooperation, information flowing back and forth between operations (production) and equipment condition (maintenance) is a key enabler to promote planning and decision making (Swanson, 1997). Figure 5 illustrates this relationship.

With this broadened view, maintenance management domain is an actor within the organisation strategy, as a conductor for acquisition, improvement, replacement, and disposal of physical assets. Also, it has to perform actions to ensure the capability of systems, such as proactive tasks, namely routine servicing, periodic inspection, preventive replacement, and condition monitoring. An important point here is to characterize capability (Tsang, 1998). Figure 32 demonstrates this level of interactions within the organisations structure.

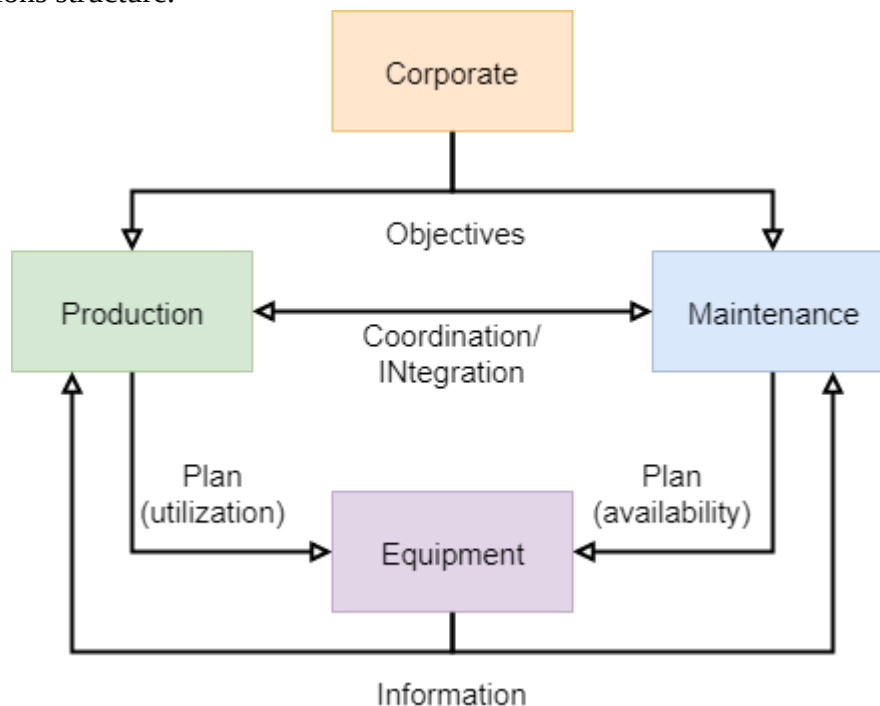


Figure 29, interaction between production and maintenance (Al-Turki, 2011)

Capability is the ability to perform a specific action within a range of performance levels, it is composed by characteristics like function, capacity, rate, quality, responsiveness, and degradation (Tsang, 1998). On the Maintenance Engineering Society of Australia (MESA) model of maintenance we can perceive the broader side of the established relationship of the Maintenance domain in terms of asset capability assurance:

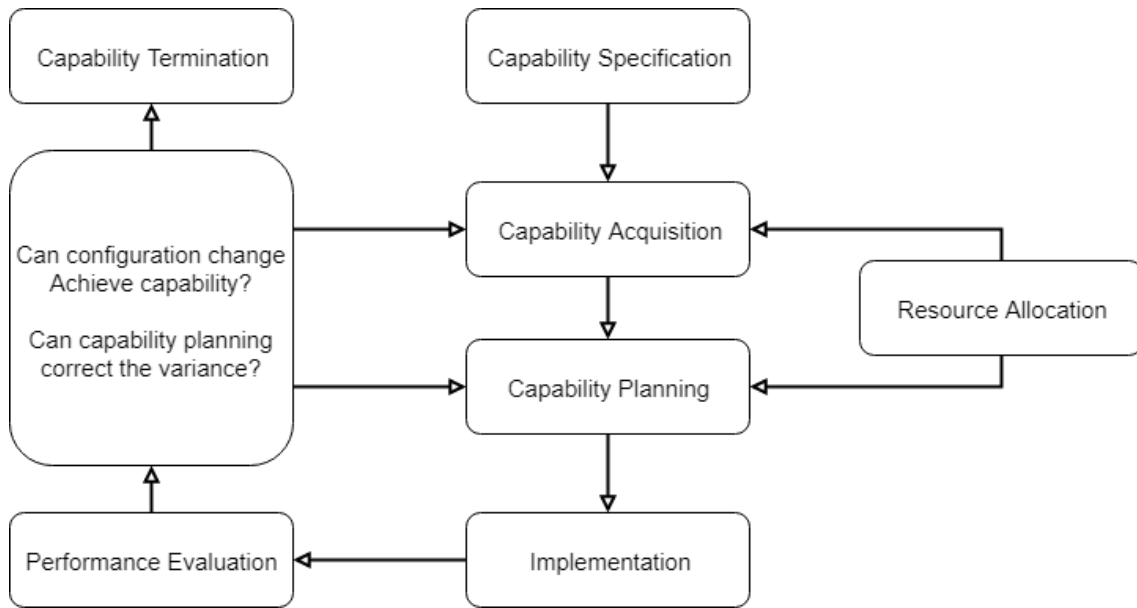


Figure 30, MESA model of maintenance (Murray, et al., 1995)

As seen further in Figure 34, to promote a strategic maintenance planning organisational vision, according to Tsang, 2002, four dimensions comprehend this service:

- 1st dimension: service delivery strategy. Choosing between outsourced or in-house maintenance. Many companies nowadays choose to outsource their maintenance activities, as it reduces problems, reduce total system costs, better and faster work done, and the organisation can use the available energy to focus on other strategic asset management issue. But, in case, this is a core competence of the organisation it should not be outsourced. As customer perceive as the most important service attribute or highly specialized activity, the organisation must be aware of the risks of outsourcing. Namely the loss of critical skills, cross-functional communications, and control over supplier.
 - Cost to outsource: search, contract, control, monitor;
 - Cost to do in-house: HR development and management, infrastructure management.
- 2nd dimension: strategic maintenance management. The predisposition of the organisation structure and work structure, that contribute for the process effectiveness and efficiency. The degree on which the maintenance service is viewed as a group owning the process will determine how the problems are analysed and solved.
- 3rd dimension: maintenance methodology. Regarding the organisation wishes to approach maintenance issues, what type of maintenance it will conduct based on the organisation global objectives.
- 4th dimension: selecting the maintenance support system. The maintenance support systems comprehend the tools, information system architecture, HR training,

performance management and rewards system. Here lies where most of the industry 4.0 proposes in terms of technological advancements, from predictive systems, algorithms, ERP.

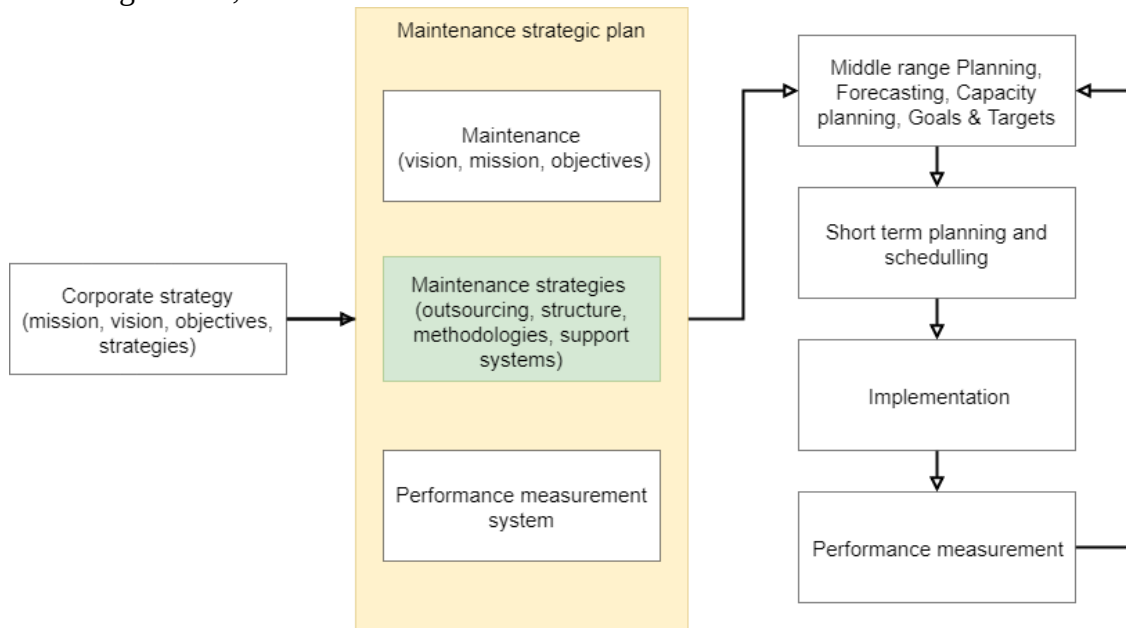


Figure 31, the maintenance planning as part of the corporate planning system (Al-Turki, 2011)

(Marquez & Gupta, 2006) propose an alignment of the Maintenance System Management strategies with the proposed Maintenance Management Framework, allowing the organisation to tackle three levels of business activities:

- strategic level – transform business priorities into maintenance priorities, allowing to develop mid-to-long term strategies to address equipment maintenance performance;
- tactical level – determine the correct assignment of maintenance resources and accomplish the maintenance plan;
- operational level – ensure procedures and processes are being followed through by the organisation, allowing to work be performed and data collected – a step required to enhance preventive maintenance.

Maintenance management process is composed by a wide range of activities, which interacts with different levels of the organisation. Having a successful Maintenance System Management integration implies working and transforming all the organisational stakeholders as contributors and agents of implementation (Al-Turki, 2011).

Maintenance Engineering Methods pillar

Maintenance has evolved with the integration of new maintenance concepts such as preventive and corrective measures.

In literature maintenance systems are composed by two types of maintenance: Corrective (or Reactive) Maintenance, Proactive Maintenance. (Exner, Schnürmacher, Adolph, &

Stark, 2017) (Swanson, 2001). The following Figure 35 illustrates the existing maintenance philosophies:

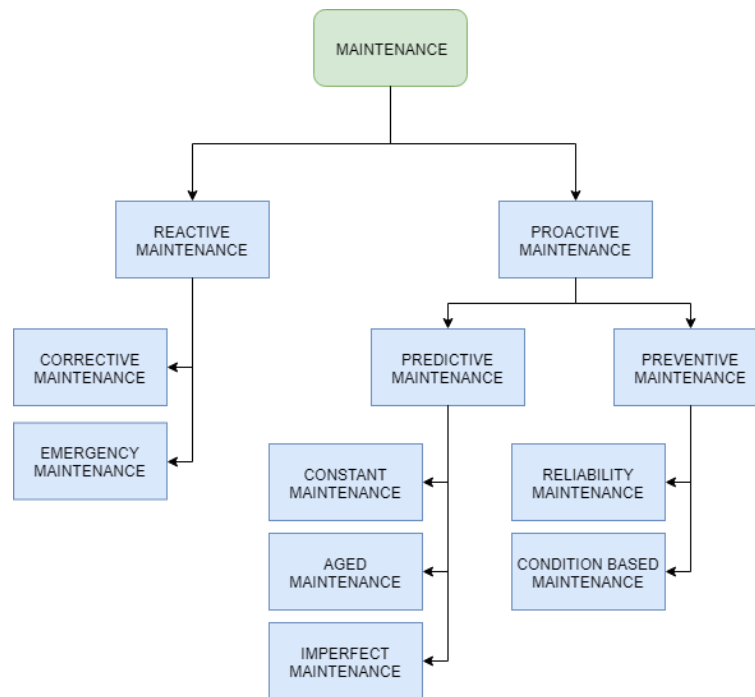


Figure 32, Taxonomy of maintenance philosophies (Kothamasu, Huang, & VerDuin, 2006)

- The Reactive Maintenance is a failure driven maintenance. Where the equipment already reached a failure point and presents a flawed operability (Corrective Maintenance required) or in extreme, equipment unavailability (Emergency Maintenance required). The maintenance activities are triggered afterwards. Temporary repairs may be used just to return the equipment to a minimum operation, postponing extensive repairs until after the maintenance activities ensure a reduced service time. This approach initially may require from companies just a minimum investment in maintenance teams or components, but in the long-run may derive to larger issues, such as unpredictable and fluctuating equipment operability, larger equipment downtime, extensive and costly repairs (EN:13306, 2010) (Kothamasu, Huang, & VerDuin, 2006).
- The Proactive Maintenance is a set of activities performed to monitor, “anticipate” and repair “minor problems” that may lead to equipment failure. These activities can be englobed into 2 main maintenance activities: Preventive Maintenance and Predictive Maintenance. For a Maintenance Service PSS, Proactive Maintenance is key to reduce or avoid product downtime and maximize equipment availability (EN:13306, 2010) (Kothamasu, Huang, & VerDuin, 2006).
 - Preventive Maintenance or use-based maintenance is the set of maintenance activities that are scheduled after a determined period. This type of maintenance is set based on estimated probability that a component will possible originate an equipment failure. When the Preventive Maintenance

is deployed it will perform small maintenance such as equipment lubrication, parts replacement, cleaning, and calibration. Also, during the maintenance, equipment inspection is performed that in signs of deterioration may trigger future prevention maintenance (EN:13306, 2010) (Kothamasu, Huang, & VerDuin, 2006).

- Predictive Maintenance or condition-based maintenance, it is triggered based on an existing equipment condition. Specific diagnostic equipment is used to measure the physical condition of the equipment, noise, vibration, corrosion, mechanism inoperability. When a certain condition reaches a certain level, the maintenance work is triggered to inspect and correct the issue (EN:13306, 2010) (Kothamasu, Huang, & VerDuin, 2006).

DSRM artifacts

The following artifacts concepts have been based upon Hevner proposal (Hevner, March, Park, & Ram, 2004):

Constructions – define the language by which the problem and solution are communicated.

Models – are construction that represent the real-world situation – problem and solution space. Models help to understand the connectivity of problem-solution components, supporting afterwards to perceive the effects of design decisions and changes done in the real-world.

Methods – define the processes. Can be mathematical algorithms, textual descriptions or a combination of the both.

Instantiations – show the different levels of interactivity that constructions, models, and methods on a working system. This allows to determine an artefact feasibility, and an evaluation of the artifacts suitability to the solution.

MIFA analysis

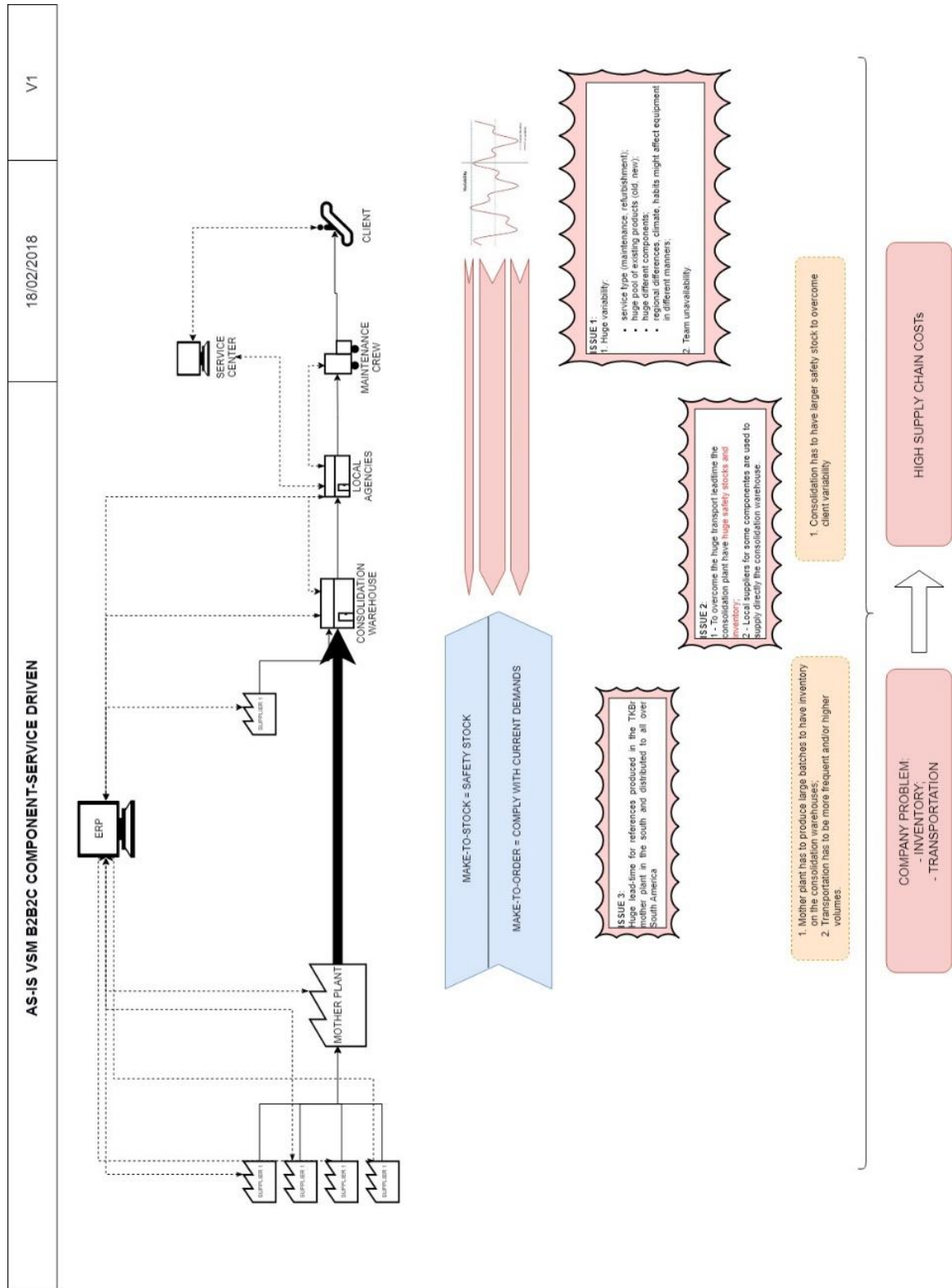


Figure 33 – Elevator Company A MIFA issue analysis

APPENDIX C: Key References Classification

Includo	Title	Author	Concept	Methodology	Literature review	Environment	Case Study	Business Management	Information Systems	Engineering
	A Methodology for Adopting Product Service Systems as a Competitive Strategy for Manufacture	G.C.J. Ang; T. Baines; H. Lightfoot		x			x			x
	A framework for PSS business models: formalization and application	Federico Adrodegaria; Nicola Saccania; Chri	x				x			x
	TRAPSS methodology – A smart solution for manufacturing SMEs	A. Dimache; S. Mitchell; P. O'Dowd	x				x			x
x	Survey on Product-Service System applications in the automotive industry	F. Mahut; J. Daaboul; M. Bricogne	x		x		x			
x	Industrial Product-Service Systems—IPS	H. Meier; R. Roy; G. Seliger	x	x		x	x			
x	In search of "product-service": evidence from aerospace, construction and engineering	Johnston, S.; Dainty, A.R.J.; Wilki	x			x	x			
	Service innovation in product-centric firms: A multidimensional business model perspective	Daniel Kindström; Christian Kow	x	x			x			x
	Towards a service-based business model – Key aspects for futu	Daniel Kindström	x				x			
x	Enabling Organizational Changes for Development of PSS Offers	Johanna Wallin; Koteswar Chiru	x			x	x			
x	Developing PSS Concepts from Traditional Product Sales Situation: The Use of Business Model Canvas	Johanna Wallin; Koteswar Chiru	x	x			x			x
x	Product-Service System (PSS) design: using Design Thinking and Business Analytics to improve PSS design	Kloecknera; Jose Luis Duarte Ribeiroa; Giuditta Pezzottab;	x	x			x			x
x	State-of-the-art in product service-systems	T S Baines; H Lightfoot; E Steve;	x		(x)		x			
x	Looking beyond the rim of one's teacup: a multidisciplinary literature review of Product-Service Systems in Information	Matthias Boehm; Oliver Thomas	x		x			x		
x	Knowledge-Sharing Network for Product-Service System Development: Is it atypical?	K. Chirumalla; A. Bertoni; Å. Ericson; O. Isaksson	x				x			
x	Product Service systems, Ecological and Economic Basics	Mark J. Goedkoop; Cees J.G. van Halen; Harry R.M. te Riele; Peter J.M. Rommens	x			x	x			
x	Moving from basic offerings to value-added solutions: Strategies, barriers and alignment	Paul Matthyssens; Koen Vandenbempt	x				x			
x	Clarifying the concept of product-service system	O.K. Mont	x				x			
x	Developing new product service systems (PSS): methodologies and operational tools	Nicola Morelli		x						x
	PSS for influencing customer barriers and acceptance	Danilo Marcello Schmidt; Paul Bauer; Markus Mörtl	x		x					x
x	Evolving to a New Dominant Logic for Marketing	Stephen L. Vargo; Robert F. Lusch	x				x			

APPENDIX D: Interviews

DATE: 2018-05-04

Contact 1	
Name	Roberto
Function	Master thesis student at INESC TEC
From	Pernambuco, Brazil
Date of contact	27.04.2018
User type	Elevator user, apartment owner in Brazil

Key insights

Interview details	
Face to face interview transcript.	
EL:	Brief intro regarding the work about elevator maintenance service, from the Brazilian user perspective. Thank you for coming. Would you mind telling which state you lived in Brazil?
RO:	Pernambuco
EL:	Do you used regularly elevator in Brazil?
RO:	Yes.
EL:	Where you an apartment owner or rented?

RO:	I was an owner.
EL:	Which floor was it?
RO:	4 th floor
EL:	So you used your building elevator regularly?
RO:	All the days. For all day to day necessities.
EL:	How was the management of the elevator?
RO:	The building had a building management company who managed every aspect, including the elevator maintenance.
EL:	So, you as an apartment owner also had assemblies where you discussed regarding elevator maintenance with the building manager. Where you sensible regarding the type of maintenance service of the elevator, price, quality of service? Which where you almost aiming – price or quality?
RO:	We primed for quality of the service, for us important was elevator availability. But there wasn't a concrete analysis if the service was provided adequately. We had the company who installed the equipment as a maintenance service, and we never changed.
EL:	So, there was no analysis by the owner to switch to a more lower cost service?
RO:	No. Because there wasn't any need to dwell in the actual cost.
EL:	Did the elevator ever break down?
RO:	Yes. But no more than a day.
EL:	So, did it did affect you?
RO:	No, because we had 2 elevators. And there were always operational.
EL:	What you aimed for a good service quality for maintenance service?
RO:	Well for the elevators always be operational. A good maintenance service will only allow for the elevators to stop during routine maintenance, and even those it should take little time to not disrupt the normal day-to-day of the building.
EL:	Do you think the numbers of floor affect the need of elevator?
RO:	I believe that after 3 rd floor a building needs a working elevator.

EL:	Do you think the status of the building, for example, higher income tenants can affect the demand of the service?
RO:	Depend on the culture of the place, in Brazil the status plays an important role in the society. And a building without a working elevator can have higher demand to the service be done faster than any other. At first the needs can be equal as any other building, but the impact and expectance can be higher.
EL:	Changing the segment. What you think about an elevator in a business? Imagine you go to a company who has its offices in a building. What kind of impact for you does a not working elevator for the business image?
RO:	Depends on what is happening. For example, for me if I knew that the company per own decision decided no to maintain properly the elevator I would have a bad feeling about the company even if they had another elevator working. But if the elevator is not working but the company warned beforehand and justified accordingly.
EL:	For 1 to 10 then was is the level of demand for an elevator be functioning on a company building?
RO:	For me it depends, if the elevator has impact on the business day-to-day. If it does, I will give it a 10, if not and the company has warned that there is a scheduled elevator unavailability, I will give it a 3.
EL:	And in case of a hospital? How would you rate?
RO:	The same way. But of course, elevator unavailability would be more harmful to the hospital day-to-day, so it would be a more exigent scale.
EL:	<i>Presenting the proposal of an intelligent elevator and collaborative maintenance.</i> The user can give input of the state of elevator and request maintenance, through photos and a app. Would you as user, be available to use such application?
RO:	For me would be excellent. My opinion is that, all the tenants should participate in the conservation of the elevators.
EL:	So for you having the maintenance company at reach, would higher your perception of quality?
RO:	Yes. But I probably this would be later an issue, as it should first be validated by the building manager. Because if then everyone has access, then every tenant would request maintenance for everything than could higher the cost of the maintenance service. So, for me this should be first addressed, that someone has to validate the request.

EL:	Would you be more comfortable that this firstly would only trigger a remote maintenance to identify
RO:	Yes. It would be great. Even better.
EL:	<i>Other aspect would be the change of ownership of the equipment to the manufacturer.</i> Would you be comfortable with that idea?
RO:	I would think better in that case.
EL:	In your opinion, what are the barriers for this shift?
RO:	For me it would be great only if we are speaking about a fixed cost contracts without paying extra services and stipulating a top-quality service provision – adequate for each building.
EL:	So, you meant some type of contract linked to the number of uses of the elevator?
RO:	For me it is important that the condominium would not be hostage to only that maintenance company. That is why I spoke about the fixed cost, integrated cost of the elevator functioning. For example “this year we will pay X, according to the usage given by the elevator, all other maintenance aspects is up to the company to check”. No unexpected cost.
EL:	And if would tell you that shifting to this business model implies that the business where to promote a more sustainable agenda. Components that are more durable, more consumption efficiency. Would you pay extra for this kind of service?
RO:	Well, I believe that this kind of model would support more cost reduction. Because then we could dilute more the cost of components, cost of maintenance. It could be a win-win situation the price could be higher, but then all would benefit, the condominium would have a more efficient elevator, and the company would reduce the maintenance and production of the components.

Impact on Business (what hypotheses were reinforced / modified / dropped)

- The type of building residential, commercial, Public can influence the urgency of having an elevator available. On the residential building also the factor of vicinity (high class) can increase the pressure to have functional.
- Switching the ownership of the equipment to the manufacturer can be forthcoming to the tenants if they gain in terms of better service and lower price. They also wish to have some flexibility afterwards if they wish to switch the provisioner of the service.

- User and tenants are open for the collaborative maintenance, and actually think would enable a higher service quality provision. But have some concerns on the abuse of such service;
- If the service will provide the maintenance and spare part replacement at a fixed price, tenants would be forthcoming in such solution;

DATE: 2018-05-24

Contact 2	
Name	Adriano
Function	Investigator at INESC TEC
From	Londrina, Paraná, Brazil
Date of contact	30.04.2018
User type	Elevator user, apartment tenant

Key insights

Interview details	
Face to face interview transcript.	
EL	<i>Brief intro regarding the work about elevator maintenance service, from the Brazilian user perspective.</i> Thank you for coming. Would you mind telling which state you lived in Brazil?
Ad	I come from Paraná, Londrina.
EL	Did you used to live in an apartment?
AD	Yes. 7 th floor

EL	Was it rented or were you a owner?
AD	It was rented.
EL	So you used quite a lot the elevator?
AD	Yes. At least 2 times per day.
EL	The apartment building had how many elevators?
AD	It had 2 elevators.
EL	So in any time did the elevators stopped functioning?
AD	Yes. At least one I was aware stopped functioning.
EL	Do you know how long it was unavaialble?
AD	No. But normally was just one day?
EL	Did you participate in any sindico meeting?
AD	No. That was tasked to the apartment owner.
EL	So, jumping to the elevator maintenance. So when do you think the elevator is required in an apartment building?
AD	I think it is a rule in Brasil that up to 4 floor building must have elevators.
EL	If the elevators stopped working would it affect you much?
AD	Well, since I do not have mobility problems. I could go up and down by stairs.
EL	But how far could you do that?
AD	Well after 2-3 days probably would start complaining. For example, if I had to carry groceries it would start miss the elevator, probably less than 1 day come to think of it. Depends on the period, if it where in the weekend that occurred would be less worried and understandable to the situation.
EL	So to whom would you approach the situation?
AD	To the doorman (porteiro). Because he is in charge of the safekeeping and maintenance of the apartment building.
EL	Do you think in a commercial building having a large period of elevator unavailable could affect its image?

AD	Yes, of course.
EL	Would it affect the image of the company localized in this building?
AD	Yes. Of course. Would not trust the company.
EL	Who you think would be responsible for this situation?
AD	Probably the maintenance company, or the system of the building who ensures these services are performed. But having said this, I would think that the company is in a building not suitable for them, or they are accountable in some sort by having chosen this building to host their business.
EL	So the same sort of perspective for a government or public building?
AD	Yes. For example it is important for person who have less mobility.
EL	Apart also from moving between floors. Do you think there are other factors that affect the demand to have a fast maintenance service? For example a higher class residential, or business building?
AD	I think not. Do not know probably.
EL	Let's say you have a friend who lives in this kind of buildings, matched to a higher wage tenant. And the building had a not working elevator. Then you come again on your next visit and the same issue happens.
AD	Probably yes. If I see a high condo, I would think that is needed a matching elevator availability.
EL	<i>Presenting the proposal of an intelligent elevator and collaborative maintenance.</i> The user can give input of the state of elevator and request maintenance, through photos and a app. Would you as user, be available to use such application?
AD	No. I am not forward having to install an app on my mobile. But if it where something installed on the elevator to speak with someone, probably would make the report. I am very resistant on installing apps.
EL	<i>Other aspect would be the change of ownership of the equipment to the manufacturer. Having the company being tied through a service contract to ensure equipment availability to the customer, covering all the aspects of maintenance and equipment management.</i> Would you be comfortable with that idea?

AD	Depends on how much that costs for the owner. For me the real perspective is if that kind of service would be more affordable at a lower price, to the owner than the current situation. For me is more relevant the price of the service rather than have a total equipment availability.
EL	So, for you, you are more price sensitive...
AD	Yes, based in my experience, I prefer to look more affordable option rather than an availability. I think that equipment are more resistant than have higher maintenance service.
EL	Taking into account the same idea. If I told you this would allow to collect more information and design more durable, sustainable spare parts to the elevator. Would you consider a service as this having this sustainable component?
AD	In my opinion, no. I do not want to pay for the company to be sustainable or reduce their costs. If the company aspires this aspect should come in to their own terms to achieve this and not pass to the consumer. It is not a factor to choose the service. Of course we are speaking about hypothetical decision, without no values added to it is difficult to measure this. So would then measure the financial aspect first when choosing the service.

Impact on Business (what hypotheses were reinforced / modified / dropped)

- Users may not be open for a collaborative maintenance if it means having to install a mobile application or have some level of effort required for them. If it is an accessible solution such a reporting button installed in the elevator they could perform.
- Owners may be more inclined when choosing the maintenance service in terms of financial gains (a affordable service) rather than total equipment availability or sustainable factors. They can overlook equipment ownership if it means better service gains for them.

DATE: 2018-07-09

Contact 3	
Name	Mariana
Function	Investigator at INESC TEC
From	Santa Catarina, Brazil
Date of contact	10.05.2018
User type	Elevator user, apartment tennant in Brazil

Key insights

Interview details	
Face to face interview transcript.	
	Please check interview audio.

Impact on Business (what hypotheses were reinforced / modified / dropped)

- Users can be open to having the manufacturer owner of the equipment as long as they ensure a proper service quality;
- User can be open to support the maintenance process, but have to be careful not to sense they are “performing all the work”;

DATE: 2018-07-09

Contact 4	
Name	Pedro
Function	Investigator at INESC TEC
From	São Paulo, Brazil
Date of contact	10.05.2018
User type	Elevator user, apartment owner in Brazil

Key insights

Interview details	
Face to face interview transcript.	
	Please check interview audio.

Impact on Business (what hypotheses were reinforced / modified / dropped)

- Sindico (the apartment owner committee) play a major role as deciders to pick the maintenance services. Normally, the proposals are made by someone who knows the maintenance company and has a contact.
- Elevator in commercial buildings play an important role for communication and advertisement points. For example, office commuting could enable persons from same office to have a task review. Or other companies can put a TV that showed the news of the company.
- So elevator in commercial buildings is not just an equipment to move between floors but can be an important business cards for the companies looked on these buildings. Not having a working elevator can hinder potential business.

DATE: 2018-07-09

Contact 3	
Name	Marco
Function	Owner of Building management company
From	Pernambuco, Brazil
Date of contact	30.04.2018
User type	Building manager

Key insights

Interview details	
Face to face interview transcript.	
	Please check interview audio.

Impact on Business (what hypotheses were reinforced / modified / dropped)

- The composition of the building is constituted by the following parties:
 - o Sindico – committee of the apartment owners, have the power to decide and vote proposals;
 - o Building management company – takes care of the financial aspects of the proposals and further maintenance tasks (such as spare part purchase). Some can even nominate a building caretaker taking in the responsibilities of this stakeholder;
 - o Building caretaker – responsible to the day-to-day building maintenance, manages the maintenance services;
 - o Doorman – normally can be the caretaker, in larger condominiums the position is split. The doorman is responsible to check the entrance of people, can also receive directly complaints and remarks from the apartment owners. Can provide 1st assistance in case of problems, such as elevator stops between floors.
- Issues with current maintenance services:
 - o Maintenance services impose their services through the acquisition of components. Through the routine check-up, they detect components and then require the purchase of the components which is performed a part of the service.
 - o Reported issue: a purchased part come rusted and was installed on the elevator. A complain was put with photos, but no action by the company was taken. In his perspective, this devaluated the quality of service.
 - o Suggestion to have a more transparent maintenance service, where there is explanation of the components used on the maintenance.
- There are other companies who are non-manufacturers that are offering elevator maintenance services at almost half the cost of manufacturers. They also present themselves very professional and with the right equipment.
 - o Manufacturers are taking action by dumping the market with lower maintenance offerings;
 - o However, they include contractual clauses which oblige for an annual (or more) subscription which can be automatically renovated in case of component purchase.
 - o Suggestion, fidelization of the customer does not mean to enforce a service to the customer. But rather supplying a correct and professional service without extra-costs.

-