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LEAN THINKING IN HEALTHCARE PHLEBOTOMY SERVICES: A CASE STUDY

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Dissertation submitted as partial requirement for the conferral of
Master in Business Administration

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May, 2017

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Abstract

Lean Thinking arises as a solution to address the rising costs of healthcare. This dissertation aims to evaluate the potential of applying Lean tools to healthcare phlebotomy services. Furthermore, a theoretical framework is provided in order to support the present research.

Case study's methodology is applied to the phlebotomy service of a private and a public hospital of Lisbon where direct observation and informal interviews are performed to internal and external customers.

Value stream mapping, process activity mapping, spaghetti diagram and time value map are applied to the core process of a phlebotomy service: blood collection. Healthcare customers are identified and their perception of value is revealed. Waste is identified using the selected tool, recognised in the methodology, and improvement suggestions are proposed.

The outcome of this research shows that the application of Lean thinking can convey possible gains to healthcare phlebotomy services if improvement suggestions are implemented, as the process would become more precise and reduce the total cycle time benefiting internal and external customers, increasing process efficiency.

Considering the elimination of waste in the blood collection process, median total time's reduction is expected to be by 47% for Lusíadas Hospital and 37% for São Francisco Xavier Hospital, in addition to reducing the median wasteful time by 54% and 46%, respectively, and the reduction of the distance covered by phlebotomists, receptionists and technical staff involved.

Keywords: Lean Thinking; Healthcare; Value Stream Mapping; Phlebotomy Services.

JEL classification system: M110 – Business Administration: Production management; I100 Health: General

Resumo

Lean Thinking surge como uma solução para lidar com o aumento dos custos em saúde. Esta dissertação tem como objetivo avaliar o potencial de aplicação de ferramentas *Lean* aos serviços de flebotomia (colheita de sangue) em saúde, sendo fornecido suporte teórico para apoiar a presente pesquisa.

A metodologia do estudo de caso é aplicada ao serviço de flebotomia de um hospital privado e de um hospital público de Lisboa, onde observações diretas e entrevistas informais são realizadas a clientes internos e externos.

Value stream mapping, process activity mapping, spaghetti diagram e *time value map* são aplicados ao processo central de um serviço de flebotomia. Os clientes de saúde são identificados e a sua perceção do valor é revelada. Os desperdícios são identificados pela ferramenta selecionada, presente na metodologia, e sugestões de melhoria são propostas.

O resultado desta dissertação revela que a aplicação do pensamento *Lean* pode trazer possíveis ganhos aos serviços de flebotomia se as sugestões de melhoria forem implementadas. O processo tornar-se-á mais preciso e reduzirá o seu tempo total beneficiando clientes internos e externos, aumentando a eficiência do processo.

Considerando a eliminação de desperdícios no processo de colheita de sangue, espera-se que a redução da mediana do tempo total seja de 47% para o Hospital Lusíadas e 37% para o Hospital São Francisco Xavier (SFX), além da redução da mediana do tempo de desperdício em 54% e 46%, respetivamente, e a redução da distância percorrida pela equipa técnica envolvida.

Palavras-chave: Pensamento *Lean*; Cuidados de saúde; *Value stream mapping*; Serviços de flebotomia.

Sistema de Classificação JEL: M110 – Business Administration: Production management; I100 Health: General

Acknowledgements

This dissertation is the culmination of the most important stage of my academic life and I owe it to people who were very important in helping to complete this path.

Thank you to my loving and supporting family who were always there for me and who provided the opportunity to achieve my dreams and always believed in my capabilities. A heartfelt thanks to my boyfriend throughout this journey for his help, patience and support.

I am forever grateful to Professor Ana Lúcia Martins for challenging me and giving me an opportunity to be one of her guiding students. Her motivation, dedication and guidance gave me the strength to finish my master thesis.

I would also like to thank everyone involved in this research and who participated and welcomed me in Hospital dos Lusíadas and Hospital de São Francisco Xavier. It could not have been possible without everyone's contribution. A special thanks to Drª. Margarida Franco, Dr. João Viana and Drª. Luísa Pinto for their quick response, opportunity and availability.

A profound gratitude and thankfulness to all the wonderful people who were involved and contributed to the end of my Master journey.

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List of abbreviations

CHLO - Centro Hospitalar de Lisboa Ocidental

Dep – Department

Dist - Distance

FVA - Future value adding activity

IT – Information technology

NPI – Number of people involved

NV – Non-value adding activity

PAM- Process activity mapping

SA - Support activity

SFX - São Francisco Xavier Hospital

TPS - Toyota Production System

VA - Value adding activity

VSM - Value Stream Mapping

W - Waste

WHO - World Health Organization

1. Introduction

In this chapter, the problem of the case study analysis and its contextualization will be introduced and its relevance will follow. Furthermore, by defining the research question, to which it is intended to answer, the general and specific objectives of this case study will be determined. Moreover, the scope of the investigation and its structure will be identified.

1.1 Problem statement

The Portuguese healthcare system has been for several years a number one concern and priority for the Portuguese government (Major & Magalhães, 2014). The increase of healthcare costs urges the need for governments to take action and create policies to become more efficient and effective with the use of available resources (Radnor, 2012; Luzes, 2013).

As healthcare costs increase dramatically worldwide, the development of innovative solutions to provide a more sustainable healthcare system is necessary (Radnor, 2012; Poksinska, 2010). Lean thinking in healthcare arises as a solution to improve patient safety and quality, as well as to reduce clinical errors and waiting time (Jimmerson *et al.*, 2005; Aherne & Whelton, 2010).

Morrison *et al*. (2011) claim that medical doctors categorize quick turnaround time in both inpatients and outpatients as one of the critical factors of laboratory service quality since most of them depend on the timeliness of specimen tests, and therefore also in phlebotomy services.

Most of the times, the solution to deal with increasing demand and rising test volumes is to add up technicians, creating space constraints (Rutledge *et al.*, 2010; Graban, 2012). Ng *et al*. (2010:51) stated that by applying Lean techniques it would "*further reduce wait times between steps, and provide exactly what the next user in the process required, quality and productivity improved*".

Lean thinking is a philosophy that analyses every process which creates and adds value and helps sustain it through a continuous process (Aherne & Whelton, 2010; Radnor, 2012) and is described as "*the dynamic, knowledge-driven, and customer-focused process through which people in a defined enterprise continuously eliminate waste with the goal of creating value*" (Murman *et al*., 2002:90). It identifies and distinguishes value-added from non-value-added activities and eliminates the wasteful activities to create a sustainable and efficient system

where every process adds value and creates customer satisfaction (Aherne & Whelton, 2010; Hines *et al.*, 2002).

Several researchers, such as Jimmerson *et al.* (2005), King *et al.* (2006) and Hawthorne and Masterson (2013), are testing and providing positive results of the implementation of Lean Thinking in healthcare. Hawthorne and Masterson (2013), both chief executive officers, applied Lean management techniques in two rural hospitals in North Carolina. After two years of the engagement in Lean thinking, these two hospitals decreased waiting time in emergency departments and surgery delays in operating rooms as well as cut more than 2 million dollars in operating and capital expenditures (Hawthorne & Masterson, 2013).

Notwithstanding the positive results obtained supporting Lean, researchers such as Dickson *et al.* (2009), Atkison (2010) and Radnor and Osborne (2013) stress that if Lean is not correctly applied according to the principles defined by Womack and Jones (1996) and there is no leadership commitment, Lean will fail with its objective.

According to Kim *et al*. (2006) and Joosten *et al.* (2009), Lean techniques have potential benefits in being applied to healthcare but the authors suggest further studies and share of publications among the healthcare community. To better analyse the potential benefits of the application of Lean, healthcare organisations should increase solution retention, involve senior management, pursue value creation for patients and promote long-term improvement (Mazzocato *et al.,* 2010). Thereby, Hawthorne and Masterson (2013:136) sustain that "*the Lean philosophy has a cumulative impact as it begins to define an organisational culture*."

The literature review in Lean has not been consistent in the healthcare area and further investigation, both in healthcare and phlebotomy services are required, due to its relevance in the diagnosis of clinical situations and its need to proceed with other medical procedures.

Several studies have been conducted in Portugal applying this recent methodology both in emergency departments and operating rooms (Luzes, 2013), but it is believed this is the first in Portugal that focuses on healthcare phlebotomy services. Furthermore, this dissertation will contribute to fill the gap present in the current literature by providing a theoretic framework and also an application of Lean tools in the phlebotomy services.

1.2 Research question

Based on past quality improvement in several hospital departments when applying Lean Thinking in healthcare, the following research question comes to light: *How can Lean Thinking add value to healthcare phlebotomy services?*

1.3 Objectives

Allway and Corbett (2002:54) declared that "*only the lean approach provides service companies with the chance to be the Toyota of their industry*".

When answering the research question, this dissertation will be grounded on Lean Thinking in healthcare by attempting to demonstrate the potential benefits of applying Lean to phlebotomy services.

The general objectives of this research are:

- Analyse Lean thinking principles, tools and applications in the healthcare area;
- Analyse and benchmark possible solutions to improve phlebotomy service quality and provide a more efficient service.

To comply with the general objectives stated above, six specific objectives were identified as milestones to answer the research question:

- Map the phlebotomy service process by identifying its different stages;
- Describe and compare the phlebotomy process in public and private sector;
- Identify the customers of the phlebotomy service process and their perception of value;
- Distinguish value-added from non-value-added activities and eliminate the wasteful ones;
- Identify and propose possible solutions to improve the value provided by the process;
- Adapt the solutions proposed to meet public and private process requirements;
- Estimate the efficiency of proposed solutions.

1.4 Case study approach

When choosing the most appropriate research methodology, the emphasis needs to be on three different conditions which are: the type of research question, the control of the investigator in the events and the focus on contemporary events rather than historical ones (Yin, 2009).

Yin (2009) argues that the research question defines the methodology chosen. If the research question is an "*how*" or a "*why*" question, it is more likely to lead to a case study methodology due to its explanatory nature (Yin, 2009).

For this research, the methodology chosen is the case study because it "*investigates a contemporary phenomenon in depth and within its real-life context*" (Yin, 2009:18). Furthermore, it intends to answer the research question presented above, which focus on "*how*" the methodology being studied affects and impacts contemporary hospital phlebotomy services by providing insights and enabling data collection from various sources (Yin, 2009).

1.5 Scope

According to the objectives previously defined, the present study will focus on the healthcare phlebotomy services from a public and a private hospital, which will be Hospital São Francisco Xavier and Hospital Lusíadas, and will lay attention on the processes that occur in the phlebotomy services from the moment the patient enters the service to the moment the patient departures, thus, the processes to be analysed are related to the blood collection process. This delimitation of processes will be identified and scrutinised in Chapter 4 through the application of Lean thinking tools.

1.6 Dissertation structure

In order to comply with the objectives set above and to provide an answer to the research question, the dissertation outline will be organised in the following chapters:

- **Introduction**: the subject of the dissertation was introduced and contextualised, the research question was identified as also the general and specific objectives were determined;
- **Literature review:** the theoretical framework that sustains this investigation was analysed and exploited;
- **Methodology**: the research methodology was disclosed, the case study approach was justified and the data gathering and tools selected were revealed;
- **Case study**: the analysed process was identified and the application of Lean tools to assess the initial status was performed. Furthermore, improvement opportunities were suggested and discussed.
- **Conclusions**: the results of the research were evaluated, its validation and limitation were considered and future research alternative were suggested.

2. Literature review

In this chapter, a theoretic framework that supports this investigation regarding the main concepts about Lean philosophy will be provided. Furthermore, the origins of Lean thinking and its evolution are going to be presented. In addition, following the objectives of this case study, the five principles of Lean are discussed as well as the types of waste (*muda*). Value stream mapping and other Lean mapping tools are described in the theoretic framework. Finally, Lean thinking in services and healthcare are both reported as well as the challenges of its implementation.

2.1 Lean Thinking

The origin of Lean Thinking comes from the Japanese manufacturing philosophy of Toyota. Following World War II, the United States of America reduced costs by mass producing fewer types of cars. However, that was not happening in Japan (Ohno, 1988; Womack, 2002). As described by Ohno (1988) and Womack, Jones and Roos (1990), Japan was starting to shift the automotive business model, giving birth to the Toyota Production System (TPS), producing different models in small quantities.

Shortage of resources and the highly competitive automobile market are the main characteristics that created the just-in-time production system and the Kanban method, tools of Lean methodology (Hines *et al.*, 2004). This approach was focused on eliminating waste and excess throughout the Toyota supply chain, which distinguished itself from the usual large batch sizes (Hines *et al.,* 2004; Rich *et al.*, 2006).

In the 70's, the Toyota Production System (TPS) was finally applied to the overall supply chain and this marked the point where supplier manuals revealed to outsider companies the secret of the Lean approach (Womack & Jones, 2003; Hines *et al.*, 2004). It was when the book "*The machine that changed the world"* was published that the western enterprises gain interest in the philosophy underneath the Toyota manufacturing (Hines *et al.*, 2004; Rich *et al.*, 2006).

Hines *et al.* (2004) described a four stage lean evolution and a fifth stage was proposed by several authors, such as Jasti & Kodali (2015) and Garza-Reyes (2015), which is summarised in Table 2-1. At the awareness phase, the western enterprises tried to adopt Lean structure and techniques but failed on creating a greater impact due to difficulties in introducing the human mind-set and organisational culture, both core to the Lean approach (Hines *et al.*, 2004). This created a weakness in dealing with variability in demand (Hines *et al.*, 2004).

Phases	1980 – 1990 Awareness	1990 – mid-1990 Quality	Mid 1990-2000 Quality, cost and delivery	2000+ Value system	2010 + Sustainability
Literature theme	Dissemination of shop-floor practices	Best practice movement, Benchmarking leading to emulation	Value stream thinking, lean enterprise, collaboration in the supply chain	Capability at system level	Lean-green as a consolidated approach
Focus	JIT techniques, cost	Cost, training and promotion, TQM, process reengineering	Cost, process-based to support flow	Value and cost, tactical to strategic, integrated to supply chain	Compatibility between lean and green, integration of lean and green
Key business process	Manufacturing shop-floor only	Manufacturing and materials management	Order fulfilment	Integrated processes, such order fulfilment and new product development	Sustainable global supply chains
Industry sector	Automotive - vehicle assembly	Automotive – vehicle and component assembly	Manufacturing in general – often focused on repetitive manufacturing	High and low volume manufacturing, extension into service sectors	Manufacturing, service sector and infrastructures
Authors	Shingo (1981, 1988) Schonberger (1982, 1986) Monden (1983) Ohno (1988) Mather (1988)	Womack *et al*. (1990) Hammer (1990) Stalk and Hout (1990) Harrison (1992) Andersen Consulting (1993, 1994)	Lamming (1993) MacBeth and Ferguson (1994) Womack and Jones (1994, 1996) Rother and Shook (1998)	Bateman (2000) Hines and Taylor (2000) Holweg and Pil (2001) Abbas *et al.* (2001) Hines *et al.* (2002)	Digalwar *et al.*, 2013; Mollenkopf *et al.,* 2010; Azevedo *et al*. (2012); Aguado *et al.* (2013); Cabral et al. (2012); Duarte and Cruz-Machado (2014a)

Table 2-1 – Lean evolution

Source: Hines *et al.* (2004:996); Jasti & Kodali (2015); Garza-Reyes (2015)

As western companies continued to adopt Lean principles (considered in sub-chapter 2.2) and techniques, they started to focus on quality (the early 1990s), quality, cost and delivery (late 1990s) and finally in 2000 in customer value (Table 2-1) (Hines *et al.*, 2004).

The fifth column (Table 2-1) proposed by Jasti & Kodali (2015) and Garza-Reyes (2015) highlights the new trend regarding Lean and sustainability. Garza-Reyes (2015:18) state

that "*the move towards greener operations and products has forced companies to seek alternatives to balance efficiency gains and environmental friendliness in their operations and products.*"

As claimed by Hines *et al.* (2004) and Rich *et al.* (2006), Lean has two levels such as a strategic level and an operational level. The strategic level – Lean Thinking – is concerned with the value creation and the understanding of customer value. The operational level – Lean Production – is concerned with the shop-floor tools and application. Furthermore, Hines *et al.* (2004) suggest that lean production should be used in shop-floor production and lean thinking should be applied to the strategic value chain dimension. If this last dimension is forgotten, organisations only focus on cost rather than value, a common mistake in shop-floor implementations (Hines *et al.*, 2004).

Understanding the distinction between strategic and the operational level instead of focusing around the shop-floor is crucial in order to apply the right techniques and tools to achieve lean's objective (Hines *et al.*, 2004).

Hines *et al.* (2008) contributed with an iceberg analogy called "*the Lean sustainable iceberg model*" by revealing that what cannot be seen is probably what is more important regarding the application of Lean. Figure 2-1 illustrates that the areas below waterline are people-related and consist of strategy and alignment, leadership and behaviour and engagement and the areas above waterline are technology, tools and techniques and process management. The meaning of this analogy is that, to establish a Lean sustainable organisation, the five elements need to be addressed and the elements below the water are what support an organisation to thrive for Lean, not just survive (Hines *et al.,* 2008).

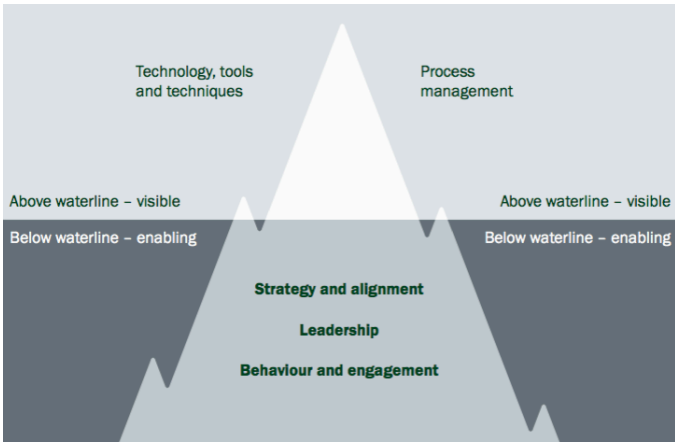


Figure 2-1 – The sustainable Lean iceberg

Source: Hines *et al.* (2008:9)

According to Graban (2012:2), "*Lean helps leaders see and understand that it is not the individuals who are broken, but the system itself*". The same author posits that Lean is a methodology that enables organizations to improve service and system quality by analysing the processes within the organization as also by promoting the connection and flow between departments. Moreover, Lean philosophy can allow achieving the highest quality by reducing waiting time and preventable errors (Graban, 2012).

2.2 Lean Thinking principles

There are five Lean fundamental concepts that can extend this methodology to go beyond automobile industry to any enterprise, in any sector (Womack & Jones, 1996; Womack, 2002; Hines *et al.*, 2002):

1. Identify what does and does not add value from the customer's perspective – specify **value**;
2. Map all the necessary steps involved in the entire value stream to identify the non-value added activities – identify **value stream**;
3. Continue the activities that create value without bottlenecks and interruptions – **flow**;
4. Adopt a **pull** strategy;
5. Continually identify and remove non-value added activities in the pursuit of **perfection.**

2.2.1 Value

The starting point of the Lean principles is specifying value. According to a Lean perspective, value is created by the producer and defined by the customer (Womack & Jones, 2003). Any process involved in the production of a good should start with the full understand of what the customer wants from it (Womack & Jones, 2003). Moreover, companies' perspective of value is often very different from the customers' point of view (Hines *et al.*, 2002).

Womack and Jones (2003:19) state that "*Lean thinking, therefore, must start with a conscious attempt to precisely define value in terms of specific products with specific capabilities offered at specific prices through a dialogue with specific customers*". How can waste be identified and removed if one cannot understand the customer's value perspective? (Hines *et al.*, 2008). In this sense, for an organization to "*go Lean*", there is a need to understand and satisfy customers by knowing what they value in the value stream as also to remove waste which customers are not willing to pay for (Hines & Taylor, 2000).

2.2.2 Value Stream

The value stream comprises all the actions involved in the flow of a good or service through three management tasks: **problem-solving task**, which consists of the activities associated with the concept of the product such as design and engineering; **information management task**, which comprehends the time the order is placed throughout its fulfilment, and **physical transformation task** that is related to the transformation of the product from raw materials to the finished product (Womack & Jones, 2003). Accordingly, Hines and Taylor (2000:4) refer the second principle as "… *all the steps necessary to design, order and produce the product across the whole value stream*…".

Hines *et al.* (2002) defined four different types of activities that can be found within any organisation when doing a value stream analysis:

- **Value adding** (VA) activity: activities that add value to the final product and make it more valuable;
- **Future value adding** (FVA) activity: activities that in the future will provide value to the customer;
- **Support activity** (SA) or necessary non-value adding activity: activities that do not add value to the final product but are necessary to achieve it. For this activity to be eliminated, several major changes should occur that may not be possible at the moment, for example, changes to the layout or in suppliers (Hines & Rich, 1997).
- **Waste** (W) or non-value adding activity: activities which do not provide any value to the final product and should be eliminated immediately such as waiting time and double handling (Hines & Rich, 1997). Womack and Jones (2003) divided this action into two types such as type one *muda* (non-value-added activities which cannot be avoidable in the current terms) and type two *muda* (non-value-added activities which can be immediately avoided).

In a time where most companies outsource some part of their business, creating Lean enterprises is one possible solution to remove waste by creating alliances with the parties involved capable of analysing the entire value chain from the initial production to the final delivery to the customer (Womack & Jones, 2003). For this to occur, transparency throughout every party involved is necessary in order to comply with the principles agreed and to achieve the final objective – create an efficient value stream and remove waste (Womack & Jones, 2003).

2.2.3 Flow

The first two principles are centred in the elimination of *muda* which can be achieved easily with little capital investment (Basu & Wright, 2008; Swank, 2003). Flow is the third principle identified by Hines *et al.* (2002) and Womack and Jones (2003). It comes after the value is specified and the lean enterprise is created to identify waste along the value stream and continue the activities which create value without interruptions (Hines *et al.*, 2002; Womack & Jones, 2003).

A very common production paradigm is that to perform efficiently it needs to be in batches. Functions and departments create the idea that every activity should be grouped by type (Womack & Jones, 2003). These batches generate long waiting time between tasks and departments regardless of keeping every member busy and equipment working hard, which does not necessarily mean efficiency (Womack & Jones, 2003).

Taiichi Ohno achieved continuous flow in small-lot production "…*by learning to quickly change over tools from one product to the next and by 'right-sizing' (miniaturising) machines so that processing steps of different types (...) could be conducted immediately adjacent to each other*" (Womack & Jones, 2003:23).

Moreover, by redefining the work of functions, departments and firms, it will help employees understand how they can add value to the value stream (Womack & Jones, 2003).

2.2.4 Pull

The fourth principle consists in producing only what the customer demands (Hines & Taylor, 2000).

Womack and Jones (2003) assert that when batches are replaced by a continuous flow of the value stream, the reduction of lead time is enormous. Lean systems provide the solution for variability in demand by producing any product in any combination (Womack & Jones, 2003). This creates an advantage because it ceases to depend on sales forecast and enables production to be made at the pull of the customer, which means customers get what they want when they desire (Womack & Jones, 2003). Furthermore, it reduces inventory level and increases return on investment (Womack & Jones, 2003).

2.2.5 Perfection

The fifth Lean principle is about seeking perfection through continuous improvement. This consists of staff working together to achieve better processes and solutions likewise to create a culture of ongoing betterment (Poksinska, 2010).

When the four initial principles are aligned, pursuing perfection is the next step. Although there is always *muda* to be eliminated, if transparency between every party involved in the value stream occurs (such as suppliers, assemblers, distributors, customers, employees), it is easier to create ways of adding more value (Womack & Jones, 2003). Moreover, it benefits from the positive feedback received by employees which are making improvements as it generates continuous efforts to improve (Womack & Jones, 2003).

2.3 Lean Thinking *muda*

Hines *et al.* (2002:7) states that "*waste is anything that does not add value to the customer*". Shingo (1989) identified the first seven wastes (*muda)* related to the Toyota Production System (Hines & Rich, 1997; Hines *et al.*, 2002; Womack & Jones, 2003):

- **Overproduction** – producing more than necessary;
- **Defects** – quality problems;
- **Unnecessary inventory** – excessive storage;
- **Inappropriate processing** – use of wrong procedures or tools;
- **Excessive transportation** – excessive movement of goods;
- **Waiting** – long periods of inactivity;
- **Unnecessary motion** – poor workplace organisation.

There are differences related to *muda* between the terminology used in a manufacturing company and a service company. For example, when referring to defects in manufacturing, the same "*waste*" in a service company would be called errors or mistakes (Maleyeff, 2006). Maleyeff (2006) defined seven different categories for waste in the service area which are:

- **Delays –** refers to time wasted in queues or information waiting to be transmitted;
- **Reviews** – refers to activities wasted in inspection for errors or omissions;
- **Mistakes** – relates to errors that cause work to be redone;
- **Duplication** – processes which are done twice in the system;
- **Movement** – wastes related to the flow of information, people and equipment;
- **Processing inefficiencies** – sequence of activities applied inefficiently when performing a specific task;
- **Resource inefficiencies** – inefficient use of resources such as personnel and equipment.

2.4 Lean Thinking mapping tools

As discussed previously, Lean focuses on creating value by removing waste throughout the supply chain. Nevertheless, difficulties arise when doing so such as lack of visibility or the necessary toolkit to provide that visibility. In addition, it is necessary to first understand the wastes to be removed before undergoing any mapping activity (Hines & Rich, 1997).

Table 2-2 correlates seven stream mapping tools with the usefulness of its application with wastes.

	Mapping Tool						
Wastes/Structure	**Process activity mapping**	**Supply chain response matrix**	**Production variety funnel**	**Quality filter mapping**	**Demand amplification mapping**	**Decision point analysis**	**Physical structure a) volume b) value**
Overproduction	L	M		L	M	M	
Waiting	H	H	L		M	M	
Transport	H						L
Inappropriate processing	H		M	L		L	
Unnecessary inventory	M	H	M		H	M	L
Unnecessary motion	H	L					
Defects	L			H			
Overall structure	L	L	M	L	H	M	H

Notes: H = High correlation and usefulness
M = Medium correlation and usefulness
L = Low correlation and usefulness

Table 2-2 – Connection between the manufacturing wastes with the seven mapping tools

Source: Hines and Rich (1997:50)

2.4.1 Value stream mapping (VSM)

Rother and Shook (2003:3) defined Value Stream as "*all the actions (both value added and non-value added) currently required to bring a product through the main flows essential to every product*". Value Stream Mapping consists of analysing the flow of raw materials and information through the system and identifying waste by creating actions and visual representation to eliminate it (Rother & Shook, 2003; Abdulmalek & Rajgopal, 2007).

Piercy and Rich (2009) acknowledged Value Stream Mapping as the best tool to identify waste and improvement opportunities because it lists all the activities in the entire process and the resources used in each activity.

Rother and Shook (2003) refer that VSM is constituted by three steps:

1. **Select a product family:** which consists in grouping similar products which go through the same processes to be the aim of improvement (Chen & Cox, 2012);
2. **Value-stream manager:** selecting a person who is responsible for the Value Stream and knows the entire information flow of a product and has the capacity to improve a product family's value stream (Rother & Shook, 2003);
3. **Using the mapping tool**: "*Value-stream mapping can be a communication tool, a business planning tool and a tool to manage your change process*" (Rother & Shook, 2003:9). First, draw the current state of the supply chain for that product family. Second, use the information gathered on the first stage to develop a lean future-state drawing. Finally, begin the implementation programme to achieve the lean future-state (Rother & Shook, 2003).

2.4.2 Process activity mapping

The engineered approach behind this tool is to map the entire order fulfilment process which enables to identify the lead time and productivity (Hines & Taylor, 2000; Hines *et al.*, 2002).

This technique comprises the elimination of waste by providing high-quality products and services through information flow. Hines and Rich (1997) and Hines *et al.* (2002) defined five phases of process analysis which consists in:

1. Analysis of the flow of processes;
2. Identification of waste;
3. Analyse if the process is done in the most efficient way;
4. Analyse the better flow pattern by using a different layout and transport routeing;
5. Analyse every stage of the system to understand and distinguish value-added from non-value-adding activities.

2.4.3 Supply chain response matrix

Time compression and logistics movement are the key factors behind this tool. Hines and Taylor (2000:32) affirmed that *"the objective of this mapping is to improve, or maintain, the service level of the entire chain but with fewer costs"* and consists in the evaluation of

inventory and identification of lead time constraints throughout the supply chain. This tool has a high correlation with *muda* related to waiting and unnecessary inventory (Hines & Rich, 1997).

2.4.4 Production variety funnel

According to Hines *et al.* (2002), this visual technique maps the differences in the product variants along the supply chain. Production variety funnel has a medium correlation and usefulness with "*unnecessary inventory*" and "*inappropriate processing*" because it helps to understand how the supply chain operates and where a product becomes very customer specific which can create inventory constraints. It provides an opportunity to identify product rationalisation and to target inventory reduction (Hines *et al.*, 2002; Hines & Rich, 1997).

2.4.5 Quality filter mapping

Hines and Taylor (2000) mentioned that this tool focuses on identifying where quality problems exist in the order fulfilment process, therefore has a high correlation and usefulness with "*defects*". This mapping technique shows three different types of quality problems in the supply chain (Hines & Rich, 1997; Hines, *et al.* 2002):

- **Product defects:** goods which are not caught by inspection and are passed on to customers;
- **Scrap defects**: defects produced in an enterprise caught by inspection;
- **Service defects**: problems that the customer experience which is not related to the product itself but the documentation or inappropriate delivery related to that product.

2.4.6 Demand amplification mapping

This tool provides the quantity of each product along the supply chain as also inventory holdings, scheduling, batch sizing policies and inventory decisions (Hines & Rich, 1997). Moreover, the ability to show how demand varies gives the opportunity to show the bullwhip effect (Hines & Rich, 1997; Hines *et al.*, 2002).

2.4.7 Decision point analysis

Decision point analysis identifies the point in the entire supply chain where products *"…stop being made according to actual demand and instead are made against forecasts alone"* (Hines & Rich, 1997:57). It is useful in the short-term to analyse if the processes are aligned with a pull or push philosophy. In the long-term, allows planning future events if the decision point analysis is changed (Hines & Rich, 1997).

2.4.8 Physical structure mapping

This is one of the tools alongside with demand amplification mapping which analyses the overall structure of the supply chain (Hines & Rich, 1997). It provides a visual diagram (by number of firms involved or by cost adding) where Hines and Rich (1997:58) stated that "*the area of each part of the diagram is proportional to the number of firms in each set or cost-adding process.*" Furthermore, it helps understand how the industry operates and see potential areas where there is a need for further development (Hines & Rich, 1997).

2.5 Lean Thinking in services

Allway and Corbett (2002) discuss the existence of five challenges in service companies when confronted with such competitive market and unprecedented economy which are rising customer expectations, revenue pressures, competitive pressures, increasing expenses and regulatory pressures.

The extension and application of Lean beyond automobile industry were first identified "*in the application to general supply chain management"* (Piercy & Rich, 2009:56). From a strategic perspective, when applying Lean across other sectors it is still possible to comply with the main objective which provides customer value and follow a Lean strategy by integrating other approaches, even though some shop-floor tools are not suitable (Hines *et al.*, 2004).

Several authors studied the application of Lean thinking in services such as Allway and Corbett (2002), Swank (2003), Hines *et al*. (2008a), Piercy and Rich (2009), Bonaccorsi *et al.* (2011) and Radnor and Osborne (2013). They have reported evidence in further exploring and implementing Lean in the service industry.

Allway and Corbett (2002) and Radnor *et al.* (2012) advocate that service industries are starting to shift their business improvement models to comply with these manufacturing techniques focused on customer and process operations. Accordingly, the authors argue that every organisation which adopts Lean thinking will rapidly discover the benefits of such tool and improve their operations to become more efficient.

Maleyeff (2006) state that service companies usually combine two to three transformations whereas manufacturing companies focus only on physical transformations. This combination of transformations may be physiological, exchange, informational, location and storage. Moreover, it may be difficult to apply explicitly the five lean principles because, for instance, in a service company all the work is started by the customer – pull strategy - as also it is very likely to experience long waiting time in poorly managed services (Maleyeff, 2006).

Radnor and Osborne (2013) acknowledged three challenges for Lean's implementation in public services: the product being "manufactured" is a service rather than a good; operating processes are often internal; the key success factors vary from the private sector. Radnor and Osborne (2013) and Radnor *et al*. (2012) argue that because of the differences between the public and private sectors, and therefore in the service user, it is difficult to recognise the value of the customer. Moreover, the authors state that in the service area there is little influence on demand because their design is led by capacity. Additionally, "*the private sector 'raison d'etre' of Lean is on efficiency and cost reduction – yet public services must also consider effectiveness and equity*" (Radnor & Osborne, 2013:268).

Hines *et al.* (2008a) analysed and compared the application of Lean Thinking in the legal sector of the Portuguese court system with the Welsh Legal Services Commission and proposed a tentative model in order to apply Lean Thinking to public legal system.

Maleyeff (2006) conducted an exploratory study to analyse and critique several internal service systems using a Lean perspective and found several common structural characteristics which helped Lean practitioners in the service area to focus on where to improve. The common structural characteristics acknowledged were the importance of information, significant task variability, process flow across departments or functions, many handoffs of information, numerous management and technical reviews, hidden costs and benefits, no explicit motivation for urgency, no one size fits all solution.

Chen and Cox (2012) applied a Lean strategy to the office's processes of a small manufacturer in order to grow the efficiency of the design department to increase customer satisfaction. Swank (2003) reviews the application of a Lean initiative in an insurance company which delivered positive results thereby reducing labour costs by 26% and the rate of reissues due to errors by 40%.

The Boston Consulting Group (2009) illustrated two examples of the application of Lean philosophy to services and healthcare. In 2008, the University of North Carolina faced a challenge of a long length of stay per patient – a measure of effectiveness and efficiency. The hospital managers understood that if they reduced the length of stay by 10%, they would free up nearly 80 beds per year resulting in an operation profit of almost $30 million dollars (Boston Consulting Group, 2009).

Despite the positive results, oftentimes Lean is failing in its implementation (Radnor & Osborne, 2013). Furthermore, as highlighted by Radnor *et al.* (2012) and Radnor and Osborne (2013), Lean's implementation depends on the context. The authors argue that the origin of this

context (manufacturing industry) affects but does not preclude its implementation in the public sector.

One of the challenges of lean implementation in service companies before undergoing the transformation is believing in lean methodology as an improvement tool and understanding and admitting that the organization needs to undergo this process and is ready for change (Allway & Corbett, 2002; Atkinson, 2010).

Implementation phases

Allway and Corbett (2002) indicate a five-step guide for lean implementation. The first phase consists of assessing your current state by mapping the entire flow of processes, identifying opportunities for improvement and to diagnose the current level of operational excellence.

The second phase is to determine the target state by identifying the objectives that need to be accomplished, which mean a vision to be pursued by the company (Allway & Corbett, 2002).

The third phase comprises the stabilization of operations. It comprehends the guarantee that stage two goes according to the plan by conducting the vision in the right direction and ensuring that the company keeps on the right track (Allway & Corbett, 2002).

When stage four is reached, organizations get to the phase of optimizing opportunities. These include redesigning the physical layout and flow of processes by ensuring a "…*continuous flow of material, people and information*" (Allway & Corbett, 2002:51).

Phase five is the institutionalization of the Lean approach. To reach a sustainable and continuous operational improvement capability, Lean thinking "*needs to become the 'mantra' for the organization…*" (Allway & Corbett, 2002:51). This stage is achieved through communication and continuous reviews of the flow of processes as also by continuously assessing and applying Lean techniques (Allway & Corbett, 2002).

2.6 Lean Thinking in healthcare

One of the first key areas of Lean service was the retail industry due to the similarities of the product flows with the automotive industry (Piercy & Rich, 2009). The second area was Lean in hospital management which did not focus on a product itself but in patients in the healthcare system (Piercy & Rich, 2009; Graban, 2012).

Researches in Lean healthcare have laid emphasis on the acquisition of hospital supplies and also the patient's flow through treatment processes (Piercy & Rich, 2009). Furthermore,

several authors such as Miller (2005), Aherne and Whelton (2010) and Radnor *et al.* (2012) provided positive evidence in the application of Lean in Healthcare.

Radnor *et al.* (2012) recognised the growing evidence in terms of both tangible results (reduction in waiting times, reduction of costs and errors) and intangible results (increased employee motivation and customer satisfaction). Notwithstanding, the authors assert that Lean in Healthcare is still failing to deliver its promise regarding the impact on organisational performance and medical staff (Radnor *et al.*, 2012).

Frequently, healthcare processes are focused on the medical staff instead of the patient which usually is the only person who sees all of his journeys (Poksinska, 2010). Sometimes, 10 minutes was the only value-added time compared to the total time (the author refer "hours") the patient spent at the hospital (Poksinska, 2010). Since healthcare processes are not clearly defined, it creates "*inconsistency in care, unreliable access to resources and processes, and constant interruptions, which in turn implies inefficiencies, long waiting times, increased potential for errors, and worker frustration*" (Poksinska, 2010:322).

Poksinska (2010) developed a three-step guide to explain the meaning of Lean healthcare. First, it is the recognition of the patient as crucial and the most important customer as also to understand the patient/customer point of view (Fillingham, 2007; Poksinska, 2010). The second step is to categorize patients by laying emphasis on their different needs, conditions and value streams (Poksinska, 2010; Radnor *et al.*, 2012). The most used Lean tool in healthcare is the Value Stream Mapping (VSM) because it enables to map the flow of patients throughout their treatments and different processes (Poksinska, 2010). In addition, it helps medical staff to recognize the need to improve the entire system and not just some processes or the individual itself (Jimmerson *et al.*, 2005; Poksinska, 2010). The third step consists of "…*standardised work, waste reduction and continuous flow*", which are the most mentioned methods and principles when improving processes by removing waste such as waiting time (Poksinska, 2010:322). The patient should be able to flow through departments without any delays and interruptions. For this to happen, medical care staff has to identify bottlenecks and the root of issues in the system (Poksinska, 2010, Allway & Corbett, 2002).

Radnor (2011) compares the seven original wastes with service and healthcare wastes (Table 2-3).

Original Wastes	Service Wastes	Healthcare Wastes
Transportation	*Delay* on the part of customers waiting for service, for delivery, in queues	*Transportation*: Staff walking to the other end of a ward, central equipment stores for commonly used items
Inventory	*Duplication:* having to re-enter data, repeat details of forms	*Inventory*: excess stock; patients waiting to be discharged, waiting lists
Motion	*Unnecessary movement*: queuing several times, poor ergonomics in the service encounter	*Motion:* unnecessary staff movement, syringes and needles at opposite ends of the room
Waiting (delay)	*Unclear communication:* confusion over product or service use, wastes of seeking clarification	*Waiting for*: patients theatre staff results, prescriptions and medicines, doctors to discharge patients
Overproduction	*Incorrect inventory:* out-of-stock, unable to get exactly what was required, substitute products	*Overproduction:* requesting unnecessary tests, keeping investigation slots "just in case"
Over or inappropriate processing	*Opportunity lost* to retain or win customers, ignoring customers, rudeness	*Over processing:* duplication of information, asking for patients' details several times
Defects	*Errors* in the service transaction, product defects, lost or damaged goods	*Correction:* readmission because of failed discharge, adverse drug reactions, repeating tests because correct information was not provided

Table 2-3 – Comparison between manufacturing, service and healthcare wastes
Source: Radnor (2011:2)

Some of the problems that clinical laboratories face are "…*the decreasing availability of technical staff, complaints about work-related stress, increasing test menu and limited space*", which can be answered by applying Lean principles and tools as also to achieve better laboratory turnaround time while reducing costs (Melanson *et al*., 2009:919).

Successful cases arise from the application of Lean in healthcare. *Alegent Health* in Nebraska reduced the laboratory turnaround time by 60% by applying Lean methods; *ThedaCare* in Wisconsin reduced waiting time from first call to orthopaedic surgery by 14 weeks to 31 hours and; in South Dakota, *Avera McKennan* avoided spending 1,25 million dollars in new department construction by reducing patient stay by 29% (Graban, 2012).

Peerson *et al.* (2006) demonstrated that if the redesign of pre-analytic processes takes place, it can decrease laboratory turnaround time. Additionally, the authors affirm that by constantly applying Lean's fifth principle, they kept identifying improvement opportunities as also waste in order to unceasingly improve their laboratory service.

The costs of healthcare are increasing worldwide at a fast pace which urges the need to develop initiatives for cutting costs in the healthcare industry (Radnor, 2012). Lean Thinking arises as a possible solution to meet that need since cost reduction may be a consequence of Lean's value enhancing. As proven by the successful cases above, which are only examples of the many applications of Lean in the healthcare area, Lean has established its reputation in the healthcare industry.

Barriers and challenges of Lean implementation in healthcare

Poksinska (2010) states that the first challenge to implement Lean in healthcare is to convince staff that it is possible to use Lean thinking in healthcare. Often what is said is that patients are not cars and healthcare has a completely different organisation than the automotive industry (Poksinska, 2010). However, when staff is trained, layers of waste are exposed and staff understands that applying Lean techniques can provide many benefits in removing waste in processes (Poksinska, 2010; Hines, *et al.* 2008; Radnor *et al.*, 2012). Nevertheless, training is very hard due to the lack of people who understand and can teach Lean in healthcare (Poksinska, 2010).

Healthcare organisations are still very hierarchical thereupon making medical doctors the top decision makers (Poksinska, 2010). Medical doctors are highly trained to be autonomous, which goes against Lean philosophy that requires teamwork, good communication and collaboration between medical staff (Poksinska, 2010; Radnor *et al.*, 2012).

Since departments in healthcare are very dependent on each other, improving the entire system needs to acknowledge all the departments involved and not just focus on solving problems at one unit which may cause problems at another unit (Poksinska, 2010). Although it is possible to improve specific situations, a holistic perspective is required to be able to expand the improvement process to the entire system. Departments need to cooperate and work together in order to improve the entire value stream (Poksinska, 2010).

2.7 Summary

The origin and main empirical and academic contributions in Lean thinking were highlighted in this chapter. Lean's evolution throughout times with different characteristics and constraints was exposed as well and the "*Lean sustainable iceberg model*" was visited.

Following, the five fundamental principles were identified as well as their relevance in the Lean methodology. Regarding the aim of this case study, Lean thinking *muda* and its tools were described, plus, the correlation of the seven stream mapping tools with the usefulness of its application with wastes is also considered.

A comprehensive analysis of Lean's application in services and healthcare is given in order to identify and acknowledge its potential as also the positive results already provided by evidence.

The implementation phases suggested by Allway and Corbett (2012) in order for an organisation to "go Lean" and apply its tools and techniques is stressed as well as the barriers and challenges of its implementation in the healthcare sector.

As reviewed in the literature above mentioned, there are several applications of Lean thinking in services and the healthcare sector but, as exploited by Luzes (2013), there is none related to the phlebotomy services in Portugal, which translates into a gap in the literature that is intended to be filled with this dissertation.

3. Methodology

The present chapter is intended to contextualize the methodology chosen, aiming at the objectives of this case study and answer the research question. The characterization of case study research is described as also its design and research ethics. The sources of evidence that support this research are revealed as well as an explanation of each. Furthermore, the selection of the process that is going to be analysed is disclosed. A link between the seven wastes with five value stream mapping tools is performed, thus providing an understanding of how the tools are selected. To conclude, the steps which guide this case study are reported.

3.1 Case study methodology

According to the research question previously defined as "*how can Lean Thinking add value to healthcare phlebotomy services?",* and in accordance with Yin (2009)*,* the research methodology which applies best regarding this type of question is the case study. Furthermore, to understand social phenomena and real-life events such as managerial processes, the appropriate methodology is the case study (Yin, 2009).

What supports the choice of this methodology of research is the use of two sources of evidence which are going to be applied in this study and that distinguish case studies from history: direct observation and interviews with the people involved in the research (Yin, 2009; Eisenhardt, 1989).

This study benefits from applying this methodology because it "*relies on multiple sources of evidence*" and it is supported by theoretical propositions which help to guide data collection and data analysis (Yin, 2009:13).

As acknowledged by Eisenhardt (1989:547), one example of limitation to the case study research methodology is that "*case study theory building is a bottom up approach such that the specifics of data produce the generalizations of theory*". According to this position, the conclusions to be obtained refer only to the applied cases and cannot be generalized for other services and industry.

3.1.1 Case study characterization

Regarding Yin (2009), when answering the research question, this case study presents two strategies:

- A **descriptive strategy**: this research will analyse the patient flow through phlebotomy services and will provide insights concerning the activities involved and wastes;

- An **exploratory strategy**: in addition to using Lean tools to map the patient's flow and the description of activities, improvement opportunities will be identified and suggested based on a Lean Thinking approach.

3.1.2 Case study design

According to Yin (2009) and Eisenhardt (1989), the present case study is classified and structured as a multiple case study, specifically the phlebotomy services of a private and a public hospital. The process that occur from the moment the patient enters the service until his/her departure will be observed and analysed.

3.1.3 Research ethics

To perform the present dissertation in Hospital de São Francisco Xavier and Hospital dos Lusíadas, an authorisation was conceded by the Technical Directors of the Phlebotomy Services of both hospitals in November 2016.

As mentioned previously in sub-Chapter 1.4 and as stressed by Yin (2009), the control of the investigator in the events is an important condition when choosing the most appropriate research methodology. Subsequently, the methodology chosen was the case study. Since the investigator develops professional activity in the same area and will play an external observer role, the investigator's position and influence in the insights and findings acknowledged will be neutral.

3.2 Data collection

For the development of this case study, there are two information sources that are in accordance with Yin (2009) and Eisenhardt (1989) suggestions: direct observation and informal interviews.

Regarding the direct observation, the information will be obtained through the observation of the main aspects of the phlebotomy service. All the activities and resources necessary will be observed and identified to map the process from the moment the patient enters the service to the moment he/she departures.

Informal interviews will be conducted with technicians/phlebotomists and receptionists involved in the phlebotomy process. The purpose of these interviews is to identify the resources needed and a number of technicians per shift as well as to map the different stages of the phlebotomy service.

The data collection was performed from the 9th of November of 2016 until the 11th of January of 2017 and the data treatment will be based on the Microsoft® office tools, particularly

Microsoft® Excel. The number of days spent in Lusíadas Hospital to collect data was 17 days with an average of 3 hours each day and performed on different days in different weeks and in the morning and in the afternoon to collect the maximum of possible different events. Moreover, 10 days were spent collecting data in São Francisco Xavier Hospital, with an average of also 3 hours per day and performed in the morning, since in this hospital, the blood collections are only performed in the morning.

3.3 Process selection

The process to be analysed will be selected from the phlebotomy services of the public and the private hospital, and will consider three different criteria:

1. Core processes

Based on the data gathering through informal interviews and direct observation of processes performed in the phlebotomy services which impact the service quality perceived by the customer, the process selected should strongly influence the value of the overall service from the moment the patient enters the phlebotomy services until it leaves the service since it is one of the first means of diagnosis.

2. Information flow across departments

Maleyeff (2006) suggests that information is the most important characteristic in a service company and the focus should not be on the documents analysed itself but on the information flow and the information that is transmitted.

Furthermore, Maleyeff (2006:681) stated that "*handoffs, for example, are known to be a major source of medical errors*". The considered process should rely on the transmission of information across functions and departments and it should be recognized by technicians and receptionists as a source of errors if there are misunderstandings in the way the information is transmitted.

3. Waste

As the ultimate goal of Lean thinking is "*focused on the removal of waste, which is defined as anything not necessary to produce the product or service*" (Nave, 2002:74), the selected process should consider the existence of waste and that waste should be acknowledged by the technicians and receptionists through the informal interviews.

3.3 Selection of Lean Thinking tools

The tools' selection will be based on the literature review concerning Lean Thinking. To remove waste inside companies which do not add value to the final service, a combination

of Lean thinking tools can be used to identify waste and help remove or reduce it (Hines & Rich, 1997).

Firstly, an overview of the initial situation to gather information and an understanding of the process will be conducted (Rother & Shook, 2003). Rother and Shook (2003) advocate that this strategy provides the ability to look at the bigger picture as well as a visual representation of the process by highlighting wastes and its source. After the overview of the value stream, a descriptive analysis will be performed.

Lean Thinking tools' selection depends on the type of waste that organisations need to reduce or eliminate (Hines & Rich, 1997; Hines *et al.*, 2002). The value stream mapping toolkit, which enables the visualization of material and information flows as well as understanding where are the sources of wastes (Singh, *et al.* 2010), has been applied consistently in multiple researches across the healthcare service area (Jimmerson *et al.*, 2005; Miller, 2005; Kim *et al*., 2006; King *et al*., 2006; Mazzocato *et al.,* 2010).

Additionally, Hines *et al.* (2002) classified through a "*yes, maybe, no*" matrix, the ability of five value stream mapping tools (process activity mapping, production variety funnel, quality filter mapping, demand amplification mapping, process costing) to be linked with the seven wastes (overproduction, waiting, transport, inappropriate processing, unnecessary inventory, unnecessary motion and defects) firstly described by Shingo (1989). Table 3-1 reveals the matrix developed by Hines *et al.* (2002).

Wastes	**Mapping Tool**				
	Process activity mapping	**Production variety funnel**	**Quality filter mapping**	**Demand Amplification Mapping**	**Process Costing**
Overproduction	maybe	no	maybe	maybe	yes
Waiting	yes	maybe	no	maybe	yes
Excessive transportation	yes	no	no	no	no
Inappropriate processing	yes	maybe	maybe	no	yes
Unnecessary inventory	maybe	maybe	no	yes	yes
Unnecessary motions	yes	no	no	no	yes
Defects	maybe	no	yes	no	yes

Table 3-1 – Evaluation of the seven wastes with five mapping tools

Source: Hines *et al.* (2002:35)

Although the types of waste mentioned in Table 2-2 and Table 3-1 are from the manufacturing area and notwithstanding the differences across sectors, the terminology used to classify waste will be the one described by Radnor (2011) – *transportation, inventory, motion, waiting for, overproduction, over processing and correction* - because it is applied to the healthcare area, the same area where this case study is going to be applied.

According to the criteria for process selection stated in sub-Chapter 3.2.1 and after the direct observation and informal interviews, the types of waste are going to be identified and the most suitable mapping tool is going to be recognized in accordance with the acknowledged waste.

3.4 Research implementation steps

Aiming at the objectives of this dissertation, Lean Thinking mapping tools will be applied in order to provide insights across the methodology's implementation steps below:

1. Selection of core processes to be analysed;

2. Identification of the customers of the phlebotomy service process and their perceptions of value;

3. Selection of the Lean mapping technique according to the identified waste;

4. Map of the chosen value stream mapping using the selected mapping tool;

5. Analysis of the detection of waste and the outcome of the Lean tool application;

6. Assessment of the efficiency of the system at its initial stage;

7. Analysis and benchmark of possible solutions to improve phlebotomy services quality, efficiency and to provide a more cost-effective service;

8. Comparison of the initial evaluation and the evaluation after the Lean tools are used, in terms of efficiency.

4. Case study

Considering the research question presented in Chapter 1, this Chapter intends to provide an analysis of the core process performed in the phlebotomy services of a public and a private hospital.

This process will be analysed based on Lean thinking tools and concepts acknowledged in the literature review and through the methodology described in Chapter 3.

First, a description of both hospitals is provided as well as the organizational chart for the two clinical pathology laboratory and its phlebotomy services. Furthermore, the criteria to select the process defined in sub-Chapter 3.2.1 is going to be applied to justify the process under analysis. Hereafter, two types of healthcare customers will be exposed and its viewpoint of value will be revealed.

As stated in Chapter 3, the methodology acknowledged will be applied in order to identify the tools which better meet the characteristics of the types of waste previously recognised. Subsequently, the selected tools will be executed to identify waste and the process will be described according to the hospital where they exist.

Moreover, as set in Chapter 1, improvement opportunities will be suggested together with what public and private hospitals can learn from each other. Additionally, the selected tools will be applied once again to the process under analysis in order to investigate if the application of Lean thinking can transmit possible gains to healthcare phlebotomy services.

4.1 Hospital's description

4.1.1 Hospital Lusíadas Lisboa

The Lusíadas Hospital is located in Lisbon and is part of a reference group with hospitals and clinics in the health sector in Portugal. The group called "*Lusíadas Saúde*" was founded in 1998 and two of their biggest milestones were the opening of "*Hospital Lusíadas Lisboa*" and "*Hospital Lusíadas Porto*" in 2008. It has established a network of services across Portugal relying on more than 4000 healthcare professionals (Lusíadas, 2014).

The management team is composed of medical doctors which creates an alliance between management and health to guarantee that the company's vision is sustained: "*ensuring that our guests feel in good hands, not only for excellence, rigor and innovation that define us, but the care in the smallest details* (Lusíadas, 2014)*."*

Figure 4-1 provides the organizational chart for Lusíadas Hospital, which evidences that the laboratory is external to the general organization of the hospital, being part of the General Lab and a member of the LABCO/Synlab group. Only the urgency analyses are performed in Lusíadas Hospital. Routine samples are sent to the central lab which is called Santa Isabel/General Lab.

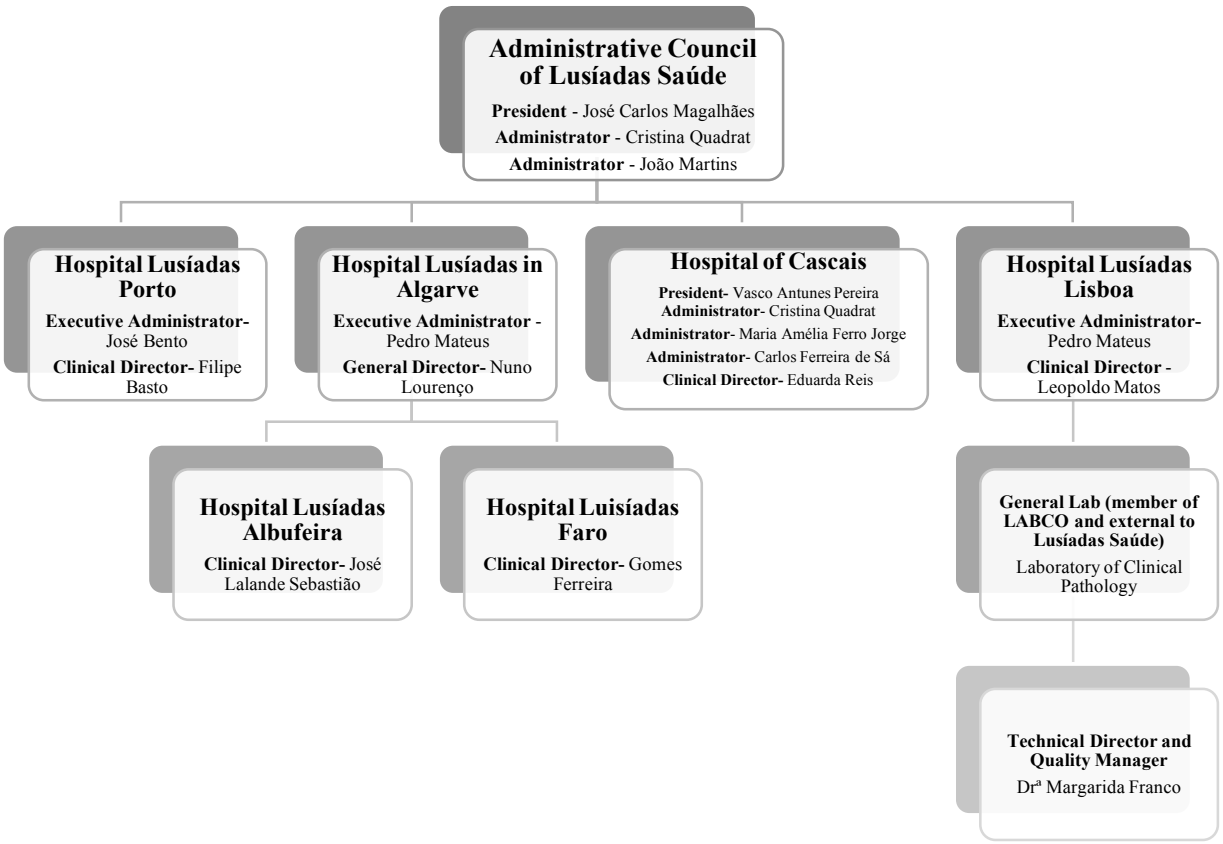


Figure 4-1 – Organizational Chart of Lusíadas Saúde
Source: Own creation

4.1.2 Hospital São Francisco Xavier

The São Francisco Xavier Hospital (SFX) is located in Lisbon, covering about 1 million inhabitants and is part of Centro Hospitalar de Lisboa Ocidental (CHLO). CHLO was created in 2005 and is constituted by two other hospitals, Santa Cruz Hospital and Egas Moniz Hospital (Ministério da Saúde, 2015).

The mission of Centro Hospitalar de Lisboa Ocidental is "*the provision of health care to all citizens within the responsibilities and capacities of the hospital units that comprise it, implementing health policy definitions at national and regional level, strategic plans and decisions that have been approved* (Ministério da Saúde, 2016)*.*"

Figure 4-2 presents the organizational chart of CHLO where the phlebotomy service is inserted in the Clinical Pathology Service of São Francisco Xavier Hospital.

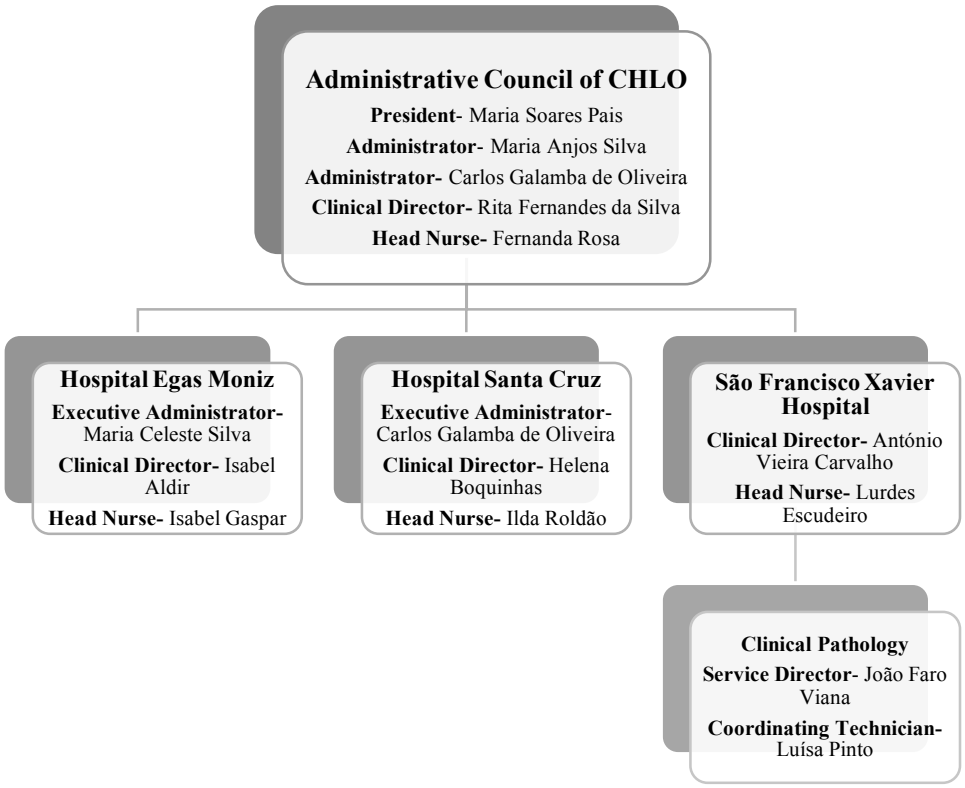


Figure 4-2 – Organizational Chart of CHLO
Source: Own creation

4.2 Process selection

The blood collection process was considered for the application of Lean thinking tools and a comprehensive analysis was performed.

The justification of the selected process in relation to the selection criteria defined in the sub-Chapter 3.2.1. is provided below according to the information gathered in the informal interviews and through direct observation:

1) Blood collection

This is the main process in a phlebotomy service and is the most frequent one. Lusíadas Hospital has an average of 110 patients each day in the phlebotomy service, it is staffed by 4/5 phlebotomists and operates between 7:30 AM and 8:00 PM. São Francisco Xavier Hospital has an average of 180 patients each day in the phlebotomy service, it is staffed by 4/5 phlebotomists and operates between 7:30 AM and 11:00 AM. It is the principal process which impacts majorly

the quality perceived by the customer through its duration, the way the customer was treated and the results delivery (Dale & Howanitz, 1996; Mijailovic, *et al.*, 2014).

The process relies fully on information transmitted electronically, physically and across the different functions and departments involved (urgency laboratory, external laboratory, reception and phlebotomy rooms). If there are misunderstandings and errors in the way the information is transmitted, the outcome may be an inaccurate result. For example, if patients do not mention their urgency in the results or if the reception department does not transmit accurately the information to the phlebotomy room, the deadlines will not be met, some clinical analyses may not be performed and the patient may have to go to the phlebotomy service again resulting in delays and decreasing patient satisfaction.

Through the direct observation and the informal interviews, it was possible to identify wastes related to waiting such as waiting for service, over processing such as duplication of tasks regarding several process' confirmations and correction of medical prescriptions in terms of the clinical analyses' codes.

4.3 Customers and value identification

"*Any activity in any business has both external and internal customers"* (McConnell, 2010:17). According to sub-Chapter 4.2, two different customers can be identified regarding the processes under analysis. The external customers, which include patients and third-party payers, and the internal customers, which include all professionals involved in the business as well as the different departments involved.

The external customers benefit most with the result of the process and the internal customers benefit from the unroll of the process' performance (McConnell, 2010).

Applied to this case study, the external customers are the patients who go to the phlebotomy services and the internal customers are the departments involved (urgency laboratory, external laboratory, reception and phlebotomy rooms) in fulfilling the patient's medical necessities.

The satisfaction of the external customers is the main goal of these processes, therefore direct observation of the healthcare professional team involved and the process as well as informal interviews to internal and external customers were performed to acknowledge the sources of value creation.

In Hospital Lusíadas, 6 receptionists and 10 technicians were observed and in Hospital São Francisco Xavier, 3 receptionists, 12 technicians and 2 healthcare assistants were also observed. In both Hospitals informal interviews were conducted regarding questions about the service and its operation, what benefits does the service offer to its customers, which of the activities that are being performed do they consider as a non-value adding activity to the customer and also, to increase the efficiency of the system, which activities can be done differently.

The activities within the phlebotomy service that provide a source of value creation are listed below and were revealed in the informal interviews with the professional team and also regarding comments observed between customers and the healthcare team:

- Quickness of the service provided in both reception and the phlebotomy room (external and internal customers) – highlighted in the informal interviews by technicians and receptionists;

- Empathy and professionalism of the healthcare professionals and receptionists (external customers) – observation of customer satisfaction and positive comments about the received treatment and acknowledged in an informal interview;

- Timely and accurate analytical results (external customers) – observation of customer requests and feedback provided;

- Precise communication among healthcare professional team (internal customers) – highlighted the importance of communication in the informal interviews by receptionists and technicians.

Finally, some differences in perception of value may differ for external costumers when they go to a public or private hospital. Although external costumers who go to public hospitals are generally more tolerant of waiting times in the phlebotomy service and waiting for their results (because there is a general perception that was also acknowledged through direct observation, that the requirement with the public health services is lower because there is no direct payment of the service, only of moderating rates), both benefit from the empathy and professionalism of the healthcare team.

The aforementioned sources of value creation do not vary for internal customers as healthcare staff often try to offer the best possible service to external customers.

4.4 Identification of waste and selection of mapping tool

Concerning the information gathered through the informal interviews with technicians and receptionists and the initial observation of processes, three types of waste were identified. According to Radnor (2011) terminology they are: *waiting for, over processing* and *correction.* Patients waiting for their turn in the reception department and in the phlebotomy room, over processing such as constant reviews of the medical prescription and correction of medical prescriptions.

As stated in sub-Chapter 3.3 and concerning the wastes identified in this case study, the most suitable tools are Value Stream Mapping and Process Activity Mapping since it is necessary to map the value added and non-value added processes that contribute to both phlebotomy services.

Firstly, to achieve a big picture map, Value Stream Mapping is performed to gain an effective understanding of the processes and where are the sources of waste (Rother & Shook, 2003). Furthermore, a spaghetti diagram is applied in order to understand the flow of information and physical activity since it "*shows clearly where activity is occurring, how complex the flows are, and how far information and products travel"* (Hines *et al.*, 2002:27).

Moreover, as revealed previously in Table 3-1, Hines *et al.* (2002) alleges that process activity mapping (PAM) is suitable for the identification and elimination of "*waiting*" and "*inappropriate processing*" and recognizes it as a possible tool to use to identify "*defects*". Process activity mapping identifies the order fulfilment process and lead time across the supply chain as also improvement opportunities (Hines *et al.*, 2002).

Therefore, process activity mapping will be applied to the initial status of the phlebotomy services before any waste removal and then, it will be applied again after the application of lean tools and the identification of improvement opportunities.

PAM will be applied to the blood collection process in both hospitals and, according to Hines and Rich (1997), consists of mapping the activities that describe the process and registering the time spent in each one of them, the distance travelled (if applied), the department where it is being performed, the number of people involved and, according to a lean perspective, classifying it as value-adding, non-value adding and support activity.

The PAM has the same structure for both Hospitals and is composed by twelve columns. The first column corresponds to the number of the activity and the second one to a small description of the performed activity. The third column refers to the classification of the activity according to the lean perspective, where V represents the value-adding activities, NV the non-

value adding activities and S the support activities. The fourth column states the department where the activity is being performed and, the fifth column, the distance travelled when performing some of the activities. The sixth, seventh and eighth column correspond to the total time taken in each activity, where the seventh and eighth column represents the minimum and maximum time found when performing the same activity, respectively. The ninth column represents the useful time found when performing processes which add value to the customer (according to a lean perspective) and the tenth column indicates the wasteful time when performing non-value adding processes. NPI is represented in eleventh column and refers to the number of people involved in every activity. Finally, the last column is a space to add comments to clarify some of the activities.

Regarding the time measurement, and according to Kanawaty (1992), a preliminary number of observations was performed and the number of observations necessary to achieve a 95% confidence level with a margin of error of 5% was calculated with the formula below (the calculations using this formula are provided in Appendix 1):

$$n = \left(\frac{40 \sqrt{n' \sum x^2 - (\sum x)^2}}{\sum x} \right)^2$$

Concerning the minimum sample size necessary calculated (n=60 for Lusíadas Hospital and n=36 for São Francisco Xavier Hospital), 80 observations of the blood collection process in both Hospitals were performed using two stop-watches. Afterwards, the data treatment was performed by calculating the median of the total time, useful time and wasted time as well as the minimum and maximum total time. Differences between the total time and the sum of useful and wasteful times are due to the use of the median as a measure of central tendency.

Although a large sample size was calculated, varying observations were obtained because of their different timing (morning and afternoon, different days of the week) to allow for as many different events as possible. When large outliers are present in a set of data, it can create heavy tailed distributions, thus "the median can be much more efficient than the average and so in many situations the median is the safest estimator to use" (Faris, 2003: 38).

4.5 Hospital Lusíadas

In this sub-Chapter, the process regarding Lusíadas Hospital will be described and the application of the above mentioned tools (PAM, VSM, spaghetti diagram) is going to be performed.

The initial status of efficiency will be analysed and a time value map will be applied to illustrate it. Furthermore, the identification of waste acknowledged during the informal interviews and direct observation will be clarified.

Finally, some considerations before the suggestions for improvement and the restructured mapping will be revealed to help understand the blood collection process of Lusíadas Hospital and the impact/benefit of the improvement suggestions.

4.5.1 Blood collection process of Lusíadas Hospital

Process description and its mapping

The objective of the blood collection process of Lusíadas Hospital is to draw blood from patients that go to phlebotomy services. The process starts when the patient enters the phlebotomy service and it ends when the blood is collected and the patient chooses the way to receive the results. A value stream map (Figure 4-3) and a spaghetti diagram (Figure 4-4; Figure 4-5) are provided in order to get a bigger picture of the blood collection process.

The value stream map (Figure 4-3) illustrates the three departments involved in the blood collection process of Lusíadas Hospital where it is possible to notice that information flows both manually and electronically depending on the departments. Furthermore, be it inventory or the patient, the flow is disrupted between departments.

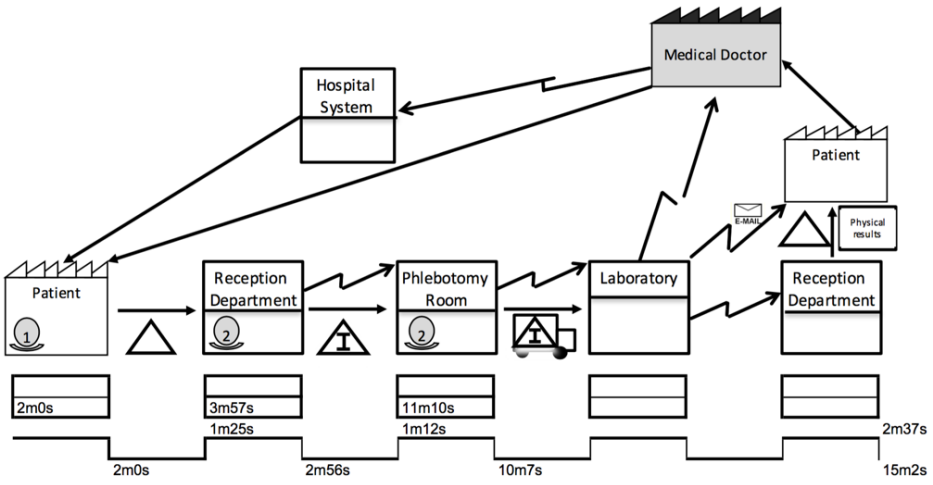


Figure 4-3 – Value stream map of the blood collection process of Lusíadas Hospital

The spaghetti diagram (Figure 4-4; Figure 4-5) highlights the physical flow of the process that occurs in the phlebotomy service namely between two main departments: reception and phlebotomy room. Firstly, the patient enters the phlebotomy service, does his/her application (service desk) and pays for the service (hospital system), then waits for his/her turn (waiting room) and moves to the phlebotomy room department (Figure 4-4) where the blood is drawn (phlebotomy room).

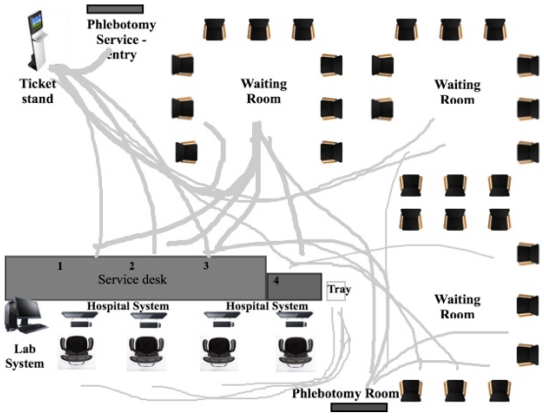


Figure 4-4 – Spaghetti diagram of the blood collection process of Lusíadas Hospital – Reception Department

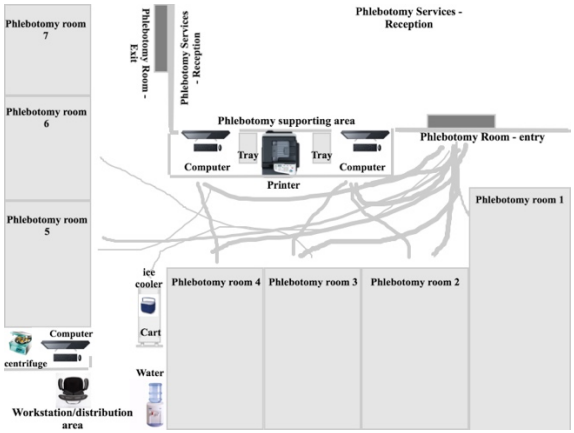


Figure 4-5 – Spaghetti diagram of the blood collection process of Lusíadas Hospital – Phlebotomy room

Table 4-1 shows the process activity mapping of the phlebotomy services and was obtained through direct observation and informal interviews.

The process starts when the patient goes to the phlebotomy service, takes a ticket and waits for his/her turn to be called to the reception desk (activity #1). The receptionist accesses the software on the computer that calls automatically the waiting tickets by order of entrance and type of ticket and the patient goes to the service counter and delivers the physical medical prescription to the receptionist (activity #2).

The receptionist confirms the patient's data with the medical prescription, searches for the patient's process number in the computer and creates a new inscription (activity #3). Then,

#	Activity	T.A.	Dep	Dist	Total time			Useful time	Wasted time	NPI	Comments
					Total	Min	Max				
1	Takes a ticket and waits for his/her turn	NV	R. D.	-	00:02:00	00:00:22	00:17:00	-	00:02:00	1	
2	Call to the reception desk and deliver of the medical prescripition	NV	R. D.	-	00:00:08	00:00:02	00:00:44	-	00:00:08	2	
3	Search for patient's process number and creation of new inscription	S	R. D.	-	00:00:40	00:00:09	00:02:15	00:00:19	00:00:25	2	
4	Photocopy the medical prescription	NV	R. D.	-	00:00:20	00:00:11	00:00:50	-	00:00:20	1	
5	Go to the insurer website to check the validity of the patient's card and insurance	NV	R. D.	-	00:00:19	00:00:04	00:02:58	-	00:00:19	1	
6	Insert the clinical analyses prescribed by the medical doctor	V	R. D.	-	00:00:24	00:00:05	00:05:00	00:00:21	00:00:12	1	
7	Confirm the clinical analyses introduced and patient's data	NV	R. D.	-	00:00:05	00:00:02	00:00:40	-	00:00:05	1	
8	Register and invoice the patient's clinical analyses	V	R. D.	-	00:01:53	00:00:11	00:21:25	00:00:45	00:01:18	2	
9	Deposit the requisition on the tray	NV	R. D.	2 - 6m	00:00:06	00:00:02	00:00:17	-	00:00:06	1	Depends on where the receptionist is sitted
10	Call the phlebotomist	NV	R. D.	-	00:00:03	00:00:02	00:00:05	-	00:00:03	1	Only in the afternoon
11	Wait for his/her turn	NV	P. R.	-	00:05:00	00:00:30	00:30:00	-	00:05:00	1	
12	Pick the requisition from the tray	NV.	P. R.	14m	00:00:17	00:00:06	00:00:51	-	00:00:17	1	
13	Order prescriptions and integrate the patient's process number on the system	S	P. R.	-	00:00:09	00:00:02	00:00:30	00:00:05	00:00:10	1	
14	Confirm the clinical analyses in the system with the medical prescription	NV	P. R.	-	00:00:10	00:00:02	00:01:31	-	00:00:10	1	
15	Print the patient's worksheet and labels	NV	P. R.	-	00:00:15	00:00:09	00:00:57	-	00:00:15	1	
16	Verify the clinical analyses and writes on the labels	NV	P. R.	-	00:00:06	00:00:02	00:00:34	-	00:00:06	1	If the sample needs to be sent to the central lab
17	Go to the waiting room and call the patient's name	S	P. R.	7m	00:00:24	00:00:10	00:01:20	-	00:00:24	2	
18	Confirm with the patient his/her date of birth	NV	P. R.	-	00:00:06	00:00:03	00:00:17	00:00:06	-	2	
19	Collect the blood sample and, if necessary, deliver a urine container to the patient	V	P. R.	-	00:03:00	00:00:24	00:11:14	00:01:05	00:02:01	2	If the patient didn't bring urine sample
20	Sign prescription and place it and the patient's worksheet in a tray	NV	P. R.	2m	00:00:10	00:00:03	00:00:50	-	00:00:10	1	
21	Access the patient's inscription to check the promise date and sign the delivery of results' paper	NV	P. R.	-	00:00:29	00:00:08	00:01:55	-	00:00:29	1	
22	Access the patient's inscription and select the e-mail of the patient	NV	P. R.	-	00:00:38	00:00:03	00:01:33	-	00:00:38	1	If the patient wants the results by e-mail
23	Print an authorization for the results to go by e-mail for the patient to sign	S	P. R.	-	00:00:27	00:00:17	00:01:38	-	00:00:27	2	
	Total			**25–29m**	**00:17:07**	**00:03:09**	**01:43:44**	**00:02:37**	**00:15:02**		

Table 4-1 – Process activity mapping of the initial status of the blood collection process of Lusíadas Hospital

- number of activity; T.A. - Type of Activity; V – value adding activity; NV – non-value adding activity; S – supporting activity; Dep – department; R. D. – Reception department; P. R. – Phlebotomy room; Dist. – distance travelled; NPI – number of people involved.

the receptionist takes a photocopy of the medical prescription (activity #4) and goes to the insurer website to check the validity of the patient's insurance in order to move forward with the inscription and invoice (activity #5).

Afterwards, the receptionist inserts in the hospital system, the clinical analysis prescribed by the medical doctor (activity #6) and confirms the data that was introduced (activity #7).

Hereafter, the receptionist registers, invoices the patient's clinical analyses (the patient pays for the clinical analyses) (activity #8), gets up and deposits the medical prescription on a "waiting" tray (activity #9). When in the afternoon or late morning, the receptionist calls the phlebotomist to let him know there's a blood collection waiting (activity #10). After activity #9, the patient waits for his/her turn to be drawn blood (activity #11).

The phlebotomist goes to the "waiting" tray and picks the medical prescriptions (activity #12). The phlebotomist orders/organizes the medical prescriptions sequentially by time of arrival and enters the laboratory system to integrate the patient's process number in the laboratory system (activity #13). This activity happens because the system which the Hospital uses is different from the system used by the laboratory (the laboratory is an external entity to the Hospital).

Subsequently, the phlebotomist confirms the clinical analyses that were integrated in the system with the medical prescription in paper (activity #14). Furthermore, the phlebotomist prints the labels corresponding to the patient's process number, the worksheet of that patient and the results' delivery paper (activity #15). In addition, the phlebotomist verifies again the clinical analysis present in the worksheet and if there are urgency and non-urgency analysis, the phlebotomist writes on the labels to draw attention in the urgency laboratory (Hospital Lusíadas) that that sample needs to be sent to the central laboratory (Santa Isabel/General Lab) as well (activity #16).

The phlebotomist goes to the waiting room and calls the patient by his full name (activity #17). When in the phlebotomy room, the phlebotomist confirms with the patient his name and day of birth (activity #18 – quality mandatory procedure). The phlebotomist prepares the material necessary and then collects the blood sample. If needed and if the patient did not bring a urine sample, the phlebotomist delivers a urine container to the patient (activity #19) and he goes to the bathroom to produce the sample.

After the blood collection, the phlebotomist signs the medical prescription with the time of the blood collection and places it along with the patient's worksheet in a tray (activity #20). Hereafter, the phlebotomist accesses the patient's inscription to check the promise date and writes it in the results' delivery paper and signs it (activity #21). If the patient wants the results by e-mail, the phlebotomist accesses the patient's inscription and selects and writes the patient's

e-mail address (activity #22). Thereat, the phlebotomist prints an authorization for the results to go by e-mail and the patient signs it (activity #23).

Initial status of efficiency

Considering the initial status of efficiency, the median of the total time spent to perform all the activities involved in the blood collection process is 17 minutes and 11 seconds. In addition, the minimum time to perform the activities is 2 minutes and 45 seconds and the maximum adds up to 1 hour, 35 minutes and 42 seconds. Furthermore, only 2 minutes and 37 seconds were spent in value-adding activities and 15 minutes and 2 seconds were spent on non-value adding activities.

The value adding activities correspond to the activities that in the end add value to the customer and contribute to the final result such as activity #6, activity #8 and activity #19. The supporting activities are activities that do not directly add value to the customer but cannot be eliminated since they contribute to the final result. This corresponds to activity #3, activity #13, activity #17 and activity #23. Finally, non-value adding activities correspond to the remaining 16 activities and are activities that do not add value to the customer. The blood collection process of Lusíadas Hospital was constituted by 23 activities where only 13,04% represents the value-adding activities, 17,34% the supporting activities and 69,57% the considered non-value adding activities.

Figure 4-6 illustrates a time value map, which is a tool that represents a graphical description of the proportion of the activities in the blood collection process of Lusíadas Hospital in the course of time. The green bars characterise the value adding activities and are plotted above the line. Underneath the middle line are displayed the yellow bars that represent the supporting activities and the red bars the wasteful ones.

Non-value adding activities and support activities occupy most of the course of the process as it is possible to visualise under the timeline (Figure 4-6). Three value-adding activities appear above the line at different times but are not enough to change the process overall tendency.

Figure 4-6 – Time value map of the blood collection process of Lusíadas Hospital

Another important aspect is the time spent by the customer in each of the departments such as the reception desk and the phlebotomy room. Considering the total time in Table 4-2 (17 minutes and 7 seconds), the total time spent by the customer in the reception desk was 5 minutes and 57 seconds, whereas the total time spent in the phlebotomy room was 11 minutes and 10 seconds. This represents that the customer spends 34,76% of the time in the reception department and 65,24% in the phlebotomy room.

Taking in consideration the sources of value creation for the customers' perspective within the phlebotomy service highlighted in sub-Chapter 4.3 and recognised through direct observation and informal interviews, the blood collection process of Lusíadas Hospital was technically performed appropriately in the majority of the time according to WHO guidelines on drawing blood (World Health Organization, 2010).

The main objective of the blood collection process of Lusíadas Hospital is to be drawn blood from customers and this was achieved mostly without any mistakes. Nevertheless, the timeliness of the service and the results fell short of the external customers' expectation according to what was acknowledged in the informal interviews and direct observation described in sub-Chapter 4.3, since 87,83% of the total time was spent in wasteful activities.

Identification of waste

After the analysis of process activity mapping, it was possible to recognise the amount of waste in the performance of the activities contained in the blood collection process of Lusíadas Hospital. As identified in sub-Chapter 3.2.1 and sub-Chapter 4.2 information is crucial when performing these activities, however some interruptions to the flow of information were noticed.

Duplication of tasks was observed several times during the blood collection process of Lusíadas Hospital. In prescribing the clinical analyses for a patient, the doctor inserts the analyses chosen in the hospital system and prints the document for the patient to take to the phlebotomy service. When the patient goes to the phlebotomy service, the receptionist in activity #6 inserts the same information about the analyses previously prescribed by the doctor into the hospital system. In addition, it was directly observed that some medical prescriptions had repeated analyses, that is, the system allowed for the same analysis to be introduced twice and that the receptionists had to correct it.

Moreover, the constant reviews and confirmation of the medical prescription with the system is unnecessary and could be avoided if accurate training regarding the hospital system and the laboratory system as well as some knowledge regarding clinical analyses was provided

to the receptionists. This situation is identifiable in activity #7, activity #14 and activity #16 when staff is confirming the activities done before (is not mandatory for quality and security procedures), which creates a duplication of tasks and does not add value to customer. Activity #18 can also be perceived as a non-value adding activity because it is a confirmation of the patient's date of birth, which was done previously in the reception, but due to the need of security for the patient's data and results, it is mandatory to confirm the patient's full name and its date of birth.

Another "waiting" waste identified during the informal interviews and the direct observation was the time spent to invoice the patient's clinical analysis and its insurer (activity #8). As verified, some insurer websites take more time than others and that is the reason for the differences that occurred in the minimum and maximum total time.

Furthermore, unnecessary and excessive movement can be identified through Figure 4-4 both in the reception desk and in the phlebotomy room because of the use of two electronic systems (the laboratory system and the hospital system) and the use of the physical prescriptions. The use of physical prescriptions requires the employee to travel a distance in the reception department to place the prescription in the tray. Also, since the information is not transmitted directly from the hospital system to the laboratory system, the physical prescription also indicates the patient's process number so that the phlebotomist can integrate it in the laboratory system (activity #13).

Additionally, the constant need to use the computer for registrations and consultation of data (in the phlebotomy room there are only two for the blood collection process), causes delays in the collecting process in the morning hours when all computers are being used and the phlebotomist needs to wait for an available computer.

Considerations before improvement suggestions and restructured mapping

Lusíadas Hospital has agreements with several insurance companies and any patient can do their clinical analyses in the laboratory even if the medical doctor does not work for Lusíadas Hospital ("external doctor"). When the medical doctor works in Lusíadas Hospital and the patient went to a medical appointment there, the medical doctor inserts in the hospital system the clinical analyses and prints a prescription for the patient to go to the phlebotomy services. This is the situation when the medical prescription belongs to Lusíadas Hospital which occurs in the majority of times.

Moreover, there are two information technology (IT) service providers along the process, one for Lusíadas Hospital and another one for General Lab, because the laboratory is an external entity apart from the Hospital.

In addition, receptionists working in the phlebotomy service lack academic health training, which makes it more difficult when training new members and to sometimes understand the relationship between clinical analyses and medical specialty.

Regarding activity #5 and activity #8, depending on the insurer, the receptionist goes to the insurer website to check the validity of the patient's insurance and copies the validity to the hospital system as a message for the accounting unit. This task is performed this way because the accounting unit confirms every invoice and insurance card and there is a security message to warn them that the insurance validity was confirmed if later problems arise with the insurance company.

Furthermore, it was directly observed that sometimes the patient has the appointment and does the clinical analyses in the same day. This consideration will be important for the next improvement suggestions regarding the validity of the insurance.

Improvement suggestions and restructured mapping

After the analysis of the detection of waste and as set in sub-Chapter 3.5, an analysis of possible solutions to improve phlebotomy services quality and efficiency and a restructured mapping will be provided.

Starting in the reception department, several improvement opportunities can be attempted. As referred in sub-Chapter 4.3 and acknowledge in the informal interviews and the direct observation, one of the major opportunities that can be put forward for the reception department and that was also mentioned by the receptionists is when the medical prescription belongs to Lusíadas Hospital. Asking and investing in the IT service provider to develop the hospital system would be of high benefit not only for the laboratory and the phlebotomy service, but also to all the departments involved in the hospital and that work together with the laboratory to provide a quality and efficient service. The benefits which can be gained with this suggestion are listed and further explanation is described below:

- Eliminate the duplication of tasks;
- Eliminate the errors in the transcription of the clinical analyses;
- Increase the quickness in the reception department.

One of the suggestions is when the medical doctor is prescribing the clinical analyses, these should be automatically available in the hospital system so that there is no duplication of

tasks. Some training could be provided to the medical doctors when prescribing the clinical analyses in order to avoid the necessity of correction of the clinical analyses afterwards (refers to considerations before improvement suggestions). This option would eliminate the duplication of tasks that occurs when introducing the clinical analyses in the system (activity #6). Furthermore, it would help reduce the errors that may occur in the transcription of the clinical analyses such as misunderstanding the doctor's handwriting because the "original" prescription is the one produced by the medical doctor and not the receptionist.

If the medical prescription is automatically displayed and there is no need to insert the clinical analyses in the system by the receptionist, activity #4 and activity #7 can be eliminated because the prescription does not need to be verified and corrected since the original is the one prescribed by the medical doctor.

Moreover, the time taken to check the validity of the patient's insurance (activity #5) could be avoided if, when invoicing the patient in the previous medical appointment, the message inserted in the system by the receptionist showing the validity of the insurance checked on that day, would be displayed electronically and would be available for every medical invoice in the same day.

A possible solution to further reduce the total time and the time spent when invoicing the patient and the insurance company would be: instead of pre-invoicing the patient and printing a paper with the codes for invoicing the clinical analysis, the printed paper would have bar codes corresponding to the codes of the analysis and the receptionist would then use a barcode reader rather than enter the codes. This suggestion could even avoid typographical errors that could lead to the performance of erroneous analysis and is performed in another laboratory, which is member of the same group (LABCO) of General Lab and that has the same IT service provider.

Regarding the phlebotomy room, further improvement suggestions may be endeavoured. According to the informal interviews with the biomedical scientists (clinical analysis technicians), one source of waste acknowledged by them was the need to integrate the medical prescription in the laboratory system and the confirmation of the clinical analysis introduced by the receptionists with the medical prescription. These correspond to activities #13 and #14 and highlight the waste related to the duplication of tasks.

Since the laboratory system is different from the hospital system, activity #13 cannot be eliminated. A possible solution to overcome this situation is to nominate a "greeter" or "workflow coordinator" every week because having each phlebotomist calling each patient is inefficient and this solution has proven success in a teaching hospital in Boston (Melanson *et*

al., 2009). The greeter would be responsible for picking the requisitions from the tray, integrating the patient's process number on the system, printing the labels and the results' delivery paper and call the patient to the phlebotomy room. This suggestion would help reduce the unnecessary movement and the time taken to perform this activity since only the greeter would be performing this activity. Additionally, the place where the tray is located should be allocated to be near the printer and in the middle of two of the receptionists. It would eliminate the travel distance of the receptionists, reduce the time to perform this activity and would reduce the time taken to order the medical prescriptions according to the time of attendance to the phlebotomy service (activity #9).

Taking advantage of the suggestion mentioned above in the reception department where the medical doctors insert the clinical analysis and that is automatically displayed, activity #14 could be eliminated.

Activity #15 cannot be eliminated but requesting the IT service provider to develop the results' delivery document to display the promise date (a document that is given to the patients so they can pick up the results afterwards) and to associate the clinical analysis that are not performed in the urgency lab to appear a different message in the patient's ticket would eliminate activity #21 and activity #16, respectively. This solution is performed in São Francisco Xavier Hospital as also in a laboratory that belongs to the same group. Moreover, it would reduce the turnaround time in the laboratory, since the technicians in the laboratory would immediately notice that the samples need to be sent to the central laboratory (an external laboratory).

To reduce by half the time spent to perform activity #20 (cannot be reduced completely because the activity still needs to be performed), the phlebotomists could previously print tickets with their initials instead of always signing the prescriptions, since the objective of this registration is just for internal purposes in case of needing to identify who performed the blood collection. This suggestion is also performed in another laboratory that belongs to the same group. In addition, the patient's worksheet (a document which contains the same information of the medical prescription but has the display of the laboratory system) does not need to be printed since it is not necessary and was a resource inefficiency.

To increase the sources of value creation for both internal and external customers, two suggestions may be attempted:

- The greeter, which is a solution that would help to invigorate the phlebotomists to release stress from the blood collection process and a break from routine since it would be a rotating function.

- The television, which is displaying the order of tickets but could also display the number of tickets in front, the busiest hours and the average time between each patient.

#	Activity	T.A.	Dep	Dist	Total time	Useful time	Wasted time	NPI	Comments
1	Takes a ticket and waits for his/her turn	NV	R. D.	-	00:01:00	-	00:01:00	1	
2	Call to the reception desk and deliver of the medical prescripition	NV	R. D.	-	00:00:08	-	00:00:08	2	
3	Search for patient's process number and integration of prescription	S	R. D.	-	00:00:19	00:00:19	-	2	If medical prescription from Lusiadas
4	Register and invoice the patient's clinical analyses	V	R. D.	-	00:00:45	00:00:45	-	2	
5	Deposit the requisition on the tray	NV	R. D.	-	00:00:03	-	00:00:03	1	
6	Call the phlebotomist	NV	R. D.	-	00:00:03	-	00:00:03	1	Only in the afternoon
7	Wait for his/her turn	NV	P. R.	-	00:02:30	-	00:02:30	1	
8	Pick the requisition from the tray	NV.	P. R.	8 – 10m	00:00:20	-	00:00:20	1	
9	Order prescriptions and integrate the patient's process number on the system	S	P. R.	-	00:00:05	00:00:05	00:00:05	1	
10	Print the patient's results' delivery paper and labels	S	P. R.	-	00:00:15	-	00:00:15	1	If results available for next consultation
11	Go to the waiting room and call the patient's name	S	P. R.	7m	00:00:24	-	00:00:24	2	
12	Confirm with the patient his/her date of birth	NV	P. R.	-	00:00:06	00:00:06	-	2	
13	Collect the blood sample and, if necessary, deliver a urine container to the patient	V	P. R.	-	00:03:00	00:01:05	00:02:01	2	If the patient didn't bring urine sample
14	Sign prescription and place it in a tray	NV	P. R.	2m	00:00:05	-	00:00:05	1	
	Total			**17– 19m**	**00:09:03**	**00:02:20**	**00:06:54**		

Table 4-2 – Process activity mapping of the first improvement suggestion: Lusíadas Hospital

- number of activity; T.A. - Type of Activity; V – value adding activity; NV – non-value adding activity; S – supporting activity; Dep – department; R. D. – Reception department; P. R. – Phlebotomy room; Dist. – distance travelled; NPI – number of people involved.

Table 4-2 illustrates the process activity mapping of the first improvement suggestions. This suggestion is in regard with the medical prescription belonging to Lusíadas Hospital and the patient chooses the delivery of his/her results to only be available for his/her next consultation (this means that only the doctor will see the results in the next consultation).

With this improvement suggestions and redesigned map, the process would start similarly with the patient taking a ticket and waiting for his/her turn (activity #1). Hereafter, the receptionist would call him/her to the reception desk and the patient would deliver his/her medical prescription (activity #2).

The receptionist would then proceed to the search of process number and would see the electronic display of the same medical prescription and subsequently would integrate it in the system (so it will be sent to the laboratory system) (activity #3).

Activity #4 represents the invoicing of the patient's clinical analysis and afterwards the receptionist would deposit the medical prescription in a tray (activity #5). Since the technicians need to prepare the distribution process, activity #6 refers to the receptionist giving a call to the phlebotomy room to warn that there is a blood collection and only happens when there is less "traffic", usually in the afternoon.

After the reception department is complete, the patient waits for his/her turn (activity #7). Thenceforward, the greeter will pick the requisition(s) from the tray (activity #8) and will order them and integrate them in the laboratory system (activity #9). Then, the greeter will print the patient's labels and the results' delivery paper (activity #10).

When a phlebotomist is available, the greeter will go to the waiting room and call the patient's name and will forward him/her to a phlebotomy room (activity #11). The phlebotomist will ask the patient's full name and date of birth (mandatory) (activity #12) and will start the blood collection (activity #13).

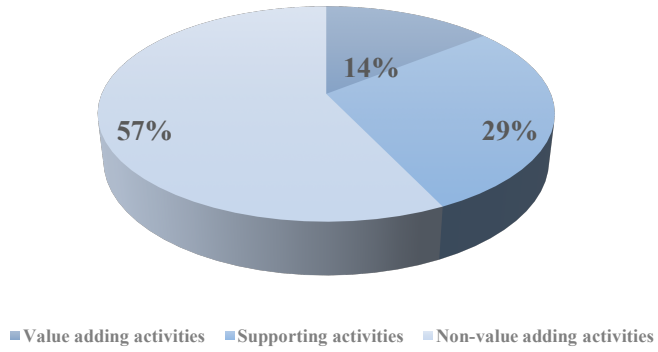
Finally, the phlebotomist will attach the ticket with his/her initials and will place the medical prescription in a tray (activity #14).

With the improvement suggestions, it was considered that activity #1, activity #5, activity #7 and activity #9 were reduced by half because it does not add value to the customer and since some activities in the middle were eliminated, the quickness of the service was improved. For activity #3, activity #4 and activity #12 the times used were according to the useful time because the wasteful tasks were eliminated. Activity #8 increased the time lost in activity #5 because in activity #5 the receptionist will no longer have to walk to deposit the physical prescription and this activity will now be performed in activity #8 by the greeter. The activities that did not changed were based on the wasted time previously measured. This correspond to activity #2, activity #6, activity #10, activity #11 and activity #13.

The improved process resulted in a total time of 9 minutes and 3 seconds, where the value time was 2 minutes and 20 seconds and the wasteful time of 6 minutes and 54 seconds. Consequently, the reduced total time would be 47,13%, where the wasted time would reduce by 54,10% and the useful time would be reduced by 10,83%.

The distance travelled would be reduced and the frequency of travel would decrease because the receptionists would not need to transport the physical prescription to the tray and with the implementation of the greeter, the phlebotomists also would not need to go to the waiting room to call the patients. The number of activities would be cut in 39,13% with only 14 activities in the redesigned map. The value-adding activities in this improvement proposal

represent 14%, the supporting activities represent 29% and the non-value adding activities represent 57% (Graphic 4-1).



Graphic 4-1 – Percentage of activities in the first improvement suggestion: Lusíadas Hospital

The first improvement suggestion took in consideration that the results would only be available for the patient's next medical appointment, which corresponds to 82,5% of the cases. During the direct observation, only 14 times in 80 observations did the patients chose to receive the results by e-mail which will not impact majorly the total time of the blood collection process.

To help reduce the time spent with activity #22 and #23 and subsequently activity #19 (Table 4-1), an additional task (asking how the delivery of results will be) can be introduced in the reception department. Table 4-3 illustrates the new redesigned map according to the second improvement suggestion.

The process would start similarly to the previous proposal with activity #1 and #2 remaining the same. When in the reception desk (activity #3), the receptionist may ask the patient how they want the delivery of results.

If the patient wants the results by e-mail, the reception will ask the patient to write his/her e-mail in the medical prescription (if it is the first time wanting to receive the results by e-mail). Hereafter, activities from #4 to #9 will remain equal.

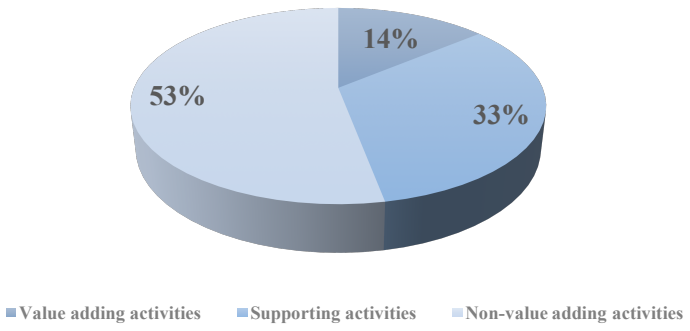
When the greeter is performing activity #10, if it is the first time of the patient receiving the results by e-mail, the greeter will access the patient inscription in the laboratory system and will write its e-mail. Furthermore, instead of printing the results' delivery document, the greeter will print the authorization for the results to go by e-mail for the patient to sign (activity #11, mandatory). Finally, the rest of the activities will remain the same according to the first improvement suggestion.

#	Activity	T.A.	Dep	Dist	Total time	Useful time	Wasted time	NPI	Comments
1	Takes a ticket and waits for his/her turn	NV	R. D.	-	00:01:00	-	00:01:00	1	
2	Call to the reception desk and deliver of the medical prescripition	NV	R. D.	-	00:00:08	-	00:00:08	2	
3	Search for patient's process number, integration of prescription and ask how the delivery of results will be	S	R. D.	-	00:00:19	00:00:19	-	2	If by e-mail, ask the patient to write the e-mail in the prescription
4	Register and invoice the patient's clinical analyses	V	R. D.	-	00:00:45	00:00:45	-	2	
5	Deposit the requisition on the tray	NV	R. D.	-	00:00:03	-	00:00:03	1	
6	Call the phlebotomist	NV	R. D.	-	00:00:03	-	00:00:03	1	Only in the afternoon
7	Wait for his/her turn	NV	P. R.	-	00:02:30	-	00:02:30	1	
8	Pick the requisition from the tray	NV.	P. R.	8 – 10m	00:00:20	-	00:00:20	1	
9	Order prescriptions and integrate the patient's process number on the system	S	P. R.	-	00:00:05	00:00:05	00:00:05	1	
10	Access the patient's inscription and select the e-mail of the patient	S	P. R.	-	00:00:19	-	00:00:19	1	
11	Print the patient's labels and authorization for the results to go by e-mail for the patient to sign	S	P. R.	-	00:00:27	-	00:00:27	1	
12	Go to the waiting room and call the patient's name	S	P. R.	7m	00:00:24	-	00:00:24	2	
13	Confirm with the patient his/her date of birth	NV	P. R.	-	00:00:06	00:00:06	-	2	
14	Collect the blood sample and, if necessary, deliver a urine container to the patient	V	P. R.	-	00:03:00	00:01:05	00:02:01	2	If the patient didn't bring urine sample
15	Sign prescription and place it in a tray	NV	P. R.	2m	00:00:05	-	00:00:05	1	
	Total			**17– 19m**	**00:09:34**	**00:02:20**	**00:07:25**		

Table 4-3 – Process activity mapping of the second improvement suggestion – Lusíadas Hospital

- number of activity; T.A. - Type of Activity; V – value adding activity; NV – non-value adding activity; S – supporting activity; Dep – department; R. D. – Reception department; P. R. – Phlebotomy room; Dist. – distance travelled; NPI – number of people involved.

The second improvement suggestion map will be redesigned in 15 activities where 14% correspond to value adding activities, 33% correspond to supporting activities and 53% to non-value adding activities (Graphic 4-2). The total median time in the second improvement suggestion is 9 minutes and 34 seconds, whereas the value added time remains 2 minutes and 20 seconds and the non-value adding activities increased to 7 minutes and 25 seconds. Differences in the sum of value added time and non-value adding time are due to the use of the median.



Graphic 4-2 – Percentage of activities in the second improvement suggestion: Lusíadas Hospital

Discussion

As the main objective of the present dissertation is to analyse if the application of Lean thinking can transmit possible gains to healthcare phlebotomy services, several possible solutions were proposed and identified in order to increase the efficiency of the phlebotomy process.

The wastes recognised with the application of process activity mapping were in accordance with the informal interviews. Waiting periods are a consequence of the constant reviews, correction and processing inefficiencies directly observed.

As referred in the identification of waste, in the morning hours having only two computers caused delays and increased the median total time spent by the customer in the phlebotomy service. If the suggestions of improving the results' delivery paper to display the promise date and to adopt the second improvement suggestion regarding the e-mail address are adopted, investing in another computer would not be necessary because the phlebotomists would not need to use the computer so frequently.

The usage of two different IT systems (hospital system and laboratory system) is because the laboratory is an external entity from the hospital (belongs to an external group called LABCO/Synlab). This creates duplication of tasks and over processing inefficiencies that generates excessive movement and increases travel distance. Nevertheless, physical prescriptions can only be eliminated if some transformations occur through the IT system and if the insurance companies change their accounting necessities and rules in order to eliminate this resource inefficiency.

Process activity mapping helped to identify the most important improvement suggestion that is the automatic display in the hospital system of the clinical analyses prescribed by the medical doctor (internally), which will impact majorly the efficiency of the phlebotomy service and the timeliness of the process. This suggestion was mentioned during the interviews and immediately recognised in the direct observation.

From a Lean thinking perspective, these improvement suggestions will be positive for both internal and external customers since they value the timeliness of the service provided in the reception department and the phlebotomy room.

Since the improvement suggestions will also benefit the internal customers who will better perform their tasks, they will indirectly benefit the "empathy and professionalism of the healthcare professionals and timely and accurate analytical results" that were valued by the external customers.

4.6 Hospital São Francisco Xavier

In sub-Chapter 4.6, São Francisco Xavier blood collection process is going to be described and its mapping will be performed through the application of value stream map, process activity mapping and spaghetti diagram. Time value map will be applied to illustrate the initial status of efficiency and the identification of existing waste will be recognised.

Finally, improvement suggestions and a reestructured map will be realised to highlight possible suggestions.

4.6.1 Blood collection process of SFX Hospital

Process description and its mapping

As stated in sub-Chapter 4.5.1, the blood collection process of SFX Hospital has the same purpose as the blood collection process of Lusíadas Hospital: collect blood from patients that go to phlebotomy services. It starts when the patient enters the service and goes to the reception desk, delivers its prescription and afterwards has its blood drawn. Once again, value stream map (Figure 4-7) and spaghetti diagram (Figure 4-8; Figure 4-9) were performed to enable an overview of the phlebotomy service.

Figure 4-6 illustrates the big picture of the blood collection process of SFX Hospital, where information flows both manually and electronically and disruptions occur throughout the flow of the departments involved due to waiting for employees' availability. The timeline underneath the figure evidences where the process is more time consuming such as the phlebotomy room. Furthermore, it is in the same department where there is more wasted time, specifically 9 minutes and 24 seconds.

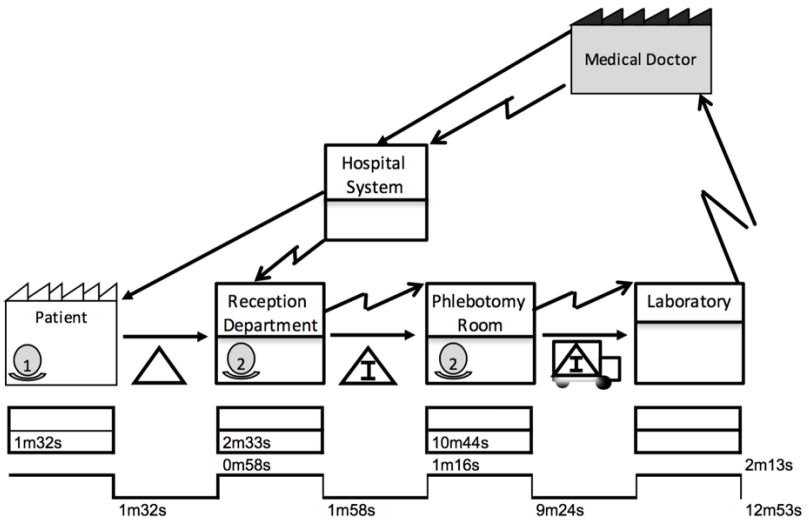


Figure 4-7 – Value stream map of the blood collection process of SFX Hospital

The spaghetti diagram presented in Figure 4-8 and Figure 4-9 elucidates the physical movement that exists when the process is being performed. It starts at the reception department (Figure 4-8) where the patient enters the service and takes a ticket (from the ticket stand), waits for his/her turn to the service desk (waiting room), does his/her "check-in" (service desk) and ends when the blood is collected (Figure 4-9 – phlebotomy room).

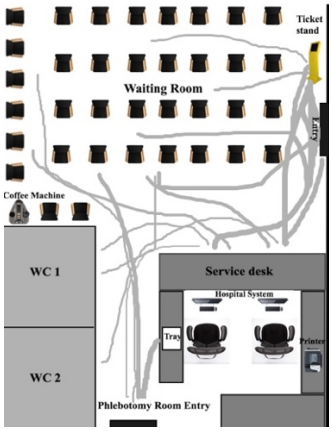


Figure 4-8 – Spaghetti diagram of the blood collection process of SFX Hospital – Reception Department

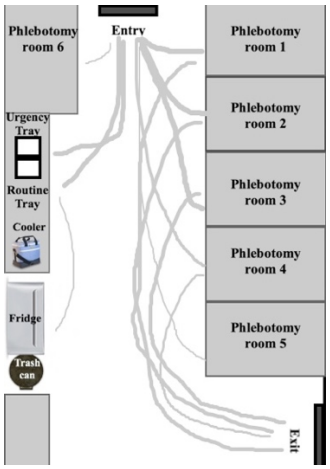


Figure 4-9 – Spaghetti diagram of the blood collection process of SFX Hospital – Phlebotomy Room

Table 4-4 demonstrated the process activity mapping corresponding to the blood collection process of SFX Hospital and was obtained through direct observation and informal interviews in São Francisco Xavier Hospital.

The process starts similarly with the blood collection process of Lusíadas Hospital, where the patient enters the phlebotomy service, takes a ticket and waits for his turn (activity #1). The receptionist calls the ticket number and the patient goes to the service desk and delivers the medical prescription (activity #2). In activity #3, the receptionist searches for the patient's hospital process number and integrates his/her prescription in the system. Hereafter, the receptionist prints the patient's label and attaches the tickets and labels to the prescription (activity #4).

#	Activity	T.A.	Dep	Dist	Total time			Useful time	Wasted time	NPI	Comments
					Total	Min	Max				
1	Take a ticket and waits for his turn	NV	R. D.	-	00:01:32	00:00:10	00:18:47	-	00:01:32	1	
2	Call to the reception desk and deliver of the medical prescripition	NV	R. D.	-	00:00:10	00:00:02	00:00:50	-	00:00:10	2	
3	Search for patient's process number and integration of the patient's prescription in the system	S	R. D.	-	00:00:24	00:00:02	00:02:41	00:00:05	00:00:18	2	
4	Print the patient's labels and attaches the ticket and labels to the prescription	S	R. D.	-	00:00:24	00:00:08	00:02:52	-	00:00:24	1	If the prescription is urgent, the receptionist attaches a urgency ticket
5	Register and invoice the patient's clinical analyses	V	R. D.	-	00:01:32	00:00:51	00:07:44	00:00:53	00:01:03	1	If the patient is not exempt from payment
6	Deposit the requisition on the tray	NV	R. D.	1-2m	00:00:03	00:00:01	00:01:24	-	00:00:03	1	Depends on where the receptionist is sitted
7	Patient waits for his turn	NV	P. R.	-	00:06:00	00:01:00	00:38:00	-	00:06:00	1	
8	Pick the requisition from the tray	NV	P. R.	20m	00:00:20	00:00:06	00:00:53	-	00:00:20	2	
9	Order prescriptions in urgents and routine	NV	P. R.	-	00:00:10	00:00:02	00:01:34	-	00:00:10	1	
10	Go to the waiting room, call the patient's name and take him to the respective phlebotomy room	S	P. R.	8 – 16m	00:00:29	00:00:14	00:01:11	-	00:00:29	1	Depends on the phlebotomy room
11	Confirm with the patient his/her name	NV	P. R.	-	00:00:04	00:00:02	00:00:11	00:00:04	-	1	
12	Collect the blood sample	V	P. R.	-	00:03:37	00:01:04	00:07:40	00:01:12	00:02:21	1	
13	Sign prescription and place it in a tray	NV	P. R.	-	00:00:04	00:00:02	00:00:20	-	00:00:04	1	
	Total			**29-38m**	**00:14:49**	**00:03:44**	**01:24:07**	**00:02:13**	**00:12:53**		

Table 4-4 – Process activity mapping of the initial status of thr blood collection process of SFX Hospital

- number of activity; T.A. - Type of Activity; V – value adding activity; NV – non-value adding activity; S – supporting activity; Dep – department; R. D. – Reception department; P. R. – Phlebotomy room; Dist. – distance travelled; NPI – number of people involved.

The patient indicates if he/she needs the results in the same day or if he/she needs the results for oncology treatment and if so, the receptionist attaches another urgency ticket (with a new ticket order) to the medical prescription.

Subsequently, if the patient is not exempt from payment of moderating fees, the receptionist registers and invoices the patient's clinical analysis and/or other debt payments the patient has (activity #5). After that, the receptionist deposits the prescription on a tray (activity #6). Furthermore, the patient waits for his/her turn again in the waiting room (activity #7).

Afterwards, the healthcare assistant goes to the reception department and picks the medical prescription from the tray (activity #8). Then, the healthcare assistant organises the prescriptions by number of ticket and separates the routine prescriptions from the urgency ones (activity #9).

When a phlebotomist becomes available (or almost finish with a previous patient), the healthcare assistant goes to the waiting room and calls the patient name. Moreover, she takes

the patient to the respective phlebotomy room (activity #10). In the phlebotomy room, the phlebotomist asks for the patient's full name (activity #11) and proceeds with the blood collection (activity #12).

Finally, the process ends with the phlebotomist attaching one of the patient's label to her/his phlebotomy record and placing the prescription in a tray in the phlebotomy room (activity #13).

Initial status of efficiency

Regarding the initial status of efficiency, the blood collection process of SFX Hospital median total time to perform all the activities involved in the phlebotomy room is 14 minutes and 49 seconds with a minimum total time of 3 minutes and 44 seconds and with a maximum total time of 1 hour, 24 minutes and 7 seconds. Moreover, only 2 minutes and 13 seconds were spent in performing value adding activities and 12 minutes and 53 seconds were spent performing wasteful activities.

The value adding activities correspond to the activities that in the end add value to the customer and contribute to the final result such as activity #5 and activity #12. The supporting activities are activities that do not directly add value to the customer but cannot be eliminated since they contribute to the final result. This corresponds to activity #3, activity #4 and activity #10. Finally, non-value adding activities correspond to the remaining 8 activities and are the ones that do not add value to the customer.

In addition, the blood collection process of SFX Hospital was constituted by 13 activities, where 15,38% represented the value adding activities, 23,08% the supporting activities and 61,54% represent the percentage of non-value adding activities.

To illustrate the above mentioned proportion of activities in the blood collection process of SFX Hospital, time value map (Figure 4-8) was performed again to illustrate it in the course of time. Figure 4-8 highlights the green bars which are the value adding activities and are displayed above the line that represents time. Underneath the time line are represented the yellow bars corresponding to the supporting activities and the red bars that correspond to the non-value adding activities.

With regard to the blood collection process of the SFX Hospital, it is possible to visualize that waste activities (red bars) follow the course of the process. There are only two value-added activities occurring at different times in the process.

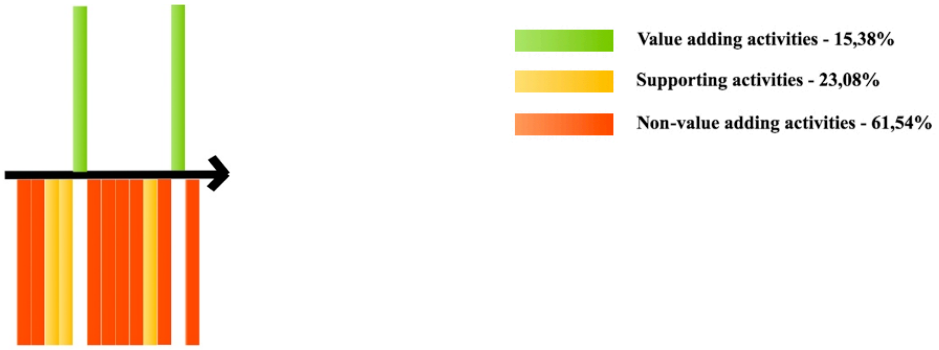


Figure 4-10 – Time value map of the blood collection process of SFX Hospital

Considering the time spent in each department (reception and phlebotomy room) and in reference to the median total time of 14 minutes and 49 seconds, the median total time spent by the patient in the reception department was 4 minutes and 5 seconds which represents 27,56 % of the total time. The median total time spent by the patient in the phlebotomy room was 10 minutes and 44 seconds which represents 72,44% of the total time.

As listed in sub-Chapter 4.3, informal interviews were performed to the external customers of these services. According to the customer's perspective and based on the informal interviews and comments heard during the direct observation, the blood collection process of SFX Hospital was performed appropriately in the majority of the time and in accordance with WHO guidelines (World Health Organization, 2010).

The blood collection process of Lusíadas and SFX Hospital have the same final objective, to draw blood from customers and once again this objective was achieved without major mistakes. Nonetheless, the timeliness of the service and the timeliness of results fell short of the customers' expectation, since 86,95% of the median total time was spent in non-value adding activities.

Identification of waste

In sub-Chapter 4.4 three types of waste (waiting for, over processing and correction) were identified as some possible wastes to be found in the course of the phlebotomy process, according to the information gathered during the informal interviews and direct observation.

Regarding the blood collection process of SFX Hospital, not much waste was identified after the application of process activity mapping. Nevertheless, disruptions to the flow of information were noticed when performing these activities.

In the reception department, the ticket holder was not electronic and therefore the receptionists had to call the ticket numbers. Since there was no previous record, they were

constantly forgetting at what number the order was, which created a delay and a disruption to the flow.

Waiting can be acknowledged throughout the process, there are disruptions in waiting for employees' availability in the reception department as well as in the phlebotomy room and physical prescriptions waiting to be moved, which confines the value creation delivered by the process.

In addition, the unscheduled constant breaks of the healthcare professional team as well as the organization of the phlebotomist's schedule creates delays in the median total time of the blood collection process of SFX Hospital due to waiting for employees' availability.

Moreover, in activity #3 it was directly observed that if the computer system was inactive even for a short time, it would leave the module in the system where prescriptions are integrated. This functionality created unnecessary delays in the process because the receptionist has to repeatedly open the software again.

Blood collection process of SFX Hospital works both with electronical and physical prescriptions, which creates a duplication of tasks and therefore over processing. Additionally, activity #4 is frequently an over processing of tasks because the criteria for urgency is very generalised. Since it is a public hospital most patients are urgent, consequently needing priority, thus the receptionist attaches a second ticket to the prescription. Diabetics, oncological patients in therapy, children up to the age of 15, medical appointments in the same day, pregnancy tests and handicapped have service priority (Ministério da Saúde, 2015).

Furthermore, sometimes in activity #3 there was a need to correct the medical prescription in the system or to join two prescriptions in one. These situations lead to wastes related to waiting and correction.

It was directly observed that the printers were often not working which made it impossible to charge patients and increased the total time spent in activity #4 and #5. Additionally, some delays in the invoice system were reported by the receptionists in the informal interviews. Activity #11 is considered a non-value adding activity since it is a confirmation of the patient's full name but this activity is mandatory due to the need of security for the patient's data and results.

Excessive movement can be seen through the spaghetti diagram in Figure 4-7. This situation occurs due to the layout of the phlebotomy service and the use of physical information.

Improvement suggestions and restructured mapping

After the development of the process activity mapping, an analysis of possible solutions to improve phlebotomy service quality and efficiency and a restructured mapping will be provided.

Regarding the reception department, some improvement suggestions more focused on increasing the value creation for both internal and external customers may be attempted.

Beginning with activity #1, a small investment in an electronic ticket stand with the corresponding information system would cause a greater impact in the physical aspect of the department as well as of the phlebotomy service in general. Customers would immediately notice the ticket stand and would understand their place in line as also urgent patients would automatically take an urgency ticket. This suggestion would further reduce the time spent in activity #2 since no more losses in the calling order would be register. To reduce the wasted median time in activity #3, the system's functionality of going to the homepage after a brief period of inactivity could be disabled since it would reduce the total time spent in the computer system to re-enter the "Appointments" module and integration of the patient's prescription in the system.

Moreover, the installation of an electronic ticket stand displaying who has priority in the phlebotomy service and in accordance with the new legal decree (nº 58/2016, 29th of August), would diminish the time spent in activity #4 since external customers would know the criteria for prioritization and would not pick urgent tickets randomly. Furthermore, this would eliminate the duplication of tasks (attaching two types of tickets) and reduce the frequency of urgency tickets (which implied changing the patient's appointment and labels to urgent).

Investing in a better printer and improving the invoice software would decrease activity #5 total median time.

In São Francisco Xavier Hospital, a healthcare assistant already plays the role of "greeter". With the implementation of the electronic ticket booth and asking the receptionists to correctly deposit the medical prescription in the tray order, the receptionist would not have to pick up the requisitions and organize them in the phlebotomy room. Instead, the receptionist would pick the requisitions from the tray and immediately call the patient's name. This suggestion would greatly reduce the frequency and distance travelled.

To further reduce the total time that the patient waits in activity #7 for employee availability mentioned in the "identification of waste", a suggestion may be put forward:

- Blood collection to babies under the age of 2 years old should always be performed in the paediatric unit;

This suggestion occurs due to the regularity of babies' blood collection that implies the necessity of two or more phlebotomists, which delays the overall phlebotomy service. When the phlebotomists are not able to draw blood from the baby they usually send him/her to the paediatric unit.

Finally, to increase the value creation for the external customers, investing in a television to display the order of tickets as also the busiest hours, the average service time and daily news.

#	Activity	T.A.	Dep	Dist	Median Total time	Useful time	Wasted time	NPI	Comments
1	Take a ticket and waits for his turn	NV	R. D.	-	00:00:46	-	00:00:46	1	
2	Call to the reception desk and deliver of the medical prescripition	NV	R. D.	-	00:00:05	-	00:00:05	2	
3	Search for patient's process number and integration of the patient's prescription in the system	S	R. D.	-	00:00:05	00:00:05		2	
4	Print the patient's labels and attaches the ticket and labels to the prescription	S	R. D.	-	00:00:12	-	00:00:12	1	
5	Register and invoice the patient's clinical analyses	V	R. D.	-	00:01:32	00:00:53		1	If the patient is not exempt from payment
6	Deposit the requisition on the tray	NV	R. D.	1-2m	00:00:03	-	00:00:03	1	Depends on where the receptionist is sitted
7	Patient waits for his turn	NV	P. R.	-	00:03:00	-	00:03:00	1	
8	Go to the waiting room, call the patient's name and take him to the respective phlebotomy room	S	P. R.	8 – 16m	00:00:29	-	00:00:29	1	Depends on the phlebotomy room
9	Confirm with the patient his/her name	NV	P. R.	-	00:00:04	00:00:04	-	1	
10	Collect the blood sample	V	P. R.	-	00:03:37	00:01:12	00:02:21	1	
11	Sign prescription and place it in a tray	NV	P. R.	-	00:00:04	-	00:00:04	1	
	Total			**9-18m**	**00:09:18**	**00:02:13**	**00:06:56**		

Table 4-5 – Process activity mapping of the improvement suggestion – SFX Hospital

- number of activity; T.A. - Type of Activity; V – value adding activity; NV – non-value adding activity; S – supporting activity; Dep – department; R. D. – Reception department; P. R. – Phlebotomy room; Dist. – distance travelled; NPI – number of people involved.

Process activity mapping of the improvement suggestions for the blood collection process of SFX Hospital is displayed in Table 4-5. The process starts similarly with patient taking its ticket from the electronic stand and waiting for his/her turn (activity #1).

The receptionist calls the patient's ticket using the electronic software and the patient goes to the reception desk and delivers its medical prescription (activity #2). In activity #3, the receptionist searches for patient's process number and integrates the patient's prescription in the system.

Hereafter, the receptionist prints the patient's labels and attaches the ticket to the medical prescription (activity #4). If the patient pays healthcare tax fees, the receptionist registers and invoices the patient's clinical analyses and bills the patient (activity #5). If the patient is exempt from payment (oncology medical treatments or chronical diseases) the patient goes to the waiting room and waits for his turn (activity #7).

After invoicing the patient (activity #5), the receptionist correctly deposits the medical prescriptions in accordance with the attendance order and separates it in urgent and routine (according to the tickets) (activity #6). The patient then waits for his turn (activity #7). The healthcare assistant/greeter, when a phlebotomist is about to become available, goes to the waiting room, picks the next medical prescription and calls the patient's name (activity #8).

From a Lean perspective, activity #9 does not add value to the customer and is consider waste but since this activity is mandatory and needed for the patient's safety, the phlebotomist confirms the patient's full name and date of birth. Subsequently, the phlebotomist collects blood from the patient (activity #10), signs the medical prescriptions and places the medical prescription in a tray (activity #11).

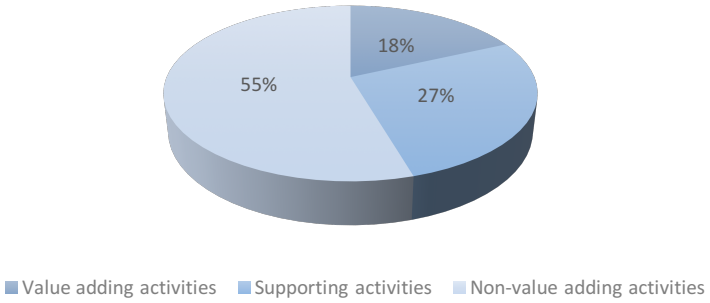
When applying the improvement suggestions, it was considered that activity #1 and activity #7 were reduced by half due to the elimination of some wasteful activities in the middle of the process and since they do not add value to the customer.

With the electronic system, it was considered that activity #2 and activity #4 were also reduced by half, and with the improvement of the hospital software, activity #3 and activity #5 was based on the median useful time since the wasteful activities were eliminated.

Activity #6, activity #8, activity #9, activity #10 and activity #11 were based on the median wasteful time previously measured in the initial status of efficiency.

The blood collection process of SFX Hospital, if the improvement suggestions are applied may result in a total time of 9 minutes and 18 seconds with a total median value time of 2 minutes and 13 seconds and with wasteful time of 6 minutes and 56 seconds. Consequently, with the elimination of wasteful activities, the reduced total time would be 37,23%, where the useful time would remain exactly the same and the total median wasteful time would be reduced by 46,18%.

The number of activities would only be reduced in 2 with only 11 activities in the redesigned map, not representing a major change. The value-adding activities in this suggestion represent 18,18%, the supporting activities represent 27,27% and the non-value adding activities represent 54,55% (Graphic 4-3).



Graphic 4-3 – Percentage of activities in the improvement suggestion: SFX Hospital

Furthermore, with the improvement suggestions, the distance travelled would be reduced in 20 metres and also the frequency of travel would diminish because the greeter would no longer take the prescription to the phlebotomy room but instead would pick the prescription and immediately call the patient's name.

Discussion

Several improvement suggestions were advanced for the blood collection process of SFX Hospital bearing in mind this dissertation's objective: to analyse the possible gains in efficiency with application of Lean thinking tools to healthcare phlebotomy services.

The identified wastes in São Francisco Xavier hospital were mainly waiting and over processing and were confirmed by the process activity mapping. The restrains in the flow of the process and information are mostly due to the waiting for employees' availability and over processing such as duplication of tasks of the attendance order tickets and the physical and electronic prescriptions.

The resource inefficiency of having both physical and medical prescription creates a duplication resulting in disruptions to the flow. Nonetheless, phlebotomists need to see the clinical analyses prescribed by the medical doctor (because there are no computers in the phlebotomy room) to verify if there are any that require some special treatment and to evaluate the blood collection tubes. This makes it difficult to eliminate the duplication of tasks. For example, some analyses have to be separated and refrigerated immediately and others must be sheltered from light.

Reducing the total cycle time by eliminating wasteful tasks and activities would be valuable for both external and internal customers due to the improved flow of the process between the reception department and the phlebotomy room. This would make the process more efficient.

4.7 Public and private hospitals: A comparison between the blood collection process

Despite the differences between SFX Hospital and Lusíadas Hospital and after the application of Lean thinking tools, the results after the improvement suggestions were very similar for both Hospitals.

Table 4-6 illustrates a summary of the initial status of efficiency for Lusíadas and SFX Hospital. The information flow is similar in both Hospitals, being transmitted electronically and physically. One important aspect to emphasize is the difference in the transmission of information between the two Hospitals regarding the transmission from the hospital system to the patient and to the reception department.

In Lusíadas Hospital, the information from the hospital system is only transmitted physically to the patient (printed medical prescription) and it is only when the receptionist introduces the prescription in the hospital system that the information is registered electronically and shared internally. In SFX Hospital, the information is transmitted physically to the patient and is transmitted electronically and displayed as an appointment in the system to be integrated in the reception department.

This second option makes the process much more efficient and eliminates the duplication of tasks that occur when reinserting the same information into the system. Physical prescriptions are resource inefficiencies and can only be eliminated if the insurance companies' requirements change as also if computers and an informational system are installed in the SFX Hospital phlebotomy room to provide the necessary information to phlebotomists.

	Lusíadas Hospital	SFX Hospital
Information flow	Electronic/Physical	Electronic/Physical
Nº of activities	23	13
Distance travelled	25-29 m	29-38 m
Median total time	00:17:07	00:14:49
Median useful time	00:02:37 15%	00:02:13 15%
Median wasteful time	00:15:02 85%	00:12:53 85%
% of time in reception department	35%	28%
% of time in phlebotomy room	65%	72%

Table 4-6 – Initial status of efficiency – Lusíadas and SFX Hospital

Furthermore, the number of activities in both processes is very different for the two hospitals, 23 for Lusíadas and 13 for SFX. On the other hand, the distance travelled is higher for SFX than Lusíadas.

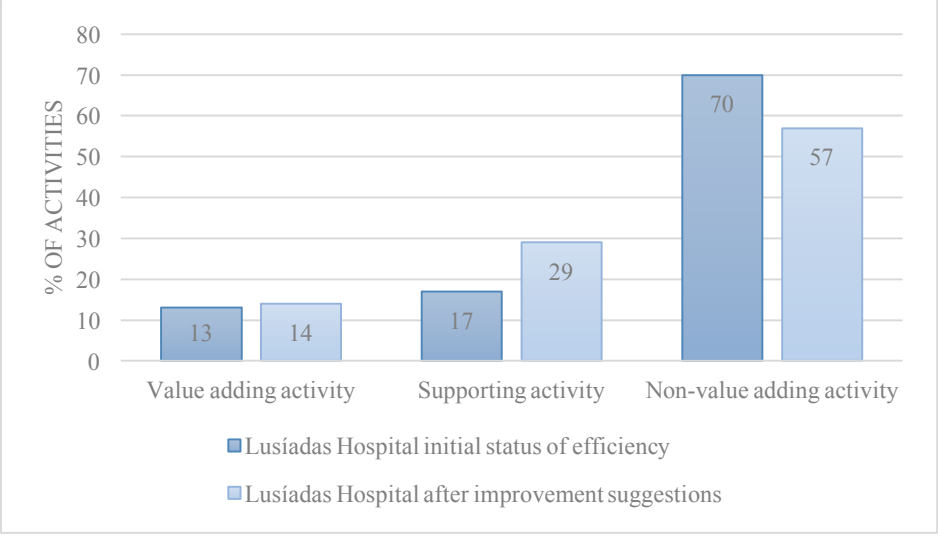
Moreover, the median total, useful and wasteful time is very similar for both hospitals in the initial status of efficiency as the percentage of time spent in the reception department and in the phlebotomy room. The question to investigate is how can both processes have similar median total time (only 2 minutes and 18 seconds different) when SFX hospital has almost half of the activities of Lusíadas Hospital.

The possible answer to this question is related to the capacity installed due to:

- High arrival rate of patients– identified in sub-Chapter 4.2;
- Variability in service delivery time (many oncology and chronic patients, babies' phlebotomy) – recognised in identification of waste;
- Employee breaks and consequent reduction in the use of capacity available – acknowledged in identification of waste;
- Staff model organization – identified in sub-Chapter 4.2 and identification of waste.

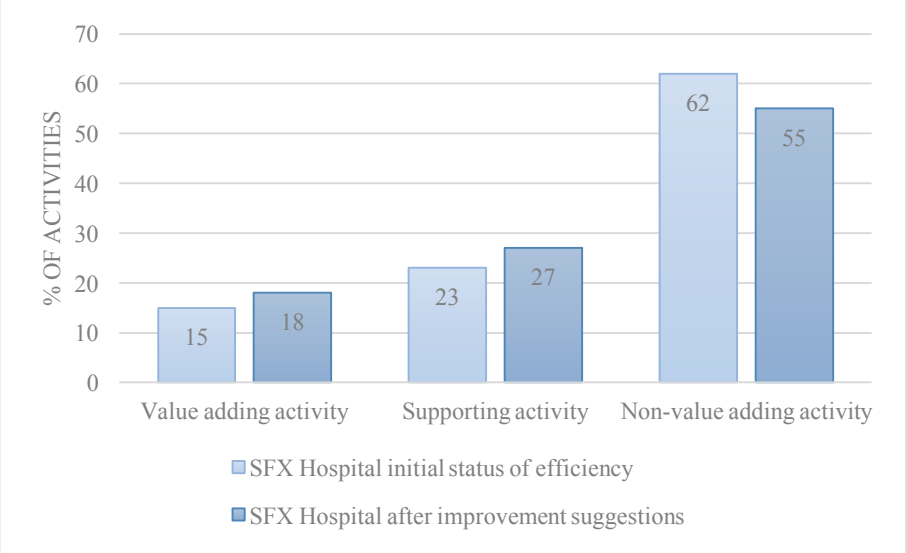
After the application of Lean thinking tools and the improvement suggestions, the efficiency of both processes became very similar. Graphic 4-4 and Graphic 4-5 represent the comparison of percentages by type of activity for Lusíadas Hospital and for SFX Hospital, respectively.

Regarding Lusíadas Hospital, the percentage of value adding activities remained almost the same, the support activities increased as the non-value adding activities decreased (Graphic 4-4).



Graphic 4-4 – Comparison of percentage of activities - Lusíadas Hospital

Concerning SFX Hospital, the value adding activities and the support activities increased as the non-value adding activities decreased (Graphic 4-5).



Graphic 4-5 – Comparison of percentage of activities - SFX Hospital

The number of activities decreased severely for Lusíadas Hospital and the frequency and distance travelled decreased noticeably for both processes (Table 4-7).

Additionally, the median total time decreased severely by eliminating non-value adding activities which helped to reduce also the median wasteful time in both processes. The median useful time was slightly reduced in Lusíadas Hospital and did not change for SFX Hospital.

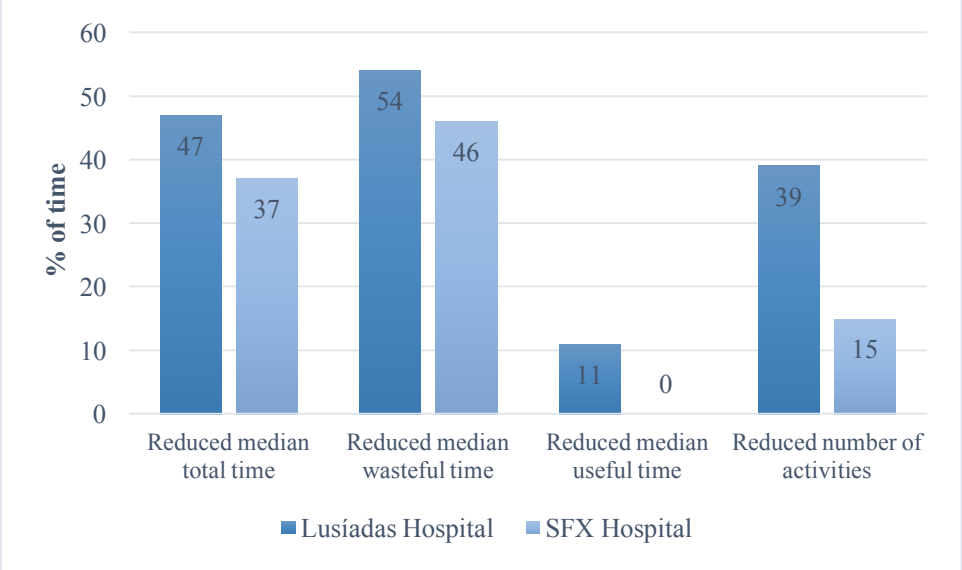
	Lusíadas Hospital (1º improvement suggestion)	**SFX Hospital**
Information flow	Electronic/Physical	Electronic/Physical
Nº of activities	14	11
Distance travelled	17-19 m	9-18 m
Median total time	00:09:03	00:09:18
Median useful time	00:02:20 25%	00:02:13 24%
Median wasteful time	00:06:54 75%	00:06:56 76%
% of time in reception department	25%	22%
% of time in phlebotomy room	75%	78%

Table 4-7 – Status of efficiency after improvement suggestions - Lusíadas and SFX Hospital

To better understand and visualise these changes, Graphic 4-6 illustrates the comparison of the reduced percentages between the public and private hospital after the application of Lean thinking tools.

Lusíadas hospital was the one that obtained more reduction in percentage, both for time and for activities. The median total time was reduced by 47% for Lusíadas and 37% for SFX and the median wasteful time was reduced by 54% and 46% for Lusíadas and SFX, respectively (Graphic 4-6).

In addition, the percentage of activities was reduced by 39% for Hospital Lusíadas and 15% for Hospital SFX, which contributed to the reduction in almost half of the total median time for both hospitals.



Graphic 4-6 – Comparison of the reduced percentages after improvement suggestions – Lusíadas and SFX Hospital

A simple template may be put forward to guide every phlebotomy service that attempts to follow a Lean approach. This template is constituted by 12 activities and demonstrated through the flowchart in Figure 4-11, which serves as a base for every organization to adapt to their service characteristics. It was achieved through a mix of what was found in both Hospitals during the direct observation and informal interviews.

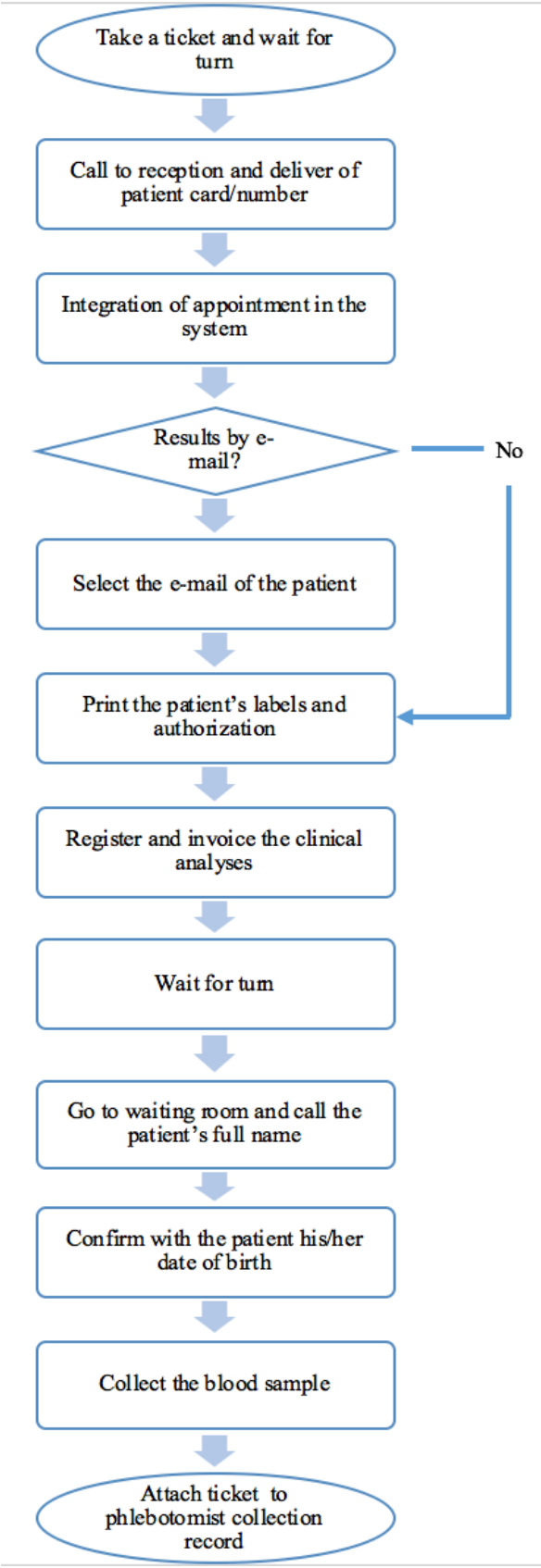


Figure 4-11 – Flowchart of the blood collection process template

5. Conclusion

The main objective of this dissertation was to analyse and benchmark possible solutions to improve phlebotomy service quality in a public and private hospital and to investigate if the application of Lean thinking tools can transmit possible gains in efficiency to a healthcare process performed in the phlebotomy services.

One process was selected based on the previous defined criteria in sub-Chapter 3.2.1. and was evaluated using the process activity mapping tool from the value stream map toolkit.

The initial efficiency of the process and the efficiency gains of the process after the improvement suggestions were obtained without loss of effectiveness and were analysed in order to meet the main objective of this thesis.

The following and final sub-Chapters present the final disclosures regarding the purpose of the research, the research question, its validation and limits. Finally, some considerations for future research alternatives are contemplated.

5.1 Objectives analyses

In Chapter 1, several objectives were defined for the present thesis. In order to assess if the present thesis was sucessful in attending those objectives, the specific objectives will be reviewed.

1 - Map the phlebotomy service process by identifying its different stages – it is considered that this objective was achieved in Chapter 4 with the application of VSM and PAM;

2 - Describe and compare the phlebotomy process in public and private sector – sub-Chapter 4.7 concludes and summarizes the description of the phlebotomy process in accordance with the differences found in the public and private sector namely, São Francisco Xavier Hospital and Lusíadas Hospital;

3 - Identify the customers of the phlebotomy service process and their perception of value – the identification of external and internal customers was attempted before the analyses of the blood collection process;

4 - Distinguish value-added from non-value-added activities and eliminate the wasteful ones – this fourth objective was addressed in sub-Chapter 2.2 where a brief description is provided and in Chapter 4 an application of this description is performed;

5 - Identify and propose possible solutions to improve the value provided by the process – during the direct observation and informal interviews, several improvement suggestions were identified and proposed in Chapter 4;

6 - Adapt the solutions proposed to meet public and private process requirements – the suggested improvement opportunities took in consideration the characteristics of the services throughout the case study analysis;
7 - Estimate the effectiveness of proposed solutions – sub-Chapter 4.7 summarizes the efficiency and effectivess that can be gained with the application of Lean Thinking tools.

According to the above review, it was considered that the objectives of this dissertation were accomplished throughout its development.

5.2 Research question

This dissertation attempted to provide an answer to the previously defined research question:

- How can Lean Thinking add value to healthcare phlebotomy services?

The use of Process Activity Mapping of the Value Stream Map toolkit proved to be a suitable guidance tool and allowed the identification of waste and suggestions for improvement for the application of Lean Thinking tools. In addition, Value Stream Map enabled the visualization of the big picture of the blood collection process in both hospitals and the Spaghetti Diagram helped to recognize the intensity of the flows of both processes and their physical movement.

Although the improvement suggestions were not implemented yet, sub-Chapter 4.7 highlights the efficiency and potential benefits that can be gained if Lean Thinking tools are applied to healthcare phlebotomy services. Both processes can be positively impacted with the application of Lean Thinking tools.

Considering the reduction in median total time by 47% for Lusíadas and 37% for SFX as also the reduction in the median wasteful time by 54% and 46% for Lusíadas and SFX, respectively, it evidences the possible gains of efficiency when applying Lean tools.

While leadership commitment is crucial for successful Lean implementation (Dickson et al., 2009; Atkison, 2010; Radnor and Osborne, 2013) and performed according to the principles defined by Womack and Jones (1996), this dissertation did not consider these aspects since its purpose was to analyse the efficiency gains of Lean Thinking tools.

The wastes identified in the informal interviews were in accordance with the mapping analysis of Process 1 and 2. As mentioned in sub-Chapter 3.2.1, sub-Chapter 4.2 and as stated

by Maleyeff (2006), information is crucial for the efficient conduct of the process. Nonetheless, waiting, over processing and correction were a consequence of the constant reviews, duplication of tasks and inefficiencies in the system which caused restrains to the flow between departments.

Following the goal set forth in sub-chapter 1.3, "*this dissertation will analyse Lean Thinking in health care, providing insights and demonstrating the potential benefits of applying Lean to phlebotomy services*," one can consider that the goal was achieved and affirm that phlebotomy services can be positively benefited by the use of a Lean approach as shown by the suggestions for improvement and redesigned maps.

In addition, as demonstrated in sub-Chapter 4.7, if wastes are accurately removed such as the elimination of waiting periods, correction, over processing, duplication of tasks and resource inefficiencies, it would decrease the total cycle time, which would increase process efficiency and benefit internal and external customers, since the process would become more accurate and therefore efficient.

5.3 Results validity

To support this dissertation during its conception, a theoretical background regarding Lean Thinking tools and concepts was considered.

The flow of information was considered in the improvement suggestions and in the blood collection process aligned with Maleyeff's (2006) input: information and its flow are the most important characteristic in a service company and the foundation for improvement.

Fillingham (2007) and Poksinska (2010) stated that it is very important in Lean Healthcare to understand the patient/customer perception of value. This was started in sub-Chapter 4.3 notwithstanding the difficulty in identifying the customers and their point of view (Radnor & Osborne, 2013), and was the basis of all analysis developed from that point forward.

Applying Lean tools to healthcare and phlebotomy services are in line with positive results obtained by Miller (2005), Aherne and Whelton (2010), Jimmerson *et al.* (2005), King *et al.* (2006) and Hawthorne and Masterson (2013) and Radnor *et al.* (2012) such as reduction in distance travelled and lead time, cost reduction and improvements in efficiency and effectiveness.

5.4 Limits to the research

The results are sustained within the structure and objective of the research. Case study's main limitation is "*the little basis for scientific generalization*" (Yin, 2009:15).

As acknowledged by Eisenhardt (1989) and Yin (2009:15), case study findings "*are generalizable to theoretical propositions and not to populations or universes*", thus the findings of this dissertation only concern the two processes studied and only apply to the phlebotomy services of Lusíadas Hospital and São Francisco Xavier Hospital.

As limited by the scope of this research and the case study methodology, the resulted findings cannot be generalised to other healthcare context. Nevertheless, it can provide insightful data for other researchers interested in Lean Thinking and its potential to improve healthcare processes and services. Thus, this thesis contributes to widen the healthcare areas where Lean can be implemented and, as far as it is known to the author, provides the first research and dissertation in Lean Thinking in Healthcare Phlebotomy Services performed in Portugal.

A different methodology should be applied in the case of a wider range of research, since the methodology applied in this case study refers only to the processes studied in the phlebotomy services considering the objective of this thesis.

Finally, the findings provided by this case study may be useful for the phlebotomy services of São Francisco Xavier Hospital and Lusíadas Hospital in view of the potential of the application of Lean tools, although the application of improvement suggestions has not been contemplated in this dissertation.

The observations were not from a random sample, but a convenience one, though all occurrences and days of data collection were considered, as well as different times throughout the week to capture the maximum possible variability.

Although improvement suggestions have not been implemented yet, which is a limitation to the research, the improvements are based on non-optimistic projections, so it is very likely that the results found after implementation will be similar to those presented in this dissertation.

5.5 Future research alternatives

As previously mentioned, the literature on the application of Lean Thinking to healthcare phlebotomy services is still at its start. Moreover, it is believed that this is the first dissertation held in Portugal focusing on healthcare phlebotomy services, although other healthcare areas have been studied.

This dissertation contributed to fill the gap in the literature and an opportunity to provide insights of Lean methodology applied to new healthcare services. Since this thesis was a multiple case study that made it possible to compare phlebotomy services and, according to Yin (2009), if more research is done on other phlebotomy services and on a wider set of processes, this will allow the generalization of results. This is an interesting topic for further research.

In addition, an implementation of improvement suggestions according to the Lean approach should be attempted. Furthermore, it may be interesting to extend the previously applied toolset to encompass more tools related to the Lean methodology, such as 5s, Kaizen, Takt time and Kanban.

Finally, since Lean Thinking has long extended to the service area from a theoretical perspective, understanding how the principles guiding the Lean philosophy can be achieved in the healthcare area, given its specific characteristics, could be relevant to increase its potential and provide a more sustained framework for researchers. Moreover, to establish a framework for applying Lean Thinking to phlebotomy services, a possible future research question comes to light:

- *How can Lean principles be achieved in healthcare phlebotomy services?*

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Appendix 1

Calculations for required number of observations

$$n = \left(\frac{40\sqrt{n'\sum x^2 - (\sum x)^2}}{\sum x} \right)^2$$

95% confidence level with a margin of error of 5%
χ = total time in the preliminary study
n = 5 observations

Lusíadas Hospital		São Francisco Xavier Hospital	
χ	χ^2	χ	χ^2
23,46	550,37	17,80	316,84
28,12	790,73	17,53	307,30
22,12	489,29	14,03	196,84
17,76	315,42	14,03	196,84
16,60	275,56	11,93	142,32
$\sum$108,06	$\sum$2421,37	$\sum$75,33	$\sum$1160,14

Lusíadas Hospital

$$n = \left(\frac{40\sqrt{(5\ (2421{,}37) - 108{,}06^2}}{108{,}06} \right)^2$$

$$n = \left(\frac{40\sqrt{12106{,}85 - 11676{,}96}}{108{,}06} \right)^2$$

$$n = \left(\frac{829{,}35}{108{,}06} \right)^2$$

$$n = 60\ observations\ required$$

São Francisco Xavier Hospital

$$n = \left(\frac{40\sqrt{(5\ (1160{,}14) - 75{,}33^2}}{75{,}33} \right)^2$$

$$n = \left(\frac{40\sqrt{(5800{,}7 - 5674{,}61}}{75{,}33} \right)^2$$

$$n = \left(\frac{449{,}16}{75{,}33} \right)^2$$

$$n = 36\ observations\ required$$