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PAULA VIEIRA MORA

APPLICATION OF LEAN PHILOSOPHY TO THE DELIVERY OF BLOOD COMPONENTS THROUGH DRONES

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Dissertation of Masters presented to Programa de Pós Graduação em Administração, Instituto COPPEAD de Administração, Universidade Federal do Rio de Janeiro, as part of the requisites necessary to obtain the title of Master in Administration.

Advisor Professor: Claudia Affonso Silva Araújo, D.Sc.

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ABSTRACT

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This research explores qualitatively how the blood supply chain can be enhanced through the use of drones in the delivery of blood components, linked to the use of Lean philosophy in its process. The aim is to understand the main challenges and wastes present in the blood supply chain. Through a literature review and the use of in-depth interviews, data is collected from 7 participants regarding the blood supply chain in Brazil and the use of drones to the delivery of blood components bags. Main challenges were identified regarding the wastage level, ability to predict demand for blood, low level of centralization in developing countries, unexpected short-term changes in demand for blood components, and sanitary, environmental and infrastructural risks. Wastes were identified mainly due to improper temperature during transportation, compromising safety of blood bags, lack of equipment maintenance, leading to higher depreciation rates, and waiting time for the delivery of biomolecular testing results. The use of drones can represent gains in time of delivery, allowing a “just-in-time” model of distribution of blood, operating through a “pull” system, reducing the need for inventories and therefore costs.

Keywords: Drones, Blood Supply Chain, Lean Healthcare, Blood Distribution

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1) Introduction

1.1 The problem and its relevance

Human blood is a complex fluid circulating in the vascular system and is composed of plasma and cellular elements that include red blood cells (RBC), white blood cells, and platelets. Blood and blood components perform several vital functions in the human body, and their loss can result in life-threatening conditions, requiring immediate blood transfusion. Transfusion of blood is also used as supportive therapy for surgery, chemotherapy, stem cell and organ transplantation, and treatment of some diseases (World Health Organization - WHO, 2017). Therefore, the provision of blood and blood components (erythrocytes, leukocytes, platelets, cryoprecipitate, plasma) is of vital importance to patients that need transfusion as a treatment.

On the supply side, each donation can save up to three lives (Sabharwal and Ülkü, 2018). Still, the human body takes up to 40 days to replenish the red blood cells, limiting the number of times an individual can donate to six times annually. Also, the supply of blood and its components is threatened by an aging population, reducing the donor base of blood. In Brazil, between 2010 and 2017, there was an average of 4.1 million candidates to blood donation. In 2017, there were 4.7 million candidates to donate, of which 3.7 million were collected. This number leads to a donor rate of 18,1 donors per 1000 habitants, representing 1,8% of the Brazilian population. The World Health Organization (WHO) recommends that a donor base should be around 3% of the Brazilian population in order to assure the safety of blood provision (ANVISA, 2018).

Another challenge in blood provision is the occurrence of some disruption in the blood supply chain (BSC), like natural disasters and climate events, and the provision of blood to remote and isolated areas (Balasingam, 2017). Following that, it is essential to have an adequate quantity of blood and blood product bags in order to fulfill demand on time, and it is necessary to ensure the means of the blood being delivered to the right place at the right time.

The distribution of blood must have a safe and robust net, capable of providing all the blood demand. Time is a critical variable in this equation since in cases like trauma patients it is vital to have the blood on hand for transfusion. Planning inventories of blood components is a complex task, and adverse events can lead to the risk of shortages. On the other hand, if there is more supply than demand, it faces the threat of wastage since blood is a perishable item and must be discarded after the expiration date (Williamson and Devine, 2013; Zhang and Wong, 2016).

The fact that blood and blood products are perishable imposes a challenge to the BSC. Each component has its own need for temperature control and different shelf lives. More than a hundred products and sub-products can be derived from whole blood, but the main are red blood cells, plasma, platelets, and cryoprecipitate (Osorio et al., 2015). Countries vary in their threshold of the maximum allowed days of storage for each component, but Williamson and Devine (2013) provide us ranges for each product: red blood cell concentrate vary between 5 and 49 days (the most commonly seen in the literature is 42 days); platelet concentrate vary between 3 and 7 days; fresh frozen plasma can last one year if frozen, and 1 to 7 days if thawed, and cryoprecipitate can last one year if frozen or 4 to 6 hours if thawed. Regarding the temperature of storage, the World Health Organization (WHO, 2017) recommends that plasma components should be frozen within a specified period after collection - preferably within 8 hours for fresh frozen plasma, or within 24 hours, whole blood and red blood cells should be refrigerated at 1–6 °C, and platelets should be stored at 20–24 °C under agitation.

Most hospitals order an amount of blood-based on the experience of staff and historical patterns (Stanger et al., 2012), and blood banks tend to deliver daily blood products as they are ordered on the previous day. However, distribution has space for improvement. Plenty of innovations are being developed in the BSC area: stem cells therapies, genetic matching, new diagnostic tests, new equipment for storage and conservation, radio-frequency identification (RFID) systems for inventory management, and using Unmanned Aerial Vehicles, or drones, to deliver blood products to hospitals (John and Kumar, 2013).

Drones could represent the ability to provide blood just-in-time as hospitals need it, reducing the amounts of necessary inventories, shortages, and wastage of blood products. Studies have shown that it is entirely possible to transport blood products through drones without significantly affecting its biochemical properties (Amukele et al., 2016; Amukele et al., 2015; Thiels et al., 2015; Amukele et al., 2017a; Amukele et al., 2017b). The only thing that should be paid attention to is to keep the blood products conserved at the proper temperature during the flight time. Still, it proves itself extremely useful for time-sensitive situations such as the before mentioned natural catastrophes. Rwanda has been employing drones to deliver blood products to hospitals, which led to a reduction of about 7% of wastage to none in 2018 (Ackerman and Koziol, 2019). Other countries are implementing tests to the viability of drone deliveries of blood products, such as Brazil, with a startup called “Tá na Escuta” in Juiz de Fora, Minas Gerais. Furthermore, drones have been used effectively for medical purposes, delivering small aid packages to the Haitian earthquake victims in 2012 (Jagyasi, 2018). One challenge remains in some countries: the legislation for flying drones. According to Amukele et al. (2016), only 57 of the 174 countries in the world have regulations regarding civilian drone use.

In turn, Womack and Jones (2005) remark the importance of the lean supplier to explore multiple channels in order to get to the consumer exactly when and where he wants. In that sense, the use of drones to deliver blood and its components can improve delivery and reduce waste in the BSC. In this context, this study aims to understand how lean philosophy and drone technology can improve the BSC. In order to do so, it’s necessary to address the following specific objectives: (1) to map the blood supply chain in Brazil; (2) to identify the main challenges and wastages of the BSC in Brazil; and (3) to investigate how drones can help the BSC reduce wastages.

This research's theoretical contribution is to analyze, in light of the Lean philosophy, how drones can impact the blood distribution system. The supply of blood and blood components is vital to patients who need transfusion as a treatment. The supply of those goods is threatened by an aging population, which implies reducing the donor base. Besides, natural disasters and climate events impose a significant risk of interruption in the blood supply chain, and those tend to increase with global warming. It is also necessary to consider blood supply to remote and isolated areas due to geography or compromised roads. Therefore, it is essential to guarantee that blood is delivered in the right place, right time. Time is precious in the event of traumas, for example, that may require a blood transfusion. The blood distribution must have a safe and robust net, capable of supplying the whole blood demand. This research will fill a gap in the literature since there are few studies focused on analyzing how the use of new technologies, more specifically drones, can help reduce waste in the blood supply chain associated with the Lean principles of management.

Regarding practical contribution, this research will help understand how drones can help deliver blood in the right place, right time, increasing the chances of saving lives, especially of patients, victims of traumas. The study will guide the main challenges of this application and the main benefits that may be obtained with its usage. Examples are the decrease of blood bags' delivery time and reduction in hospitals’ stocks, reducing costs.

1.2 Delimitation of the study

This study investigates aspects of the BSC distribution, specifically the possible use of drones for the delivery of blood products. The BSC stages related to the collection, productions, and inventory are out of the scope of this study. Also, this research is delimited to the Brazilian context. It aims to be a source of information to understand challenges that may emerge in developing countries for the expansion of this type of service, such as regulations challenge.

Although the Brazilian logistics network is a significant bottleneck, the idea is not to evaluate the network itself but the challenges inherent of the products that must be overcome, like the product's perishability and needs for refrigerated storage and transportation. The main blood products considered are red blood cells, plasma, platelets, and cryoprecipitates. Each has different shelf lives and needs of temperature conservation. Since Brazil has a continental size, high temperatures, and big cities that often face problems with traffic and floods, drones would be a useful tool for this environment, since they can fly over larger speeds, they can carry a reasonable payload, and they do not require somebody on board to be utilized. For this reason, this study focuses on the specific use of drones in the delivery of blood components.

In addition, the aim of this study is not to increase the available quantity of blood in Brazil for donation (what could have as an innovation artificial blood to supply-demand), instead, it focuses on how to reduce the wastages of donated blood.

This research will also not exhaust all the norms from the main regulatory agencies studied, like ANVISA (National Sanitary Vigilance Agency), or specific standards of the country regarding blood transfusions and its chain. The focus will be specifically on the distribution and storage of blood regulations. International norms were used to specific consultation and comparisons to Brazilian practices but were not deeply studied.

A further delimitation of this study is that it is focused on the perception of executives and specialists of some companies that are part of the blood supply chain (from both public and private sectors) and do not include the patient's or the doctor's point of view.

1.3 Study Organization

This study is divided into four sections: Introduction, Literature Review, Methodology, and Conclusion. The Introduction chapter presents the objective of the research and its relevance. It is also considered the delimitations of the study, that is, its scope.

The following chapter brings the literature review of the analyzed subjects in this study: Blood supply chain and Drones. It is also studied the Lean philosophy and its principles, introducing the concept of Lean Healthcare.

The third chapter explains the methodology employed in this study. It proposes the type of method and its motivations, as well as its limitations. It is also presented the data collection and treatment procedures. Furthermore, we have the results found in the study and the analysis of data collected.

The following chapter, the fourth, comprehends the conclusions of this research. It presents a summary of the discussion and suggestions for future research in the field.

2) Literature Review

In order to develop a consistent literature review, some steps were followed: (i) observation of a phenomenon, (ii) creation of the research question, (iii) selection of the keywords, (iv) selection of the databases, (v) definition of research criteria, (vi) reading the titles and eliminating duplicates, (vii) reading the abstracts, (viii) reading the full text and (ix) text analysis.

The search terms used in this research were “blood” AND “supply chain” OR “blood supply chain”. Those terms were researched in five key databases: EBSCO, ProQuest, Science Direct, BVS, and LILACS. After the filters and removal of duplicates, it resulted in 289 useful articles for this research. For the drones and blood products research, the search terms used were (blood OR "blood bag" OR "bolsa de sangue" OR sangue) AND (Drone OR UAV OR " unmanned aerial vehicle" OR " uncrewed aerial vehicle" OR VANT OR ARP OR " aeronave remotamente pilotada" OR "Veículo aéreo não tripulado") in the following databases: Pubmed, ScienceDirect, Proquest, Web of Science and EBSCO. These terms should be available on abstracts, and the research was performed in December 2019. As expected, the theme of drones transporting blood products is not yet much debated: after filtering and removing duplicates, eleven articles remained to be used in this research.

2.1 Blood Supply Chain

According to Pedroso and Nakano (2009), the supply chain consists of the flow of goods, services, and information across organizations connected among themselves, aiming to fulfill a market need. For these authors, a considerable amount of research on the supply chain information is related to studying the upstream flow of demand information and its effects on material flows. A different definition can be found in Stevens (1989), where a supply chain can be defined as the connected series of activities which is concerned with planning, coordinating and controlling material, parts and finished goods from suppliers to the customers, and relates to the flow of material and information through the organization. It begins at the source of supply and ends at the point of consumption. In the vision of Delen et al. (2011), the success of a supply chain system depends on the level of visibility of the resources from the suppliers to the customers. That is, transparency. Further on it will be discussed the importance of transparency in the supply chain for Lean thinking.

The blood supply chain (BSC) consists of the flow of blood products, services, and information across organizations connected among themselves, like blood banks, blood distribution centers, and hospitals. Blood products can be classified mainly as platelets, red blood cells, cryoprecipitates, and plasma, but there are other sub-products (Osorio et al., 2015).

Most of the research on BSC consists of optimization models, simulations, and logistics studies in order to determine several aspects and policies, like the amount of blood necessary, the best collection campaign - according to Beliën and Forcé (2012), only about 5% of the eligible donor population actually donates -, the best location for the blood facilities and the best route between different agents of the supply chain.

In contrast with the literature, the most used solution for selecting the blood products bags is a “rule of thumb” like the OUFO (oldest-unit-first-out) or the FIFO (First in First out) method (Stanger et al., 2012; Williamson and Devine, 2013). The oldest bags on the refrigerator should be the first used in order to reduce wastage, being placed on the easiest spot to be picked up, with the newer bags placed on the back of the machine. They should also have the expiration dates labeled and visible to avoid possible mistakes. Some blood banks are testing the RFID (radio-frequency identification) system to improve information. The RFID helps to attain inventory visibility and accurate counts at every stage of the supply chain and reduces shrinkage and shipping errors (John and Kumar, 2013).

Balancing the blood supply and demand is not an easy task because of the stochastic phenomenon in the supply and demand. The BSC management's main challenges are related to shortage, outdate, and supply chain cost, which needs to be minimized. Besides, inflicted risk, the uncertainty of supply and demand, blood nature as a perishable commodity, demand uniqueness, and cost occurred are some of the difficulties of managing the BSC (Mansur et al., 2018; Amukele et al., 2017b). In particular, due to its high levels of perishability, scarcity, and non-interchangeability with other products, blood deals with a significant trade-off between shortage and wastage (Marques et al., 2020).

The requirements for new blood bags usually rely on the experience of staff and are adjusted continually over time rather than using complex mathematical systems to estimate the adequate number of bags to be ordered (Stanger et al., 2012). Differently from what is preached in the literature, that complex policies, models, and techniques are the key drivers to low wastage levels in the blood supply chain, on the mentioned study, six key themes emerged as drivers for good performance in blood stocks inventory management: human resources and training, stock levels and order patterns, transparency of inventories, simple inventory procedures, focus on freshness, and internal collaboration within the hospital. Besides, forecasting blood demand tends to be based on historical patterns of use (Williamson and Devine, 2013; Osorio et al., 2015).

Blood services worldwide are increasingly organized on a national basis, in line with the WHO recommendations. This means there is a centralized blood system distribution. Usually, those are arranged on a national or a regional basis. Those systems rely on information technology (IT), which is now an integral part of blood component testing and manufacturing, with a single system potentially controlling national blood stocks. Consequently, more attention is being paid to resilience and disaster recovery – the absence of contingency plans can mean a disruption in the blood supply chain, compromising the distribution center's ability to meet the hospitals' demand for blood products (Morgan et al., 2015).

There is a national blood policy instituted by law in Brazil called the National Policy for Blood, Blood Components, and Blood Derivates. There is a central institution for its management, called SINASAN (National System of Blood, Blood Components and Blood Derivates), that has among its goals the assurance of national self-sufficiency of blood components and derivates, and harmonization of the public power in all levels of government, related to blood assistance. Instituted in 2001, the National Blood Policy has several objectives, some of them are universalization of the aid to the population, use of voluntary donations, the prohibition of payments per donations, protection of the donor with several pieces of information available about the procedure and secrecy of their data, mandatory vigilance and control, safety on stock and transportation of blood products and mandatory individualized testing of samples or units of blood products.

2.1.1 The Chain

Firstly, it is essential to mention that most of the literature regarding BSC focuses on individual echelons (hospitals, blood distribution centers, etc.) instead of considering relationships between the different stages (Osorio et al., 2015).

A supply chain consists of the flow of goods, services, and information across organizations connected among themselves, aiming to fulfill a market need (Pedroso and Nakano, 2009). The BSC is composed of different agents, the goods and services related to the blood transfusion system. Those actors interact with each other in different ways. For example, the hospital will interact with the blood distribution center requiring more blood and its components and receiving them.

In the vision of Contreras and Martínez (2015), the BSC includes the voluntary donor, Blood Centers services, transfusion medicine units of the hospitals, the medical prescription, the administration of blood components, and the vigilance of the receptor of the blood component. However, for Sabharwal and Ülkü (2018) and Osorio et al. (2018), the chain stages are quite simple: collection, production, inventory, and distribution. In the present research, the focus of analysis will be placed on the fourth stage – distribution – in order to study the possibility of improvements in this stage with the assistance of new technologies – in this case, drones. Drones can be used to improve blood delivery and its components to different agents of the chain – for example, from blood distribution centers to hospitals.

In Brazil, according to Osorio et al. (2018), there is a decentralized BSC system. Although the authors focus on the benefits of centralization in its models, such as economies of scale, large distances, high transportation costs, and geographic remoteness tend to favor decentralized systems, like the one in Brazil.

The Brazilian government defines the blood cycle in 12 different stages: reception, register, clinical screening, collection, laboratory screening, processing, storage, distribution, transport, transfusion, quality control, and waste disposal (Brazil, 2016).

Marques et al. (2020, p.2) mention the importance of investigating the blood supply network, notably including horizontal and diagonal ties between agents. According to the authors,

> "Horizontal ties represent collaboration among actors at the same level of supply (i.e., competitors), seeking to split costs and exploit advantages in similar markets, such as technology or geographic segmentation (…) Diagonal ties refers to a link between a traditional supply chain member (e.g., either a supplier or the focal organization) and a non-traditional actor, which is the term used to denote actors often neglected in SCM research such as regulators, a domain expert, academics, or a not-for-profit organization".

McKone-Sweet et al. (2005) emphasize that despite the understanding that collaboration is vital, coordinating the healthcare supply network is difficult once it depends on the alignment of multiple actors with distinct agendas in one common direction. For John and Kumar (2013), creating a collaborative environment that reduces costs and adds value to the entire supply network is essential.

Further in this study, it will be discussed the adoption of lean practices in the BSC in order to improve it. One important theme that emerges is the importance of collaboration between different supply chain agents - for example, buyers and suppliers - to enhance the system's capabilities, agility, and precision.

2.1.2 Agents

The BSC comprises different agents who interact with each other, exchanging products, services, and information. Those agents can be either people, like blood donors and staff, or institutions, like blood distribution centers and hospitals. This section will discuss who the agents are and what their main functions in the BSC are.

According to Pirabán et al. (2019), the BSC manages blood products' flow from donors to patients through five echelons: donors, mobile collection sites, blood centers, demand nodes, and patients. The whole process of extracting blood from a donor and giving it to the recipient is often called "vein to vein".

For the WHO, the blood transfusion system consists of care centers like hospitals, surgical centers, and outpatient facilities - and sometimes ambulances - that utilize blood and blood components to treat patients. Some of the activities performed by those centers are: storing at appropriate conditions the blood and blood components, developing procedures for further processing of the blood and blood components prior to transfusion, pre-transfusion testing of patients and cross-matching to ensure compatibility, maintaining appropriate records to ensure that blood components can be traced to their recipients and from recipients back to their donors, reporting adverse events and reactions that are related to the quality of blood components to the blood establishments/banks, investigating, evaluating and documenting all adverse transfusion reactions and ensuring the appropriate use of blood and blood components by clinicians (WHO, 2017).

In Brazil, as mentioned before, there is a decentralized system composed of the national blood center, state blood centers, public blood transfusion services, and private blood transfusion services. The public services are composed of Blood Centers, Blood Nucleus, Collection and Transfusion Units, Transfusion Agencies, and Collection Posts. On the other hand, the private services are composed of Blood Banks, Hospital Blood Services, Collection and Transfusion Units, Transfusion Agencies, and Collection Posts (Brazil, 2000).

2.1.3 The BSC Process

The BSC composition varies by authors. For Osorio et al. (2015), it is composed of the processes of collecting, testing, processing, and distributing blood products from donor to recipient. On the other hand, for Pirabán et al. (2019), it comprises six processes: collection, testing, component processing, storage, distribution, and transfusion. Furthermore, in the vision of Mansur et al. (2018), the stages are merely collecting, production, inventory, and distribution. An efficient chain should meet demand while reducing wastage and minimizing costs. In this section, it will be analyzed in more detail each step of the process.

The first stage, collection, comprises the processes of procurement of blood and blood products. Its purpose is to obtain the number of blood products necessary to meet the demand. Decisions in this step are mainly related to blood collection management, related to location and capacity decisions, collection methods, and donor management (Osorio et al., 2015). The entire collection process from start to finish takes about one hour and includes the extraction of one unit of blood and four test tubes of blood used for the testing phase (Sabharwal and Ülkü, 2018).

The second stage, production, is where a unit of blood is received at the blood center and is tested and possibly fractionated, separated into components. This stage is concerned with replenishing inventories of blood products during regular and emergency periods. At this level, decisions are related to how to exploit the fractionation alternatives and advantages of collection methods to improve the performance of the blood supply chain (Osorio et al., 2015).

Distribution is mostly related to the transport of blood and blood products from blood centers to other agents, especially hospital blood banks. However, in the vision of Osorio et al. (2015), it also comprises the transport from the hospital blood bank to the operating room, care unit or ward where the recipient is located. Furthermore, the Inventory stage covers storage at blood centers and hospital blood banks, both assigned and unassigned.

In the studies related to each stage of the BSC, it can be noticed that real-world data are more commonly used in the inventory, collection, and collection-transportation configurations. Conversely, synthetic data are more frequently used in the transportation, inventory, and transportation-inventory design (Pirabán et al., 2019).

To each process, there is a cost associated. However, the blood supply chain's main costs are related to wastage, spoilage, and stock-out costs, rather than traditional supply chain optimization costs such as transportation, storage, and routing methods (Sabharwal and Ülkü, 2018).

2.1.4 Blood Supply Chain Challenges and Peculiarities

The BSC has peculiarities that change around the world. It differs, for example, in the structure of hospitals (public vs. private), the type of supply (free vs. paid donations), pricing for blood, the distribution of blood, and the handling of shortages (Rock et al., 2000). However, all systems have the same objectives: to provide sufficient supply while keeping wastage to a minimum.

The ability to predict the demand for blood and blood components is tricky since it differs in countries and is the consequence of demographic changes, health policies, and conservation and usage strategies (Contreras and Martínez, 2015). Another factor countries often differ in is the hemoglobin thresholds. In blood systems in high-income countries, transfusion is usually of specific components (for example, red cells, platelets, fresh frozen plasma) rather than whole blood (Williamson and Devine, 2013). Besides, there are also regulations specific to countries about the maximum wastage level. For example, in the United States, it has to be less than 6% of demand (Fortsch and Perera, 2018).

In most developed countries, returning unused blood from the hospital to the blood center is not allowed. Furthermore, most developed countries have, or are moving towards, centralized BSC that relies on large regional production and distribution centers. However, the level of centralization is usually lower in developing countries, which is Brazil's case (Osorio et al., 2018). For the World Health Organization:

> “where possible, it is recommended that countries move towards a nationally regulated and coordinated blood supply system in order to: (a) harmonize procedures and best practices at the national level; and (b) provide assurance that blood and blood components from different areas are of equivalent safety and quality and thereby facilitate the exchange of these products across the country”. (WHO, 2017, pp. 154)

In the study of Seifried et al. (2011), it is stated that in the future, today’s predictable requirements for blood products for standard procedures are likely to become more driven by acute, unexpected short-term changes in demand for blood components, due for example for the aging of the population, increasing demand for blood components and at the same time reducing the active donor base. As a result, the whole blood supply chain will become more sensitive to logistical problems, and wastage rates are predicted to increase. This makes the present study even more important since it deals with the distribution stage of the blood supply chain.

In Brazil (2011), there is the definition of risk for the BSC's stability and adverse events that may affect the cycle of blood. Those risks are sanitary (for example, epidemics or pandemics, immunizations, temporary disabilities), environmental (floods, tornadoes, droughts, earthquakes), and infrastructural (disasters, terrorist acts, aircraft crashes).

> "In UK and Australia, incident management is facilitated by a national approach, which aims to improve resilience through consistent practices across sites, allowing transfer of manufacturing activity and finished stock between them". (Morgan et al., 2015, pp. 152)

Table 1 presents the challenges identified in the blood supply chain and the respective authors who mention them.

Table 1 – Challenges in the Blood Supply Chain

Challenges	Authors
Provide sufficient supply while keeping wastage to a minimum	Rock et al. (2000)
Ability to predict the demand for blood	Contreras and Martínez (2015)
Staying below the maximum wastage level allowed	Fortsch and Perera (2018)
Low level of centralization in developing countries	Osorio et al. (2018); WHO (2017)
Unexpected short term changes in demand for blood components	Seifried et al. (2011)
Sanitary, environmental and infrastructural risks	Brazil (2011)

2.2 Lean philosophy

In this section, the lean principles will be introduced and defined. Furthermore, it will be analyzed how those principles can be used in the BSC and if there are already examples of their use. Lean healthcare will be studied as well, that is, the application of lean principles in the healthcare sector, a well-documented segment of study.

The first concept that should be mentioned is the *muda*, which means "waste". It is specifically any human activity that absorbs resources but creates no value at all, therefore requiring rectification. Womack e Jones (2003) consider seven types of waste in the processes: excess of production, excess of process or incorrect process, unnecessary movement of parts, unnecessary movements of people, excess of inventories, defects, and wait. It is illustrated as the production of goods and services no one wants, piling up inventories, process steps that aren't necessary, movement of employees and goods from place to place that don't have a purpose, idle time (people and machines in a downstream activity waiting because an upstream activity hasn't delivered on time) and goods and services produced that don't meet the needs of the customer.

Lean thinking comes out as an antidote to *muda*. Womack and Jones (2003) proposed five principles that translate the lean thinking concept: identify the value, identify the value stream, develop a flow, use pull techniques of production and aim for perfection. In their vision, lean provides a way to do more with less – less human effort, less equipment, less time, and less space, while coming closer to give customers exactly what they want. In their words:

> "It provides a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively". Womack and Jones (2003)

2.2.1 Value

The first lean principle is related to identifying value. It is crucial to rethink the value of the activities being performed from the customer's perspective since it is the one for whom the value is being created in the first place. Specifying value accurately is the critical first step in lean thinking.

For Womack and Jones (2003), when providers decide to rethink value, they usually fall back on simple formulas, like lower cost, increased product variety through customization, instant delivery, rather than jointly analyzing value and challenging old definitions to see what is really necessary. Their focus tends to be inward to their own operational efficiency, rather than looking at the whole product – and every step required to make it – through the eyes of the customer.

Rethinking value is not a one-step task. It must be an exercise consistently done repeatedly with the product teams to ask if they got the best answer. This will help to produce steady results along the path to perfection (which is also continuous). Relentless scrutiny of every activity along the value stream must be performed. The real cost firms must analyze is the *muda*-free cost, that is, the production cost once all the unnecessary steps are effectively removed from their processes.

2.2.2 The value stream

According to Womack and Jones (2003), the value stream is the set of all the specific actions required to bring a particular product or service through three critical management tasks: the problem-solving task, the information management task, and the physical transformation task. Identifying the entire value stream for each product is the following step in lean thinking, and it often exposes large amounts of *muda*.

The firm should not consider only its own value stream for inward production but rather think of the whole process of creating that product, involving other agents as well, for example, suppliers and customers. The lean enterprise concept relates to a continuing conference of all the concerned parties to create a channel for the entire value stream, eliminating all the *muda*. This requires a new way of thinking of firm-to-firm relations, increasing communication and transparency among the players.

The starting point should be looking at all the specific actions required to see how they interact with each other and create a value stream map. The initial objective of creating a value stream map is to sort the actions performed in the production process into three categories: (1) those which actually creates value as perceived by the customer, (2) those which create no value but are currently required by the product development and (3) those which don't create value as perceived by the customer and can be eliminated immediately.

2.2.3 Flow

The principle of Flow relates to the continuous flow of activities without interruptions, and therefore without waste. The easiest way to achieve it is to quickly change over tools from one product to the next and by "right-sizing" machines so that processing steps of different types of products can flow smoothly and efficiently. The creation, ordering, and provision of any good or service can be made to flow.

The greatest challenge for achieving Flow, in the vision of Womack and Jones (2003), is that flow thinking is counterintuitive – it seems clear to most people that work should be organized by departments in batches. According to the authors, if people can overcome this issue and adopt flow, the amount of human effort, time, space, tools, and inventories can be quickly cut in half.

Once value is defined and the entire value stream is identified, the first step is to focus on the actual object and never let it out of sight from beginning to completion. The second step is to ignore traditional boundaries of jobs, career functions, and firms to create a lean enterprise, removing all barriers to a specific product's continuous flow. Next, the third step is to rethink specific work practices and tools to eliminate backflows, scrap, and stoppages so that the design, order, and production can proceed continuously. The lean approach is to create genuinely dedicated product teams with all the skills needed to conduct all the activities. Work should be standardized so that a team follows the same approach every time.

The best way to achieve this is by focusing on an equilibrated takt time, that is, precisely synchronizing the rate of production to the speed of sales to customers, evidencing the flow of the production activities. Production should always be precisely synchronized with demand, leading to the reduction of inventories. An essential tool to help this process is having full transparency or visual control of the production line. Everyone should be able to see where the production stands at every time.

By design, flow systems have an everything-works-or-nothing-works quality that must be respected and anticipated – if one step of the process stops, the downstream activities also become compromised since production flows with demand. This means that the production team must be cross-skilled in every task and that the machines must be made fully available. It also means that work must be rigorously standardized, as mentioned before.

The American Production and Inventory Control Society (APICS) defines JIT (just-in-time) as

> “In broadsense, an approach to achieving excellence in a manufacturing company based on the continuing elimination of waste (waste being considered as those things which do not add value to the product). In the narrow sense, JIT refers to the movement of material at the necessary place at the necessary time. The implication is that each operation is closely synchronized with the subsequent ones to make that possible" (APICS, 1987, pp. 77).

Just-in-time can only work effectively if machine changeovers are dramatically slashed, so that upstream manufacturing operations produce small amounts of each part and then produce another small amount as soon as the amount already produced is summoned by the next process downstream. JIT is also helpless unless downstream production steps practice level scheduling to smooth out the perturbations in day-to-day order flow unrelated to actual customer demand, like flaws in production. Otherwise, bottlenecks will quickly emerge upstream, and buffers ("safety stocks") will be introduced everywhere to prevent them.

2.2.4 Pull

The ability to design, schedule, and make exactly what the customer wants just when he wants it means you can simply make what the customers tell that they need. This means a firm can let the customer pull the product from it as needed, rather than pushing products onto him. No one upstream should produce a good or service until the customer downstream asks for it. The ability to reorder in small amounts is key to reducing inventories in a complex production and supply stream. A natural product of flow and pull is the continuous improvement of quality, which relates to the next and last lean principle.

2.2.5 Perfection

The final lean principle is seeking perfection, which is illustrated by the continuous improvement of the processes. Getting value to flow faster always exposes hidden *muda* in the value stream. The principles interact with each other in a virtuous circle. The more there is pull, the more the barriers to flow are exposed so that they can be removed. But the most important spur to perfection is transparency, the fact that in a lean system, everyone (subcontractors, first-tier suppliers, assemblers, distributors, customers, employees) can see everything, and so it is easier to discover better ways to create value. Furthermore, there is an almost instant and positive feedback for employees making improvements, a powerful spur to continuing efforts to improve.

2.3 Applicability of the lean principles on the Blood Supply Chain

This section will analyze how Lean principles can be applied specifically to the BSC and the consequences of such adoption. For John and Kumar (2013), it is considered a challenging task to recognize solutions that will help reduce inefficiencies and drive down costs in the healthcare supply chain. Besides, the industry struggles to meet on-time delivery, and the major drawback remains in the fact that each part of the supply chain works independently, preventing it from working as a system. Supply Chain Management in healthcare should ensure complete end-to-end visibility of information among suppliers, manufacturers, distributors, and customers, that is, full transparency.

> Lean healthcare is a management philosophy to develop a hospital culture characterized by increased patient and other stakeholder satisfaction through continuous improvements, in which all employees (managers, physicians, nurses, laboratory people, technicians, office people, etc.) actively participate in identifying and reducing non-value-adding activities (waste) (Dahlgaard *et al.*, 2011, p. 677).

For De Souza and Pidd (2011), there are three main reasons for the adoption of lean techniques in the National Health Service of UK – cost pressure has stimulated a search for improved working practices, national targets (standards) for waiting times have encouraged time compression and the removal of non-value adding tasks and the promising initial results in other countries. Those drivers can also be found in other countries. The authors explore implementation problems to lean techniques in healthcare.

De Souza (2009) does a literature review about lean healthcare, and according to the author, this is a concept that was first applied and published in the 2000s. The author states that there is a need for improving healthcare delivery, and Lean methods can help achieve this. The author's other possible approaches are Total Quality Management, Systems Dynamics, Theory of Constraints, Reengineering, and Discrete Event Simulation. However, the lean healthcare field has experienced an increase in demand for literature adapting the lean theory to the healthcare context. Lean can consistently improve the effectiveness and efficiency of a system by eliminating waste (Costa and Godinho Filho, 2016).

Lean tools and methods adapted to the healthcare context can be many, classified as helping assessment (5 Whys, Value stream mapping, A3), improvement (5S's, workload balancing, Kanban, mistake proofing, production leveling, standardized work, Kaizen), and/or monitoring (visual management, PDCA) and each can lead to different results, such as in the fields of costs (cost reduction, productivity enhancements, inventory reduction), time (reduction in time looking for supplies, waiting time reduction), defects (rework reduction, medical error reduction) and value (service capacity increase, improved patient satisfaction, reduced readmission rate) (Costa and Godinho Filho, 2016).

Hallam and Contreras (2018) mention that even though lean healthcare literature acknowledges performance improvements, there is limited empirical research to assess how Lean has been implemented, its specific tools, what waste has been reduced, and what quality improvements have been systemically achieved, and how transformation is sustained.

In the vision of Jones and Mitchell (2006), lean healthcare can offer four benefits for health services: increase in patient safety by reducing mistakes and accidents; improved delivery of better service; reduction in the use of resources and organization of work through the creation of protocols. Through the standardization of procedures, there is a foundation for continuous improvement to Perfection. The authors mention a real case in Bolton Hospital where the journey of blood samples was tracked back and forth, and many unnecessary steps and blockages became clear to them (for example, the laboratory could not analyze a sample before the information had been put into the computer, but inputting delays are common, caused by samples arriving in large batches). A routine blood sample's journey once involved 309 steps, but with a redesign of work, machine relocation, and so on, this could be reduced to just 57 steps. The workspace redesign would lessen the distance staff has to walk each day by 80%, saving vast amounts of both time and energy.

Another author that mentions the importance of standardization and clear mapping of the value stream is Quaranta et al. (2015). According to his article, an effective quality system provides a framework in which activities are formalized, carried out with a constant concern for quality, and continuously evaluated to improve results. It is necessary to have a clearly defined organizational structure that specifies the responsibilities, competencies, and attributions of people and the identification of specific processes and procedures and their critical control points.

Kollberg et al. (2007) mention that the factors related to the second principle of Lean Thinking (map the value stream) should include mapping the process of the patient for identification of waste present in the steps of the treatment. They suggest it should be done a follow-through of the patient in every step of the process, ignoring different departments, borders, or activities and functions. However, Brandão de Souza and Pidd (2011) state that hospital organizations are usually segregated in silos (professional or functional), and this structure imposes an obstacle to the flow of patients, resources, and information.

The World Health Organization establishes as one of the principles of good management of the blood supply chain implementing quality management systems (QMS) in place, established for all functions performed by manufacturers and distributors (WHO, 2012). Transparency and accountability, according to the document, should also be ensured. As we have seen before, this resembles the fifth principle, Perfection, where transparency is a crucial tool to improvements in production. Furthermore, WHO advocates for standard operating procedures containing step-by-step instructions for all activities undertaken during product preparation, as well as specifications for the resulting blood components (WHO, 2017).

Likewise, Williamson and Devine (2013) present some ideas for applying Lean principles on the blood supply chain. Even though the expression Lean is not used, the practices resemble some of those preconized by Lean. First, the author states that individual hospital blood banks' decisions ultimately affect the entire system's ability to meet demand, so considering the whole value stream is essential to the successful balance between adequate supply and minimum wastage. In his vision, hospitals and blood providers could work together to manage inventory using return or reissue programs designed to reduce the expiration of blood products. Second, the author advocates for a line of sight on all blood inventory in the hospital, including other locations such as the emergency ward – this resembles a lot with the transparency preached by Lean. Furthermore, the article also advocates for standard protocols to minimize the so-called just-in-case ordering behavior, reducing inventories and wastages.

Therefore, it is possible to adopt Lean principles on the blood supply chain. However, it remains unsolved in the literature if the adoption of Lean practices is actually effective due to a methodological deficiency in the studies published on this theme. For Moraros et al. (2016) and Woodnutt (2018), the design of Lean studies methodologies in healthcare should be more rigorous and have some standards, so they become comparable.

2.3.1 Examples of application

In this study, it was not found any specific paper focused on Lean application in the BSC. However, there were found two examples of the application of Lean Principles in the chain. The first case is a study from a regional blood transfusion center, and the second is the Brazilian legislation for blood therapy.

The first example of this section constitutes an intervention in a regional blood center in Iran. According to Javadzadeh Shahshahani and Taghvai (2017, p. 349), the main reasons for blood wastage included "expiry date, inappropriate volume, hemolysis of red blood cells, contamination of plasma or platelets with RBCs, blood bag leakage, reactive infectious disease tests and inappropriate temperature during storage or transportation". After the intervention, PLT (platelet) wastage due to preparation decreased by 89%, and the number of plasma units discarded due to expiration or inappropriate temperature during storage or transportation was nil. The total wastage rate dropped from 5.7% to 2.1%.

The strategies they adopted for intervention had the objective of reducing wastage, and it included: i) Re-evaluation of the optimal inventory level for RBCs such that the inventory was reduced to 7 days of hospital requirement; ii) Standard Operating Procedure (SOP) was prepared for blood wastage management – a) Blood donor recruitment and blood collection were adjusted based on demand from hospitals rather than the annual increase of blood collection rate of the previous years; b) Adoption of daily monitoring of inventory to reduce blood donor recruitment and mobile teams at the time of sufficient inventory; c) Calibrated and validated equipment was used for storage of blood components – iii) Introduction of continuous education programs to improve performance of staff and reduce wastage levels; iv) Optimization of dispatching; v) Regular monitoring of blood components wastage. In cases of non-conformity, the root causes were found, and corrective actions performed if needed.

Reduced wastages post-intervention years led to saving more than eight thousand blood units collected and the production of eighteen thousand blood components units and approximately US$1.500.000. The study concludes by mentioning that establishing a centralized information system in Iran to determine the surplus of each provincial center, along with the precise needs of all centers, can lead to effective inventory management and a meaningful reduction in wastage of blood and blood components in the country.

The second example comes from the study of the Brazilian law on the blood supply chain. In the Brazilian Ministry of Health, there's the "Portaria nº 158" of February 4th, 2016. The objective of it is to redefine the technical regulation of blood therapy procedures in the country. Some of its articles resemble Lean Principles. Article 240, for example, mentions the policy and actions that assure the quality of products and services, guaranteeing that the procedures and processes occur under controlled conditions. In the actions mentioned, there are methods and tools of continuous improvement and preventive and corrective proposition processes similar to the Lean principle of Perfection. Besides, there is a level of standardization of work, prevalent in article 242: the requirements for work and task performance shall be formally documented.

The Swedish healthcare system can provide an extra example. According to (Kolberg et al. 2007), they have developed a measurement system for following up lead-times in order to deal with long waiting times and delays. It is called the "flow model," and it allows the patient's follow-up through the path on the healthcare system by focusing on measures that relate to a specific date or time in the patient care chain.

Therefore, as demonstrated in this section, systems often do not mention the explicit adoption of Lean principles but can adopt them. Especially in terms of continuous quality improvement programs, it is possible to see Lean intricated in plans and practices.

2.4 Drones

2.4.1 Drone definition

Drones are also called unmanned aerial vehicles (UAVs), Remotely Operated Aircraft (ROA), Unmanned Aircraft (UA), and Remotely Piloted Vehicle (RPV). Drones are defined as “autonomous or teleoperated flying machines that do not require constant user control” (Rabta et al., 2018). They have been used since the early 1900s, but mainly in military operations at the beginning. Only recently have drones been adopted for commercial purposes, as the delivery of goods or filming from the air. Drones may vary in their weight capacity, type of aircraft (fixed-wing, helicopter, multi-rotor), the capability of take-off, price, energy consumption, and other mechanical aspects.

It has been proved that drones can be used for the transport of blood and blood products without significantly affecting the biochemical composition of the samples (Amukele et al., 2016; Amukele et al. 2015; Thiels et al., 2015; Amukele et al., 2017a; Amukele et al., 2017b). As long as the temperature is controlled to maintain the necessary level for blood products storage, there should be no problem in this type of transportation. Drones can be used to deliver blood products, medicines, vaccines, equipment, and other medical supplies.

One challenge for the extensive adoption of drones as a source of delivery is the regulations regarding using those machines. Few countries have established rules for drones' commercial use (Poljak and Šterbenc, 2020; Prasad et al., 2019).

Drones are a cheaper way of transportation than conventional helicopters. They have lower maintenance and supervision costs and do not need an onboard pilot, making them an even safer option (Mesar et al., 2018). Prices for drones vary by several logs depending on the grade (military versus civilian) and technologic endowment (flight controller, sense-and-avoid ability, etc.) of the vehicle (Amukele et al., 2017b)

2.4.2 Possible association with Lean principles

The five lean principles, as mentioned before, are value, value stream, flow, pull, and perfection. Drones used in the delivery of blood and blood components can be related to those principles since they have several advantages, like the capability to avoid traffic and the ability to reach higher average speeds. Besides, drones are smaller than conventional, crewed helicopters, less expensive, and require significantly less human resources even when accounting for maintenance and system supervision (Mesar et al., 2018).

Drones can provide a closer to "just-in-time" delivery system (Ling and Draghic, 2019), distributing orders as demanded with a lower time gap and improving response times. This would allow blood distribution centers to operate by a "pull" methodology, dispatching orders only when required. For hospitals and clinics, this would represent the ability to ask for blood only when virtually necessary, reducing their inventories, wastage rates, and therefore reducing costs.

> "Drones enable improved response times and reduced transportation costs, particularly in remote and/or underserved environments. Conversely, the need for drones can also be true for urban areas, where congestion can be an impediment to emergency medical delivery" (Ling and Draghic, 2019, p. 1609)

In remote or underserved environments, drones can represent reduced transportation costs since there is no need for infrastructure to work. They do not need a highway to reach locations since their route is by air. Besides, there are no costs with fuel or road tolls.

In customer-oriented distribution systems, which is related to the focus on the customer's value, the central aspect relies on minimization of the waiting time of the customers to maximize their satisfaction, therefore leading to increased profit. A study conducted by Moshref-Javadi and Lee (2017) showed that the waiting time could be reduced by 58% and 38% when using three and two drones, respectively.

2.4.3 Application possibilities

Ever since the recent popularization of drones, their applications are continuously expanding. According to Rabta et al. (2018), drone applications have mainly been considered in the commercial supply chain context, focusing on cargo delivery, mapping, target covering, and surveillance. In the healthcare context, drones can be used to provision disaster assessments when other means of access are severely restricted, in the delivery of aid packages, medicines, vaccines, and blood (Scott and Scott, 2019; Kim et al., 2017), providing safe transport of disease test samples and test kits in areas with high contagion, and have the potential for providing rapid access to automated external defibrillators for patients in cardiac arrest. Another possible capability would be to help with telemedicine in distant areas.

Those applications face challenges such as national legislation, climate zones and topography, medicolegal and licensure issues, finance and reimbursement, and community attitudes and acceptance in different nations (Balasingam, 2017). Besides, the time of flight (endurance) and the distance covered (range) are the two performance parameters evaluated. UAVs' (drones) major limitations are the battery power and payload able to carry (Prasad et al., 2019).

In the vision of Pulver and Wei (2018), drones can be used to minimize response times, using a network of medical drones to provide service to large areas adequately. The right location should be chosen in order to reduce travel delays, minimize cost and maximize service coverage. It is also essential to have additional resources and facilities that can provide some level of service in disruptive situations as well. The reduction of response times fits well with the Lean philosophy, providing faster responses to upcoming demands.

Amukele et al. (2017b) suggest that until May of 2015, more than four million drones had been shipped worldwide, but only 57 of the 174 United Nations–recognized countries in the world had publicly available drone regulations. The paper analyses the different types of drones that could be used to deliver blood and blood components, comparing the multirotor with the fixed-wing models.

> “a multirotor drone that undergoes significantly less acceleration and deceleration in takeoff and landing. In addition, because multirotors can launch and land vertically, their use allows products to be dispatched closer to the blood bank and received closer to the patient. Their disadvantage however is that they are significantly range limited relative to plane-type drones and so may not be able to transport blood products over large distances”. (Amukele et al., 2017b, pp. 5)

Those issues should be considered when selecting the appropriate drone model for delivery, especially the geographical distance between places. In Rwanda, Zipline chose to use a plane-type drone to deliver blood products to hospitals in the region, reducing their wastage levels to zero.

Currently, the transportation of medical goods in times of critical need is limited to wheeled motor vehicles and crewed aircraft, options that can be costly and slow, especially when dealing with remote areas with poor road infrastructure (Thiels et al., 2015)**.** The faster drone response increases the chance of survival to 80% versus 8% for traditional emergency services (Scott and Scott, 2019).

According to Thiels et al. (2015), it is clear that distribution, not supply, remains a critical problem, which could be addressed by using drones. Furthermore, reported wastage rates still range from 1% to 26%. In the USA, the maximum wastage level indicated is 6% of demand. With the ability to deliver on time blood products, drones can decrease the need for extensive inventories at the hospitals, reducing the wastage and discard levels.

2.4.4 Comparison with other delivery methods

This section will address the study of the capabilities of drone delivery systems compared to other delivery methods, like ambulances or motorcycles. It is necessary to compare both cost and time between different distribution methods to analyze the feasibility of the use of drones in the blood supply chain.

In the study by Mesar et al. (2018), delivery time was compared to the US military standards for traversing uneven topography by foot or wheeled vehicle. It concludes that drones are feasible for the delivery of life-saving medical supplies in austere environments. They repeatedly delivered supplies faster than other methods (ambulances and by foot) without additional risk to personnel or manned airframes.

Another study that analyzes drones' use compared to other vehicles is Kim et al. (2017). In this study, a cost-benefit analysis method is developed. It reveals that besides the already mentioned possible benefits of using drones, it can also create additional benefits for patients from the receipt of care from drone centers: reduction of driving cost and copayment.

In 2017, Switzerland paved the way for drone-based specimen transport in Europe by allowing autonomous drone flights for healthcare services over cities at any time (Poljak and Šterbenc, 2020). Drone-mediated vaccine transport's economic and operational value was recently assessed using a computational model (Haidari et al., 2016). Compared to traditional land transport, drone delivery increased vaccine availability and decreased costs in all sensitivity analyses ($0.05 to $0.21 per dose administered), proving that drones are cost-effective and useful in a variety of circumstances and settings if used frequently enough to overcome the system installation and maintenance costs. Medical drones will most likely prove to be cost-effective, particularly in developing countries.

To conclude, a table is presented showing the results found in the literature about Lean principles, the challenges of the blood supply chain in Brazil, and the drone advantages.

Table 2 – Lean Principles, Challenges of the blood supply chain and drone advantages

Challenges of the blood supply chain	Drone advantages	Lean Principles
Provide sufficient supply while keeping wastage to a minimum (Rock et al., 2000)	Do not require constant user control (Rabta et al., 2018) and may vary in its weight capacity, type of aircraft (fixed-wing, helicopter, multi-rotor), the capability of take-off, price, energy consumption, and other mechanical aspects.	Value
Ability to predict the demand for blood (Contreras and Martínez, 2015)	It has been proved that drones can be used for the transport of blood and blood products without significantly affecting the biochemical composition of the samples (Amukele et al., 2016; Amukele et al. 2015; Thiels et al., 2015; Amukele et al., 2017a; Amukele et al., 2017b)	Value, Value Stream
Staying below the maximum wastage level allowed (Fortsch and Perera, 2018)	Drones are a cheaper way of transportation than conventional helicopters. They have lower maintenance and supervision costs and do not need an onboard pilot, which makes them an even safer option (Mesar et al., 2018)	Value Stream, Flow
Low level of centralization in developing countries (Osorio et al., 2018; WHO, 2017)	"Drones enable improved response times and reduced transportation costs, particularly in remote and/or underserved environments. Conversely, the need for drones can also be true for urban areas, where congestion can impede emergency medical delivery" (Ling and Draghic, 2019). A study conducted by Moshref-Javadi and Lee (2017) showed that the waiting time could be reduced by 58% and 38% when using three and two drones, respectively.	Flow, Pull

Unexpected short term changes in demand for blood components (Seifried et al., 2011)	In the healthcare context, drones can be used to provision disaster assessments when other means of access are severely restricted, in the delivery of aid packages, medicines, vaccines, and blood (Scott and Scott, 2019; Kim et al., 2017)	Value Stream, Flow, Pull
Sanitary, environmental and infrastructural risks (Brazil, 2011)	The faster drone response increases the chance of survival to 80% versus 8% for traditional emergency services (Scott and Scott, 2019)	Value, Perfection

Source: The author.

3) Methodology

3.1 Type of Research

The project consists of an exploratory, qualitative research, according to criteria suggested by Malhotra (2004). The study seeks to understand how drones and the application of Lean Philosophy can positively influence the blood supply chain. For this purpose, the approach chosen was in-depth interviews, including managers that act on the blood supply chain and an executive that works with the transport of blood products by drones.

The option to conduct in-depth interviews is based on Fitzpatrick and Boulton (1994), who define this approach as the main one to obtain data for qualitative analysis. It is defined as a flexible tool for gathering data. The aspect of being "in-depth" permits the interviewer to get more detailed information than it would be possible using, for example, from a questionnaire. The interviews conducted in this work can be classified as "semi-structured" since there is a fixed set of topics to discuss, using open-ended questions to improve freedom in responses.

3.2 Data collection and treatment

In-depth interviews were conducted with six hospital and blood center managers, chosen for their ease of access and the desire shown to participate in the research. In addition, an interview was held with the executive director from the startup "Ta na Escuta", which operates in Juiz de Fora, distributing blood bags to hospitals via drone. As it is a qualitative research, the number of respondents was not defined a priori, being adopted the saturation criterion to determine the moment to stop the interviews. Besides, according to McCracken (1988), the first principle for selecting participants is "less is more", being more important to work longer and with greater care, with a few people rather than superficially with many people. In his view, eight respondents are entirely sufficient.

A total of seven interviewees was chosen by the different backgrounds those specialists had to understand the challenges and wastages of the Brazilian blood supply chain and verify their opinion about how new technologies, and more specifically drones, can help increase efficiency in this chain.

The data collection instrument was an interview script (Appendix I), carried out from the literature review, which served as a guide for the interviewer, leaving the interviewee free to express their motivations, opinions, and beliefs about the topic under analysis. The questions were presented in a conversational tone, not necessarily following the structure of the script. Whenever possible, the interviews were recorded with the interviewee's consent to facilitate further analysis by the interviewer. If the interviewee did not feel comfortable being recorded, the researcher would note the main points that arise in the interview.

The interviews were conducted throughout the year of 2020, being recorded with the interviewees' consent. The estimated time for each interview was 40 minutes. The time, date, and place of the interview were defined according to the interviewees' availability.

Fitzpatrick and Boulton (1994) described the analysis of the interviews is performed in a few steps. After the interviews were conducted and recorded, they were transcribed into texts. The first stage of processing text is to code and classify, which was done using aiding software for visualization purposes. The next step is coding in terms of concepts and categories that may emerge. The coded material can then be transformed to be regrouped or indexed in order to facilitate the analysis. In this study, the interviews were coded based on the lean principles (Womack and Jones, 2003) and the dimensions and concepts that emerged from the reviewed literature. The last stage of analysis relies heavily on creative interpretation of evidence, "thought processes include constant comparison of evidence regarding different settings or viewpoints represented in the data and the search for deviant or contrasting observations" (Fitzpatrick and Boulton, 1994, p.111). Thus, the respondents' responses were grouped by the dimensions that emerged from the literature and crossed to find similarities and variations from the perspective of managers. This analysis was performed with the aid of *Microsoft Excel software*.

This study's ethical approval was obtained from the Ethics and Research Committee of the Federal University of Rio de Janeiro (process number 4.266.749). No interviewee will be identified, being cited, when necessary, as Interviewee 1 (I1), Interviewee 2 (I2), and so on. The data was used strictly for academic purposes, and no part of the data will be produced for any commercial activity. Data access is restricted to the researcher. Table 3 presents the profile of the interviewees.

Table 3 – Interviewees‘ background

Interviewee	Background
I1	Has been working for years at HEMORIO, the main blood center of Rio de Janeiro, especially with histocompatibility

I2	Worked on the Municipal Secretary of Health of Rio de Janeiro and posteriorly on the Ministry of Health and private service, all on hematology areas
I3	Has been working with blood since 1989, managed blood banks, assuming the national coordination of blood banks network, and currently manages HEMOSC (the main blood bank from Santa Catarina)
I4	Has been working on INCA (National Institute of Cancer) since 1985, also with hematology
I5	Has been working on INCA in the sector of blood donation for the past nine years
I6	Hematologist graduated at USP (University of São Paulo) who worked on the reference hospital Albert Einstein for eight years and currently works at a Hemocenter as a director
I7	The executive director of the startup “Tá na Escuta”, the first in Brazil to transport blood bags via drones.

Source: The author.

3.3 Research limitations

This research is subject to limitations, which should be considered, among which: (1) Subjectivity of the information collected and analyzed - the information provided derives exclusively from the respondents' perceptions and there is also the subjectivity of the interpretation of the data collected by the interviewer ; (2) Voluntary participation of respondents - according to Triolla (2008), this procedure can introduce a bias in the selection of respondents and consequently in the information collected; (3) Way of conducting the interviews - to facilitate the participation of the interviewees, and in view of Covid19, the interviews will be conducted online, using the Zoom software, which can introduce a bias due to the oscillation of the internet signal and the fact that the interviewer is not in the same environment as the interviewee; and (4) Not possible to generalize the results - given the qualitative scope of the research, the results found in this research cannot be generalized.

4) Results and Analysis

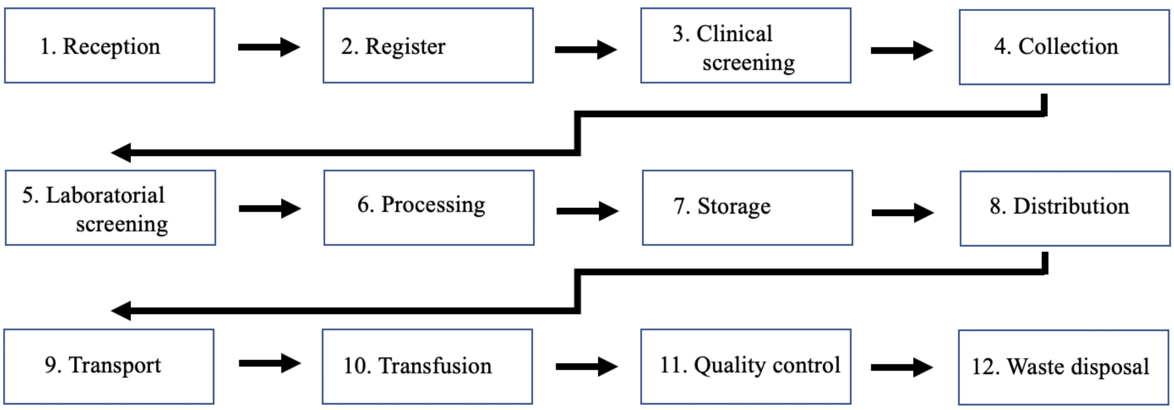
In this section, the results will be presented according to the research questions explicit in this work. In the first part, it will be analyzed the results related to the blood supply chain. In the following part, it will be analyzed the challenges in the blood supply chain. Following that, results are presented related to the wastes present in the chain, and lastly, results are presented linking how lean and drones can help in the blood supply chain.

a. The blood supply chain

All interviewees agreed on the fundamental importance of blood, mentioning that there are no substitutes for platelets and red blood cells. It is hard to find a replacement for the primary function of oxygen transport. The main usage of blood is related to chronic diseases like hemophilia, transfusions in trauma patients, viabilization of surgeries, and some specific treatments like chemotherapy. This is following what was seen in the literature review (World Health Organization - WHO, 2017), and it was mentioned in one of the interviews that "blood is everyone's right".

All the interviewees described the process of blood collection to blood transfusion quite similarly, in accordance with what emerged from the literature review (WHO, 2017). The steps are highly standardized and comprise interviewing, collection, fractionation, testing, labeling, quality control, etc. A figure of the blood supply chain stages can make it easier to see all the Brazilian chain steps. This is provided in Figure 1.

Figure 1 – The Brazilian Blood Supply Chain



Source: The author.

During the interview with I6, it emerged that his institution (Hemocenter) has interactions with clients (like hospitals and patients), with commercial partners (who supply medical equipment, materials, blood bags, and other supplies), and with the medical and nursing teams. Those complete the three critical points of interface. It also emerged from interviewee 3 that the blood centers have strong interactions with regulatory agencies like ANVISA that can enhance their quality indicators.

The collected blood is kept under a “quarantine” until their samples are tested for infectious diseases that are most risky to patients, such as Chagas disease, hepatitis B and C, syphilis, HTLV-1 (human T-cell lymphotropic virus type 1), and HIV (human immunodeficiency virus) and ABO typing is completed. ABO typing involves identifying ABO antigens on red blood cells and identifying ABO antibodies in the plasma. This is following what is seen in Maeng et al. (2018) 's research, who presents a table with the blood types, antigens produced, and antibodies produced. It usually takes about 24 hours to get all the information needed. The next phase is labeling the blood bag and addressing it to transfusion services if everything is ok.

Interviewee 5 mentions that the main objective of the first screening (and posterior screenings as well) is to minimize the risk to patients who will need a blood transfusion. In this step, a questionnaire is applied to the potential donor in order to try to identify the possible risks of that donation. According to Maeng et al. (2018), this process maximizes the likelihood of usable samples and minimizes the number of unusable collections. Even if the laboratory tests do not show one of the infectious diseases analyzed, there are still some diseases that they don’t do the specific tests because if there were a profound test of all possible illnesses, it would get cost prohibitive since it would become too expensive to test the samples. Instead, in this questionnaire, they try to reduce risks with specific questions such as if the potential donor has traveled to a region of endemic diseases such as malaria. If the answer is positive, it is recommended that the donor waits more time to donate blood.

In addition to preserving the health of the patient who will receive a blood transfusion, blood centers also care about the donor's health. Interviewee 5 mentions that the donor arrives in good health conditions and should exit the process in the same way. If in the initial screening phase, it is perceived that donating blood can represent a potential risk for the donor (for example, if the donor is anemic or underweight), they do not proceed with the donation in order to protect this donor of potential health damages.

It emerged in different interviews that, in blood banks, the process of predicting the demand for blood and therefore planning the collection relies heavily on the use of historical data and correction according to perceived variances in need for blood. This matches exactly what was identified in the literature (Williamson and Devine, 2013; Osorio et al., 2015; Stanger et al., 2012).

b. Challenges on blood supply chain

A difficulty that emerged during the interviews is the transports' ability to keep the proper temperature for the conservation of the blood components. One of the main issues with waste in the blood supply chain happens when during transportation, the appropriate temperature cannot be kept, compromising the blood bags' safety and therefore incurring in the discard. Interviewee 2 mentioned that sometimes HemoRio sends blood bags that take around two to three hours to arrive due to traffic.

For interviewee 3, the Universal Healthcare System in Brazil (SUS) is highly decentralized, with a philosophy based on municipalization and decentralized decision making. However, this creates an asymmetry between cities since the interviewee observes high differences related to quality, commitment, and efficiency. The management system, in his view, is ineffective. There is a geographical distribution of resources that focus more on the South of Brazil, which is currently more developed than other regions that would need much more resources. As mentioned in the literature review, having a more centralized system can improve the blood supply chain (Osorio et al., 2018; WHO, 2017).

The difficulties that emerged in the blood supply chain can be classified in the chain's different steps. The first, collection, still faces a challenge in Brazil regarding the number of donors, as cited by some interviewees. Once again, it appeared in the data from the literature review that WHO recommends that at least 3% (WHO, 2017) of the population should be donors, and Brazil does not even reach 2%. There is a need to find new strategies to reach the donors, and some initiatives include the mobile collection units or the creation of small collection centers in more distant cities.

A second difficulty that emerges is in the distribution phase when the temperature must be kept appropriate to conserve blood and blood components (which, as was mentioned before, have different needs of temperature). It is often a stage where the temperature gets compromised, and therefore the shelf life is damaged as well. Interviewee 7 mentioned that an innovation in the transport of blood components through drones is a thermal automatized box that guarantees the proper temperature to be kept during the entire trip. I2 mentions that blood bags' improper storage is the second main reason for discards, being the first serology.

Interviewee 2 also brought an interesting perspective on the public healthcare service in Brazil. While in their blood bank they would do preventive maintenance of equipment, many hospitals, in fact, did not have a contract for maintenance of equipment because they consider it too expensive, having higher depreciation rates.

It has been brought to attention from interviewee 1 that even though the regulations in place say that it is the Hemocenter responsibility to deal with the transport and distribution of blood, in Rio de Janeiro, it does not apply in reality. In many cases, the hospital gets the responsibility to pick up the blood at HemoRio. HemoRio only sends blood and its components to its own transfusion agencies.

Interviewee 2 affirms that it would be mandatory to improve the transportation system for the blood supply chain if possible. It is mentioned that transportation relies much on the traffic, the path traveled, availability of car/motorcycle, and that when there is urgency, it can get harder to deliver blood components on time properly.

It was also identified a need for the congruence between the institution targets and planning the blood stocks. For example, imagine a reform in the surgical center that would increase surgeries capacity. It would also be necessary to plan your blood stock because more surgeries represent more demand for blood. So those objectives should be aligned in order to prevent any type of shortage.

c. Wastes in the chain

In one of the National Institute of Cancer (INCA) interviews, it emerged that blood collection centers have to send their samples for biomolecular testing to a central testing laboratory in the state. This procedure enables financial gains due to the scalability, but this also represents a bottleneck since the institutions must wait at least one day for the analysis results. This waiting time represents an increased risk because if this central laboratory delays the delivery of results, it can affect all institutions' whole transfusion process that depends on this laboratory. They don’t have the autonomy to perform this test by themselves.

Furthermore, the main reasons related to the disposal of blood bags were expiration date, that is, the blood bag would not have been used within its limited amount of time of shelf life. According to Williamsom and Devine (2013), expiration rates of plasma concentrate in countries with a 5-day shelf life can reach 25%. From the interviews, it emerged that this happens mostly with blood bags from rare blood types that were not enough demand for them and for platelets, that have a lower shelf life. In addition, discard happens when there are issues with compromised temperatures during transportation and storage stages. Besides, one of the main reasons for disposal of blood bags is also related to the testing phase. If a blood sample turns out to be positive for one of the forbidden diseases, it has to be discarded to ensure the safety of the patient.

Interviewee 6 mentions that every collection is centralized. Few hospitals have their own blood bank. After, blood is distributed to be fractionated and transfused. The logistics are fundamental in this process in order to reach those hospitals and fulfill demand. It is essential to have a safe transportation net that can guarantee the preservation of the necessary temperatures to conservation each blood component. Otherwise, it can compromise the shelf life of the product and lead to its disposal.

According to interviewee 6, there is an indicator that measures the collection efficiency, that is, how much is lost in blood bags that are not used for transfusions. For him, the hardest part is getting the donor to donate the blood, once it is collected, everything that is not used can be considered a waste of the supply chain.

The first bottleneck is at the screening phase. This usually happens when the donor arrives but finds out that due to a weight restriction, or a restriction regarding the use of medicaments he/she takes, it is not possible for him/her to donate blood. This is called a clinical disability or inaptitude. Next, there are losses in the collection process, where the blood donor can have some issues like feeling sick or not being able to get venous access, leading to not completing the donation, and therefore, waste. The third bottleneck is in the fractioning stage, where the full blood bag is subdivided into different components. Waste can happen for several reasons, including mechanical issues such as the rupture of a blood bag or a system opening/leakage, visual issues of the blood bag, like lipaemia (the presence in the blood of an abnormally high concentration of emulsified fat) and last, serological factors, like a positive test for an infectious disease. The last bottleneck relies on the transfusion agency, and waste can happen due to the end of shelf life in storage, system leakage, and improper conditioning.

Overall, interviewees had a favorable view of bureaucracy since it enhanced the security of the blood supply chain processes and, therefore, the patients' safety. There is an explicit tradeoff between responsiveness (response time) and security, which is ideal to find a balance between them. However, it was mentioned that in emergencies, exceptions to the protocols might arise, and after the occurrence, it is evaluated whether the situation was controlled in the best possible way and if there are opportunities for improvement in the established processes.

The higher idleness time is perceived to happen in two phases: during the serological exams, which consumes at least 12h while that blood bag is waiting for the results to be cleared, and in the transportation phase, where the blood bag awaits in transit to other location.

d. Lean philosophy and drones help in the blood supply chain

Going back to the Lean principles, as presented before in this research, those are Value, Value Stream, Flow, Pull, and Perfection (Womack and Jones, 2003). This session will analyze whether the Lean principles can be related to insights gotten from the interviews conducted.

An interesting point brought to attention by interviewee 2 is that the sanitary authority inspections were an important element to improve institutional quality. With the inspection reports, it was possible to reach out to the board to take initiatives to correct issues and perfect quality.

Another way that institutions that work with blood have to perfect their quality is blood regulation in Brazil. There is a total quality system installed that englobes internal controls, qualification, education, and continuous training. There is a specific team in interviewee number 1 institution dedicated to quality management and control. Other interviewees that worked with blood banks confirmed they also had internal and external controls for quality management. For example, interviewee 3 works in a blood bank that is qualified as ISO 9001 since 1998 and has a specific quality team that runs internal and external audits three times a year.

Interviewee 7 commented about the relationships his company has with a specific hospital and a blood bank. They are financing the project, and those institutions are contributing with transportation and temperature standards and having employees available to learn about the logistics of blood components delivery through drones. There are built platforms for the operation of the drone in each institution. This is a good path to have Flow in the supply chain and reduce inventory.

The necessary process in the blood chain is highly documented and standardized. The standardization is reinforced through training for the employees that work with blood. There are regulations that say what is necessary to do in each step of the process, what is allowed and what is not. More than one interviewee mentioned this. This high standardization matches with Lean principles as well, since one of the recommendations relates exactly to standardized processes (Womack and Jones, 2003). Interviewee 2 mentioned that to work in a blood bank, it is necessary to like protocols, flow, paperwork, bureaucracy because everything is highly documented, including conditions of transportation. Interviewee 7 mentions that the company's main differential is the speed of communication (which could be associated with "Flow") and processes formalization, that is, standardization.

Interviewees mentioned their control IT systems, which would record all the steps being performed, monitor everything all the time. For example, it is possible to see in-stock how many blood bags are available of a specific blood type. It is possible to see how many transfusions there were in a day, knowing how the stock of blood was affected and therefore helping in the planning of collection of new blood bags. It is also possible to see the amount of discard of blood bags by their leading causes. This helps to track the entire production process, increasing the steps' visibility, matching again with Lean principles (Womack and Jones, 2003).

Another point of visibility in the supply chain emerged during the interview with interviewee 6. There are internal auditing committees that go through all the indicators of the blood bank's performance and share that information with both the clients (like hospitals) and regulation agencies (like ANVISA – in this case, it is mandatory to notify monthly those indicators).

It emerged during the interview with interviewee 5 that drone technology for the transport of blood bags is quite advanced, however, the legislation in Brazil is still outdated concerning this topic, so this becomes an obstacle to the use of drones in operation. It still has to face a lot of bureaucracy in order to get permission to operate since the regulations are not up to date. This was also seen in the literature review as a possible challenge to drones' use (Poljak and Šterbenc, 2020; Prasad et al., 2019).

Some interviewees mentioned the need to consider the contingencies of drone usage, even though there were several advantages mentioned. For example, in the case of climate events with heavy rain, would the drone be able to operate under such challenging conditions? It would possibly be necessary to have a contingency plan.

Interviewee 7 also mentioned that the main challenges in delivering blood rely on time and temperature. Time because the blood out of storage is already in improper conditions, so the less time the blood bag spends outside, the better. And temperature because, as mentioned before, components need different temperatures in order to be preserved. In his vision, drones have the advantage of not facing traffic and floods, and they are a faster way of delivery, which adds reliability to the product being delivered and increased quality. His company is currently testing bigger drones that can fly at a higher speed and carry more payload. He also believes that drone use will expand quickly not only in Brazil but in the whole world as a safer and faster option.

To conclude, a table is presented to summarize the findings from this research. It relates the blood supply chain main challenges, the drone advantages, and lean principles. This allow the reader to have a better view of how it all links together.

Table 4 - Benefits of applying drone technology in the Brazilian BSC and the lean principles

BSC challenges	Drones advantage	Lean Principle
In the screening and collecting stage: ***From literature and field research:*** *- To predict the demand for blood (Seifried et al., 2011; Stanger et al., 2012 Williamson and Devine, 2013; Osorio et al., 2015; Contreras and Martínez, 2015; Amukele et al., 2017; Mansur et al., 2018).* *- To provide sufficient supply while keeping wastage to a minimum (Marques et al., 2020).* *- To be prepared to face events that can affect Brazil's BSC stability, like epidemics, floods, disasters, etc. (Brazil, 2011).* *- To increase the amount of collected blood - WHO recommends a rate of 3% of the population as blood donors; in Brazil, this rate barely reaches 2% (ANVISA, 2018).* ***From interviews:*** *- In Brazil, blood collection centers have to send their samples for biomolecular testing to a state's central testing laboratory. It usually takes about 24 hours to get all the information needed.*	***Filed research contributions:*** *Drones can help to adjust faster do the demand variation:* Drones can increase the collecting stage's flexibility since it can reach distant places to collect blood and deliver it where needed faster. *Drones could help face unexpected situations*, like a COVID pandemic, delivering blood in a faster way. *Drones could help reduce the time to get testing results:* They could transport test samples from the blood center to the laboratory faster, avoiding traffic and natural events such as floods. *Drones could help increase the donor base reaching remote and distant places to get potential donors, increasing the quantity of blood bags.*	Value; Flow; Pull production

- *Due to the great geographic distances in Brazil, there is a need to find new strategies to reach donors. Some initiatives include the mobile collection units or the creation of small collection centers in more distant cities.*		
In the distribution stage: ***From literature and interviews:*** To distribute the collected blood to the transfusion centers on time, considering distances, accidents, and traffic. To reduce wastages due to inventories and spoilage. To deliver blood on time when an emergency occurs (Stanger et al., 2012; Osorio et al., 2015; Mansur et al., 2018; Sabharwal and Ülkü, 2018). To guarantee the right temperatures for the conservation of each blood component (Thiels et al., 2015). To maintain blood bag exposure to inappropriate conditions as low as possible (SINAVAN, 2001)	***From literature:*** Drones can transport blood products without significantly affecting their biochemical properties (Thiels et al., 2015; Amukele et al., 2017). Drones improve response times and reduce transportation costs, particularly in remote and underserved environments (Ling and Draghic, 2019). Drones can provide closer to a "just-in-time" delivery system (Ling and Draghic, 2019), distributing orders as demanded with a lower time gap and improving response times. (Scott and Scott,2019). ***Filed research contributions:*** *Drones could reduce transportation time to send blood bags to the transfusion centers:* They could reach remote and distant places faster, avoiding traffic and natural events such as floods. *Drones could help reduce discard due to shelf life and could reduce inventories to face demand variation:* They could transport the collected blood faster, reducing discard due to expiration date and allowing for the reduction of stocks. *Drones could easily maintain the right temperature using a cool box.* *Drones could deliver blood faster, reducing blood exposure to*	Value; Value steam; Flow; Pull production; Perfection.

	unacceptable conditions, increasing its reliability, and preserving its quality.	

Source: The author.

5) Conclusion

This research was elaborated on three specific objectives in order to understand how Lean philosophy and drone technology can improve the blood supply chain. Those objectives were (1) to map the blood supply chain in Brazil, (2) to identify the main challenges and wastages of the blood supply chain in Brazil, and (3) to investigate how drones can help the blood supply chain reduce wastages

The Brazilian blood supply chain is well established by national regulations, having the specific phases and processes deeply documented and described. There are regulatory agencies, like ANVISA, that, as emerged in the interviews, help improve the quality of the blood services through their supervision. According to the literature, distribution, not supply, remained a critical problem in the BSC. However, what emerged from the interviews was that there is still an issue with getting the proper donor base in Brazil. While WHO recommends a rate of 3% (ANVISA, 2018) of the population as blood donors, this rate barely reaches 2% in Brazil.

The main challenges in the Brazilian blood supply chain relate to providing sufficient supply while keeping wastage to a minimum, the ability to predict the demand for blood, staying bellow the maximum wastage level allowed, increasing centralization of blood supply systems, dealing with unexpected short-term changes in demand for blood components, especially with an aging population, and dealing with sanitary, environmental and infrastructure risks. The results of this study indicate that drones can reduce response times and transportation costs. In addition, drones do not need an onboard pilot, which makes them a safer option. Besides, the faster drone response increases the chance of survival to 80% versus 8% for traditional emergency services (Scott and Scott, 2018).

The wastes (things that do not add value to the product) related to the blood supply chain were identified mainly due to reasons such as when during the transportation the proper temperature cannot be kept, compromising the blood bags' safety incurring in the discard. In addition, many hospitals, in fact, did not have a contract for maintenance of equipment because they consider it too expensive, having higher depreciation rates for their equipment. Furthermore, biomolecular testing also represents a bottleneck when it is centralized in one particular laboratory. The exposure to risks increases, and the test's waiting time also increases, although the costs do get lower due to economies of scale.

The use of drones can represent gains in delivery time, allowing for more like a "just-in-time" model of distribution of blood. In this way, it would be possible to pull demand directly from the hospitals or transfusion agencies as they needed blood and blood components and, therefore, it could lead to a reduction in stocks and costs. Drones allow reaching isolated areas or places with disrupted infrastructure. It also allows avoiding traffic, a problem of many big cities. If the regulations are adjusted to comprehend the use of drones for commercial purposes, their use can be spread to different locations.

This study has a few limitations, as previously mentioned, among which are the subjectivity of the information collected and analyzed, the voluntary participation of respondents, the way of conducting interviews (via telephone or Zoom software), and the generalization of results are limited, due to the qualitative scope of the research. However, the study can also bring several contributions, such as fulfilling a gap in the literature, analyzing how drones can help reduce waste in the supply chain of blood associated with the Lean principles of management. In the field of practical contribution, this research helps understand how drones can help in the delivery of blood in the right place, right time, increasing the chances of saving lives, especially of patients, victims of traumas. The study is a guide about the main challenges regarding this application and the main benefits that may be obtained with its usage. For society, this study can represent suggestions for improving the blood supply chain and its response time, increasing chances of survival in events like traumas. This would mean a gain to the whole healthcare sector.

As this is a qualitative research, a venue for future research is establishing a quantitative analysis about the results obtained in this study. It would also be interesting to analyze the risks included in the Brazilian blood supply chain in more in-depth detail, such as the sanitary, environmental, and infrastructure risks. A third possible venue for research is a more technical analysis of drones' capacity in terms of weight to carry. This would be helpful to establish a maximum threshold for the transport of blood products by each drone. A final future research suggestion would be, based on the interviews, to investigate the relationship among regulatory agencies and blood banks, to see the synergies and challenges between each other.

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Appendix I – Interview Scripts

ROTEIRO DE ENTREVISTA – BLOOD SUPPLY CHAIN

1) Do seu ponto de vista, qual é a importância do sangue e seus subprodutos para a sociedade?

2) Qual é o seu papel na cadeia do sangue? Qual o papel da instituição em que você trabalha?

3) Quais são os principais desafios na cadeia de abastecimento de sangue no Brasil?

4) O que você identifica como uma possível oportunidade de melhoria da cadeia de sangue no Brasil?

5) Quais foram as últimas inovações na cadeia de sangue com as quais você teve contato?

6) Com que outras instituições ou agentes da cadeia do sangue sua instituição interage?

7) Quais são as etapas de produção da cadeia do sangue no Brasil?

8) Quais os principais pontos de desperdício que você identifica na cadeia do sangue?

9) Como você acha que poderiam ser solucionados esses desperdícios?

10) Como sua instituição gera valor na cadeia do sangue?

11) Qual a metodologia adotada para prever o nível adequado de coletas de sangue?

12) Existe alguma ferramenta que facilite esta tarefa?

13) Existe um programa de melhoria contínua da qualidade?

14) Existem protocolos que padronizam o trabalho com o sangue?

15) Qual é o nível de transparência, isto é, visibilidade dos processos e dados, na cadeia de produção do sangue?

16) Como é definida a política de gestão do sangue, isto é, decisões de quanto demandar, quanto estocar, como priorizar atendimentos, etc?

17) Há algum entrave burocrático na gestão do sangue?

18) Há muito tempo de ócio na cadeia produtiva do sangue? Em quais etapas?

19) Quais são os agentes mais importantes, na sua visão, na cadeia nacional do sangue?

20) Qual o nível de interação com outras instituições relacionadas ao sangue? Quais são as principais trocas?

21) Quais são os principais motivos para descarte de sangue?

22) Como garantir que a produção de sangue seja adequada à demanda por sangue?

23) Há algum comentário final que deseje fazer sobre a cadeia do sangue?

ROTEIRO DE ENTREVISTA – DRONES

1) Do seu ponto de vista, qual é a importância do sangue e seus subprodutos para a sociedade?

2) O que é um drone? Como sua empresa faz uso dele? Qual o tipo de drone usado e quantas viagens por mês são feitas?

3) Qual é o principal valor gerado por sua empresa, isto é, o que você produz que considera que agrega valor aos seus consumidores? Quem é beneficiado por isso?

4) Quais são as principais aplicações de um drone, isto é, como ele pode ser usado e com quais finalidades? Quais são suas vantagens?

5) Quais são as principais dificuldades de usar o drone no Brasil?

6) Como o drone influencia na cadeia de sangue? Há possibilidade de uso em larga escala?

7) Com quais instituições do sangue sua empresa se relaciona?

8) Como se dão as interações com outras instituições relacionadas ao sangue?

9) Quais são os principais empecilhos na distribuição de sangue? Como o uso de drones pode ajudar a resolvê-los?

10) Você enxerga outras inovações que possam ajudar na cadeia do sangue?

11) Existe um programa de melhoria contínua da qualidade em sua empresa?

12) Como o uso de drones poderia ser facilitado no Brasil?

13) Há alguma área da cadeia de sangue na qual o drone poderia atuar, mas ainda não atua? Por que não atua ainda?

14) Há algum empecilho na adoção do uso de drones na distribuição de sangue por parte de outras instituições?

15) Você identifica alguma etapa da cadeia do sangue em que haja desperdício? Qual?

16) Como é definido o número adequado de estoque de sangue?

17) Com que frequência as instituições solicitam sangue? Como isso afeta os estoques delas?

18) Existe uma política de prioridade na distribuição do sangue?

19) Existe transparência, isto é, visibilidade dos processos e dados, na cadeia do sangue? Como?

20) Como você melhoraria a cadeia do sangue se fosse possível?

21) Qual é o maior empecilho para expandir suas atividades?

22) Há algum comentário final que deseje fazer sobre a cadeia do sangue ou sobre o uso de drones?