

# Managing shortages of products in the Dutch healthcare sector: a typology

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## ABSTRACT

*This thesis investigates the issue of product shortages in the Dutch healthcare sector, specifically within hospitals, and proposes a typology to manage these shortages effectively. It will start highlighting the impact of increasing global wealth and the adoption of just-in-time (JIT) manufacturing, which, exacerbated by the COVID-19 pandemic, has led to widespread shortages affecting various sectors, including healthcare. The cascading effects of these shortages, particularly in critical sectors like healthcare, underscore the importance of addressing supply chain disruptions to ensure the timely treatment of patients and the economic stability of healthcare systems. Subsequently, it delves into the definition and economics of shortages, exploring supply and demand dynamics and the concept of market equilibrium. It examines the risks associated with global supply chains and the specific challenges faced by the healthcare sector, including regulatory issues and the unique vulnerabilities of hospitals as major procurement entities. The review also covers existing policies and organizational responses to shortages, highlighting the need for robust healthcare policies to mitigate these disruptions. The methodology combines qualitative desk research with expert input gathered through semi-structured interviews. The desk research involves a comprehensive review of academic articles, policy documents, and secondary sources to propose a typology for managing shortages. Expert interviews with procurement professionals within and outside the healthcare industry provide practical insights to refine the typology, ensuring its applicability in real-world scenarios. The results present detailed analyses of shortages across three product categories: medicines, personal protective equipment (PPE), and diagnostics (equipment). It identifies the underlying factors causing these shortages, the responses of procurement professionals to these shortages. The proposed typology integrates these findings, offering a structured approach for procurement experts to address shortages effectively. It emphasizes the role of government intervention, collaboration with stakeholders, and the preferred customer principle in securing essential supplies. The typology also considers variations in shortages and responses across different healthcare departments, such as cardiology, oncology, and surgery. The thesis underscores the critical role of procurement in managing healthcare shortages and presents a comprehensive typology that can serve as a framework for professionals. The implications of this research extend beyond the healthcare sector, offering insights into supply chain management practices that can enhance resilience and responsiveness in times of crisis. Future research should explore the application of this typology in different contexts, evaluate its effectiveness in mitigating shortages across various sectors, and investigate the long-term impacts of such strategies on overall supply chain resilience and efficiency.*

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# 1. INTRODUCTION

Decreasing poverty, increasing health and increasing average human life expectancy led to increasing wealth across the world (Ortiz-Ospina & Roser, 2024). Increasing wealth led to increased competition, which meant companies had to look for minor innovations within operations. An example of such a minor improvement is just-in-time manufacturing (JIT), which involves having the right items of the right quality and quantity in the right place at the right time (White & Prybutok, 2001). JIT has resulted in increases in quality, productivity and efficiency, improved communication and decreases in costs and wastes (Cheng & Podolsky, 1996). However, in recent years the philosophy of JIT amongst others, in combination with disruption caused by the COVID-19-pandemic, has led to global shortages of many goods in many different economic sectors (Goodman & Chokshi, 2021). A big problem of a shortage is the cascading effect it creates. This cascading effect can be described as a shortage of a good needed for manufacturing a product leading to a delay in creating this product, which leads to unavailability of the product for customers, which delays this customer's operations etc. i.e. a shortage of a single manufacturing material can lead to disruption of a whole supply chain (Goodman & Chokshi, 2021). This process can be exacerbated by the existence of global supply chains in recent years, with increasing lead times as a result (Woxenius, 2007). Increased dispersion of the supply base across national boundaries leads to bigger uncertainties in receiving the right items at the right quality and quantity in the right place at the right time, for example through increased lead times (Woxenius, 2007). These issues create a bigger potential for shortages to exist, while on the other hand it must be stated that global supply chains also offer solutions to shortages, as global shortages in PPE during the COVID-19-pandemic could only be tackled in a relatively short timeframe by the scale of these global supply chains (Panwar et al., 2022).

Shortages exist in many different product categories and sectors, however shortages and supply chain disruptions have an especially dangerous effect in the healthcare sector. That is, because the healthcare sector deals with ill people, who need to receive treatment in order to become healthy or feel better. This treatment should be received in due time, as illnesses might progress in the meantime. If the supply chain gets disrupted in any shape or form, this directly impacts the customers of the healthcare sector, which are the patients, through both the lack of drugs or the inferiority of alternatives (Fox et al., 2014). Apart from the importance due to the type of customer in this sector, the healthcare sector is also a large cost factor, as almost 11% of total GDP in the world was spent on health (Worldbank, 2023). Supply chain disruption in the healthcare sector can thus have a large impact on countries' economies as a whole as well, as indicated through the large proportion of GDP being spent on health (Worldbank, 2023).

As the healthcare sector is such a large sector, to scope this research, not all healthcare institutions are analysed, as this creates a research which may be too broad. As a result, institutions such as general practitioners, physiotherapy centres, nursing homes, etc., are not included, which limits this study in only analysing hospitals. This scoping ensures that the proposed typology can be applied to hospitals in a detailed and specific manner. Hospitals are chosen as the analysed healthcare institution, as hospitals amount to a very substantial part of total procurement costs of a country. For example, in the Netherlands in 2019, the total amount spent on healthcare was 80.9 billion euros (CBS, 2023). Total procurement costs for hospitals in 2019 in the Netherlands were 11 billion euros (Lippolis & Lankhorst, 2019), proving the substantial impact of hospitals on the total healthcare sector. Before describing potential forms of shortages in the healthcare sector, across product category or cause of shortage, the health

system of a hospital will be outlined in more detail, as supply chain disruptions in the healthcare sector can only be understood when the health system and supply chain itself are apparent.

The health system consists of multiple independent agents, such as insurance companies, hospitals, doctors, employers, and regulatory agencies, whose economic structures, and hence objectives, differ and in many cases conflict with each other. Both supply and demand for services are uncertain in different ways, making it very difficult to match supply to demand. This task is complicated because demand for services is determined by both available technology (i.e., available treatments) and financial considerations, such as whether or not certain treatments are covered by insurance (Uzsoy, 2005). A schematically created health system, specific to a hospital is added below as ‘Figure 1’, based on the description provided by (Uzsoy, 2005). This figure contains some of the most important actors in the health system of a hospital, however it might fluctuate between hospitals, as differences might exist in the specific layout of health systems specific to hospitals.

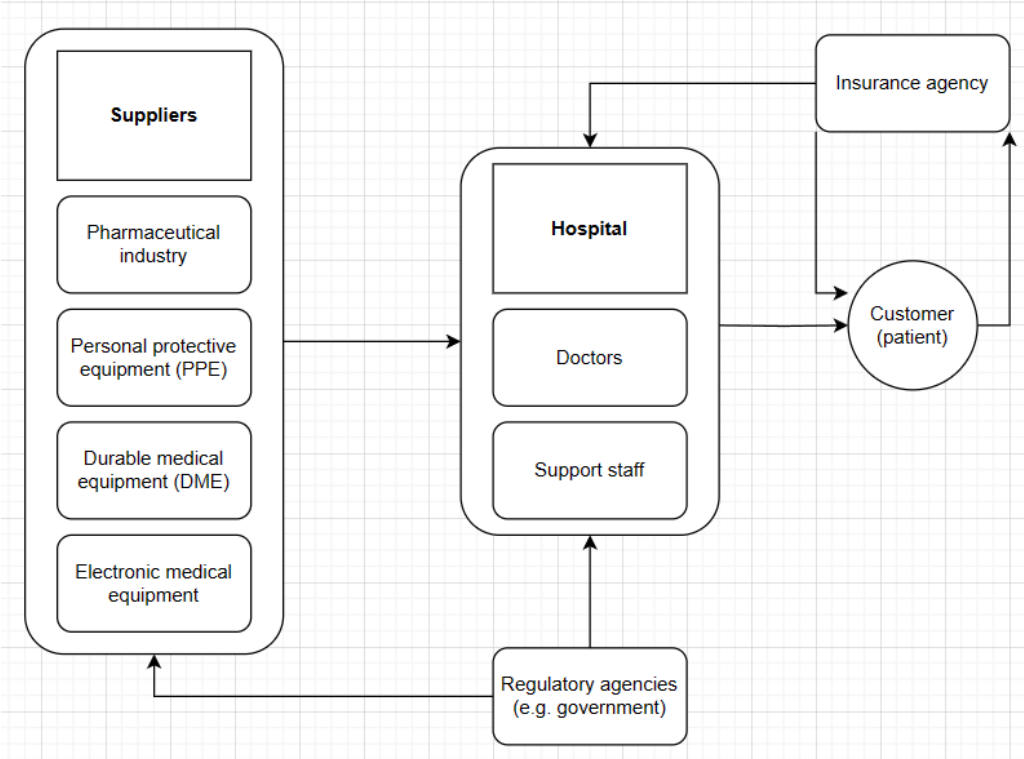


Figure 1: Simplified display of a supply chain of a hospital

Main supply chain disruptions are in the supplier-buyer relationship, or in the health system specifically between suppliers (e.g. pharmaceutical industry, personal protective equipment manufacturers) and the hospital (buyer). Within this health system, three different product categories are analysed in this research. That is to further scope this research, excluding e.g. services and shortages in staff. Three main product categories have been established, as these categories oftentimes have to deal with shortages. These categories are medicines / drugs, personal protective equipment (PPE) and diagnostics (equipment) and these categories will be explained in more detail further in this research. To schematically portray these categories within the health system, known to having to deal with shortages, figure 2 is provided below.

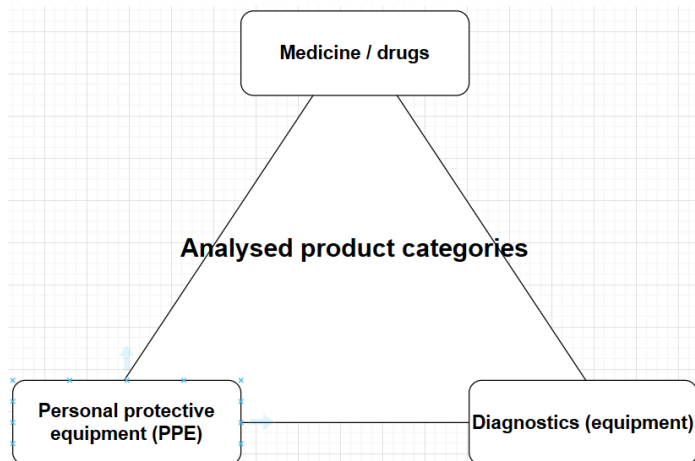


Figure 2: Product categories analysed in this thesis

The procurement department within a hospital is concerned with purchasing medicine, PPE and diagnostics equipment, i.e. all categories analysed within this research. The money spent on buying medicine is a large part of total money spent within healthcare, as 40 to 60 percent of total public sector health budget of any country is spent on buying medicine (Iqbal et al., 2017). Moreover, problems in the procurement process can also contribute to medicine shortages (Modisakeng et al., 2020), for example through inaccuracy of systems and suppliers not performing. Following this logic, procurement plays an important role in addressing medicine shortages. Similar to JIT, procuring of medicines in an effective way leads to the right drugs being in the right place, in the right quantities, at the right time, for the right patient at a reasonable price. Procurement is as a result an important part of efficient drug management and supply (Ombaka, 2009). PPE also is purchased by hospitals, both individually or by being part of hospital purchasing groups. Normally PPE would be a stable product category regarding shortages, with stable supply and demand. Global events such as COVID-19, however, could disrupt this equilibrium though. As PPE is mostly outsourced, leading to a global sourcing system, any disruptions can lead the whole health system to suffer (Verschueren & Blome, 2020). This global system is in place, because outsourcing generally leads to cost advantages. Increased difficulties with logistics and production lead to decreased availability of PPE, or in other words, shortages. Governments are analysing potential mistakes leading to shortages in PPE during the pandemic and making improvements to ensure a better procurement process (Verschueren & Blome, 2020). In other words, procurement plays a large role in PPE (shortages) as well. Lastly, hospitals and hospital purchasing groups are also concerned with procuring diagnostics equipment and diagnostic materials. For example, within the UK 338 million pounds of a total of 1513 million pounds spent on consumables is spent on diagnostics (capital medical equipment) (Skipworth et al., 2020). Potential shortages within this product category are as a result also dealt with by procurement professionals.

On top of different kinds of shortages and different solutions across different products categories, differences might also exist between departments within healthcare. For example, dealing with a shortage of a medicine in the cardiology department might be quite similar compared to dealing with a shortage of a medicine in the neurology department, while shortage of a medicine in the first aid department might completely different due to the urgency involved. Besides differences in dealing with shortages across departments, differences in shortages itself across departments will also be looked at. As an example, some kinds of shortages might be more apparent in a specific department. A good example of this would be that diagnostics equipment is especially needed within the radiology department of a hospital, while personal protective equipment might be more useful within the first aid department and surgery

department. Different necessities might lead to different kinds of shortages, which might lead to different ways to deal with shortages.

Linking the importance of procurement on dealing with shortages as well as increasing shortages in several parts of the healthcare sector in itself, the following research question has been established:

**~ What strategies could buyers adopt to tackle shortages in the healthcare sector? ~**

To analyse the research question, it can be divided into four sub questions:

**SQ 1 ~ What are underlying factors that cause shortages in the healthcare sector? ~**

**SQ 2 ~ What are the impacts of shortages in the healthcare sector? ~**

**SQ 3 ~ What are responses of buyers to shortages in the healthcare sector? ~**

**SQ 4 ~ How do factors and responses vary within healthcare? ~**

These sub questions will help answer the research question, because every single sub question is able to answer a part of the research question, merged together leading to a complete overview. Causes of shortages will be analysed, as well as impacts of these shortages and responses of the buyers within the hospitals to these specific shortages. Furthermore, differences within these causes and responses per specific department within healthcare. Together these sub questions will be able to paint a picture of generic strategies for procurement experts to tackle shortages in the healthcare sector.

Various research has been conducted on shortages in the healthcare sector and shortages in hospitals, both in academic literature and in secondary literature, however a typology proposing generic strategies to deal with shortages independent of product categories or cause of shortage is a subject on which no literature is found. Most research addresses a single case, for example the shortage of PPE during COVID-19 and effects of this shortage on surgeons (Jessop et al., 2020) or the shortage of PPE during COVID-19 and the effect of this shortage on healthcare staff in the UK (Oliver, 2021). These kinds of COVID-19-related analyses of situations make up most of the literature present on shortages in healthcare, as COVID-19 created high amounts of shortages. As a result a large amount of articles analysing these shortages can be found. A conceptual contribution to existing literature is thus the typology proposed within this research. In this typology an overview of what is found across large amounts of literature is presented, to gain an overview of what the general causes, impacts and responses of buyers to shortages in healthcare are. To help answer the research question, the research will especially focus on generic strategies to deal with shortages, or in other words the responses of the buyers. Little literature is found mentioning different generic strategies to deal with shortages across product categories and healthcare departments, which means this research can have a theoretical contribution to existing literature. The typology can potentially act as a framework for procurement professionals in the health industry, helping them to deal with future shortages. The practical application of this could be apparent when procurement professionals start using this typology in their daily activities. If shortages are managed through the generic strategies proposed in the typology, the typology might help procurement professionals in dealing with shortages in a way used (and proven to be useful) by other procurement professionals.



## **2. LITERATURE REVIEW**

In this section, several key concepts will be explained, as well as the theoretical framework, which will be used in the results section to analyse the literature found through the desk research. Key concepts that are explained in this section are the concept of shortage, both conceptually and microeconomically. Related to the concept of a shortage, the concepts of scarcity, risk and resilience will also be explained, as well as specific healthcare-related policies to tackle shortages. After the presentation of the theoretical framework, the base of this research has been clearly presented.

### **2.1 Shortages**

#### **2.1.1 Important definitions**

To create products, first of all resources are needed. Resources are explained as essential inputs to the economic process. Resources may be material or immaterial (e.g. information), with material resources consisting of natural or man-made resources (Ayres, 2001). Examples of natural resources are water, gas, coal, fuel, metals, sunlight, etc. These resources can be used in the production process of products. The necessity of resources creates a problem in itself, as most natural resources are non-renewable, depletion leading to a loss for future use (Neumayer, 2000), examples of these non-renewable resources being water, coal, fuel, metals. Of these natural resources a limited amount to be used in production exists on earth. Examples of renewable energy also exist, such as sunlight and wind, however in the manufacturing of products mainly non-renewable natural resources are used.

The fact that a resource is non-renewable means that any usage of this resource leads to depletion of the total available amount of this resource. Any depletable resources with high demand can become scarce or exhausted. Actual historical examples of natural resources becoming scarce or even exhausted are charcoal scarcity in western Europe in the 17<sup>th</sup> century, a natural rubber scarcity at the outset of World War II and the exhaustion of natural cryolite for the smelting of aluminium (Ayres, 2001). These examples explain the limitation that all natural resources face due to finite availability.

To phrase differently, a shortage refers to a situation where the supply of a resource falls short of the demand of this resource at a particular time and place. For scarce resources, demand might often be larger than supply of this resource, as not much of this resource is available at all, due to the scarcity associated with it. However, even for abundant resources demand might be larger than supply, due to disruptions in supply chains, mismanagement or overconsumption (Gurr, 1985). In the broader context, scarcity and abundance of natural resources drive economic and environmental policies. A resource like crude oil is abundant in certain regions of the globe, leading to economic prosperity in these regions, yet globally it is scarce because of its non-renewable nature and the uneven distribution across countries. This difference can lead to greater material inequalities within and among societies and internal and international conflict (Gurr, 1985). The political impact of scarce resources goes to show the importance of availability and effects of potential shortages.

Not only scarcity is a factor that might lead to shortage in products, as environmental circumstances might also play a role. As mentioned, supply chain disruptions, mismanagement and overconsumption might lead to shortages as well. Factors that might also lead to shortage of a product are supply chain disruptions. A disruption in the supply chain leads to unavailability of the products downstream in the supply chain. Supply chains can be disrupted through internal and external effects, examples of external effects being natural hazards,

terrorism and political turmoil (Lian & Erichsen, 2019). These are classified as external effects in supply chain disruptions, as companies within the supply chain cannot prevent these from happening. In other words, a production crisis leads to a shortage of the product. On the other hand, internal effects can also lead to supply chain disruption, i.e. effects caused by one or more of the companies within the supply chain. Examples are operational problem at suppliers, leading to suppliers being unable to supply the right quantity and quality, also leading to shortage of the product in the market of the buying firm. Other internal effects could be challenges with forecasting demand and navigating legal and bureaucratic processes emerging from a global supply chain (Lian & Erichsen, 2019).

Mismanagement and overconsumption are also causes of shortages of products and resources (Gurr, 1985). Mismanagement is related to the internal effects of supply chain disruption, because when products within a firm in a supply chain gets mismanaged, this might lead to lower supply of the product, which can lead to a shortage that cascades throughout the supply chain. Overconsumption of natural resources is also a large cause of shortages. Overconsumption can be explained as the excessive use of goods and services arising from the mistaken belief that possession of an increasing number and variety of goods is better (Brown & Cameron, 2000). When overconsuming an already finite resources, this depletes this resource even more, leading to more scarcity and thus a lower supply of this resource. A lower supply with a high demand through overconsumption leads to a shortage of this resource.

A last concept to be explained, related to shortages, is that shortages can happen due to different reasons. Shortages can be structural or operational. An operational shortage is the type of shortage that will be analysed in this research, as this type of shortage is caused by operational issues. These shortages are oftentimes transient, because the operational issues can be tackled to make sure the shortage is dealt with (European Labour Authority, 2022). Examples of operational shortages are the mentioned shortages due to mismanagement, or shortages due to a temporarily high demand. The other type of shortages are structural shortages. These shortages are shortages that are not easily tackled and are generally persistent. In other words, this shortage happens (almost) all the time. Examples of this are the shortage of water resources (not healthcare related) in the Segura river basin in the Spanish province of Alicante (Redondo-Orts et al., 2023) or the shortage of qualified medical personnel in large parts of Africa, as many parts of Africa are still classified as rural or semi-urban (Adebisi et al., 2022).

Before moving on to the economics of shortage, the definitions of the different product categories will also be discussed. The three product categories, briefly introduced in the introduction are drugs, PPE and diagnostics (equipment).

- **Drugs**

According to the European Medicines Agency (EMA) a medicine or a drug is “a substance or combination of substances that is intended to treat, prevent or diagnose a disease, or to restore, correct or modify physiological functions by exerting a pharmacological, immunological or metabolic action.” (European Medicines Agency, 2024).

- **PPE**

According to the Occupational Safety and Health Administration PPE can be explained as “personal protective equipment, commonly referred to as "PPE", is equipment worn to minimize exposure to hazards that cause serious workplace injuries and illnesses. These injuries and illnesses may result from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards. Personal protective equipment may include items such as gloves, safety glasses and shoes, earplugs or

muffs, hard hats, respirators, or coveralls, vests and full body suits.” (Occupational Safety and Health Administration, 2024).

- **Diagnostics (equipment)**

According to ISN Medical diagnostics equipment is “a form of medical equipment used to diagnose health conditions. Diagnostic devices can be simple, such as an otoscope for examining ears, or complicated, such as magnetic resonance imaging (MRI) machines. Diagnostic devices are used to detect and monitor diseases and assess the severity of injury or illness. Diagnostic equipment includes a wide range of medical instruments used in clinical care.” (ISN Medical, 2022).

**2.1.2 The economics of shortage: supply, demand and market equilibrium**

Shortages can be observed in almost all resources used in supply chains, examples being labour shortages, material shortages, energy shortages and capital shortages (Ivanov & Dolgui, 2022). To understand the concept of shortages, one should look at two important factors, supply and demand (Klein, 2010). Demand can be explained as the amount of a product that buyers are willing and able to purchase at all prices. Demand is more thoroughly understood through the law of demand. The law of demand is an observation of a consumer’s general response to changes in a product’s price. As price decreases, consumers tend to be willing and able to purchase more of a product, and vice versa (Klein, 2010).

Not only demand is of importance to a market, as sellers also play an important role. Supply is defined as the amount of a product sellers are both willing and able to provide to the market at all prices. Regarding supply, the law of supply comes into play, which is similar to the law of demand. As price increases, sellers increase the quantity that they are willing and able to provide to the market and vice versa. Supply and demand create an important dynamic, as both can change and fluctuate. With stable supply and demand, the market acts in equilibrium (Klein, 2010). An example of this can be seen in figure 3 below.

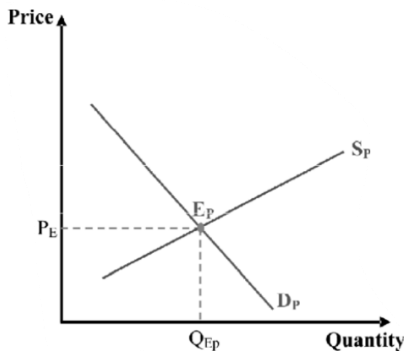


Figure 3: Market equilibrium (Trinh, 2014)

In figure 3 two curves can be seen, addressed as  $S_p$  and  $D_p$ . These are respectively the supply and demand curves. A low quantity would lead to a low demand with a high price, while a high quantity would lead to high demand with a low price. A low quantity would lead to little supply with a low price and a high quantity leads to a high supply with a high price. The market is situated in equilibrium at the intersection of the supply and the demand curve, or  $E_p$  in figure 3. At this point there exists stable supply and stable demand within the market, with a stable price,  $P_e$ , and a stable quantity  $Q_e$  (Trinh, 2014).

### 2.1.3 The economics of shortage: market disequilibrium

To understand the concept of a shortage to a greater extent, some additional basic microeconomic concepts are essential to understand. When a market is in perfect equilibrium, shortages do not exist. In equilibrium, supply and demand are exactly the same. Every product that is supplied to the market is also purchased by a consumer. This, in result, creates an equilibrium price ( $P_e$ ) and an equilibrium quantity ( $Q_e$ ). However, price might also fluctuate due to a variance of circumstances. Klein (2010) poses that two circumstances that might influence the price of a product are government-imposed price floors and price ceilings. A price ceiling is a legally established maximum price intended to lower the price below the market equilibrium price. A price floor is a legally established minimum price, intended to establish a price above the market equilibrium price. With a lower price, more produce can be bought with the same sum of money, the exact opposite being the case for a higher price. This creates a higher demand at a lower price, and a lower demand at a higher price, with supply in both cases remaining the same. With the same supply and a lower demand due to a higher price, this means that not all supply can be sold to existing demand. This creates a surplus in the market, as not all of the product can be sold. With the same supply and a higher demand due to a lower price, this means that not all demand can be fulfilled from the existing supply. This creates a shortage. In other words, in markets normally acting through a market equilibrium, a surge in demand with less of a surge in supply can create a shortage of this product (Klein, 2010).

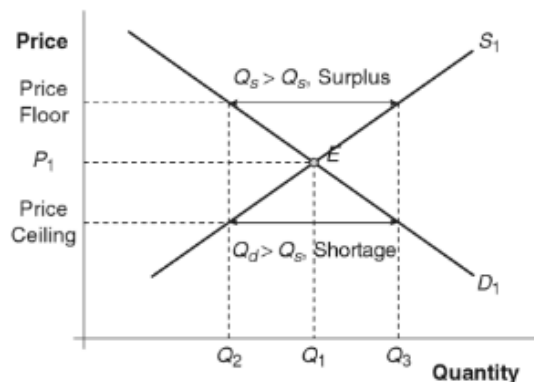


Figure 4: Dynamics of a surplus and a shortage (Klein, 2010)

The situation of the market disequilibrium described above is also shown in figure 4. To elaborate, when price goes down from market equilibrium price through a price ceiling, the difference between the demand curve and the supply curve can be explained as a shortage. The same logic applies to when a price floor is established, raising the price above the market equilibrium price, with the difference between the supply curve and the demand curve being explained as a surplus. Surpluses and shortages are thus antonyms (Klein, 2010).

## 2.2 Risk, resilience and global shortages

With the concept of shortage clearly being delineated, the impact of a shortage is also of importance. To understand global shortages, it is first important to understand the concept of risk and resilience. Risk and risk management have been topics of increasing importance throughout recent years (Merna & Al-Thani, 2008). To understand the concept of risk, two factors are of importance. These factors are combined into and explained through the probability-impact matrix. The matrix is able to calculate risk associated with events, however it is also able to explain the two factors that lead to a specific risk. In other words, the matrix shows the consequences of something bad happening and the probability of something bad happening (Al-Zuheri et al., 2019). If the consequences are little, the risk is little and if the chances are very low, the risk is little as well. Risk can be associated with many sources,

examples being political, environmental, economic, financial, planning, legal, etc. Various risk sources can also correlate to create an increased risk to an organisation (Merna & Al-Thani, 2008). As risks are ever-present, it is important to timely identify risks.

To also relate this example to shortages, a company can understand which products might be the most risky for its operations. If a company buys exactly the same product in the same quantity for the same price from two different suppliers, the first supplier being situated next-door and the second supplier being situated in an area prone to ecological disasters or political turmoil, the impact would be the same for both suppliers, however the probability of something bad happening would be larger for the second supplier, which would lead to the second supplier being classed as riskier than the first supplier.

Risk management is the process identifying risks specific to an organisation and responding to them in appropriate ways (Merna & Al-Thani, 2008). Risk management can also be explained as any set of actions taken by individuals or corporations in an effort to alter the risk arising from their business. Risk management can be further divided into identification of risks, analysis of implications of the risk, responses to minimise the risk and allocation of appropriate contingencies (Wieland & Durach, 2021). Not only organisational risk management is of importance to organisations, but also supply chain risk management (SCRM), where risk is managed within supply chains, as risk to other organisations within a supply chain can also influence organisations up- or downstream (Wieland & Durach, 2021). SCRM is of increased importance with the globality currently involved in supply chains. Related to SCRM is the concept of supply chain resilience, as supply chain resilience is the capacity of a supply chain to persist, adapt, or transform in the face of change (Wieland & Durach, 2021). Resilience is needed by global supply chains, to prevent shortages from happening, before they have occurred, or by learning from past shortages. This concept is important to this report, as the research question is about generic strategies to deals with shortages, in other words, making the organisation more resilient.

Supply chains have become increasingly global due to the existence of international manufacturing sources. International suppliers are cheaper, create higher revenues and higher reliability. Direct labour costs less in certain countries, capital subsidies exist and in foreign markets logistics costs might be lower (Meixell & Gargeya, 2005). These advantage related to global supply chains lead to the increased prevalence of increased global supply chains. Increased global supply chains, also create higher risks, due to the presence of the supply chain in multiple environments. Different political or environmental situations can impact the global supply chain, while in the original supply chains within a single country merely had to deal with a single political or environmental situation (Baldwin & Freeman, 2022). Supply shocks include classic disruptions such as natural disasters, cyberattacks, labour strikes, bankruptcy of suppliers, and industrial accidents, as well as disruptions from broader sources such as trade and industrial policy changes and political instability. On the demand side, firms face risks including damage to product and to company reputation, customer bankruptcy, entry of new competitors, policies restricting market access, macroeconomic crises, and exchange rate volatility. Transportation disruptions can be put in a separate category since they are both very frequent and not associated exclusively with supply or demand (Baldwin & Freeman, 2022).

Due to increased risks associated with global supply chains, shortages might happen in these supply chains. For example, according to the New York Times (Barboza & Sui-Lee, 2020), China dominates the market of medical supplies, both throughout the COVID-19-pandemic, but also throughout potential subsequent pandemics. When the supply in China gets disrupted,

for example due to a new pandemic, an environmental disaster or political instability, this means that supply cannot meet market demand, which would lead to a shortage in the medical supplies market. As most countries buy its medical supplies from China, this creates a shortage in the whole world, or a global shortage. The impact of global shortages is especially felt in medical product markets, as patients throughout the whole world are impacted by a shortage of a single product. In this report a drug-, a PPE- and a diagnostic equipment shortage are more elaborately analysed.

### **2.3 Policies on shortages in healthcare**

Shortages in healthcare can be unlike shortages in other sectors, as healthcare shortages - whether of personnel, medical supplies, or essential medications - directly affect patient outcomes, potentially leading to increased morbidity and mortality. The intricate nature of healthcare delivery makes it particularly vulnerable to disruptions, underscoring the necessity for robust healthcare policies (Jones, 2024). Effective policies are essential to mitigate shortages, ensuring that healthcare systems remain resilient, responsive, and capable of providing uninterrupted, high-quality care. Firstly, some organisations involved in formulating policies for health(care) are mentioned, after which specific policies related to shortage will be outlined.

Shortages in healthcare get a lot of policy attention, as shown by policies of the OECD, United Nations, WHO, US and EU. The United Nations have created a set of goals as a blueprint for peace and prosperity for people and the planet, now and in the future. At its heart are 17 sustainable development goals (SDGs), which are an urgent call to action for all member countries. Of these 17 sustainable development goals one in particular is of interest to the topic shortages in healthcare, i.e. 3. Good health and well-being (United Nations, n.d.). SDG 3 can be divided into specific targets and indicators, of which the main indicator related to these two targets that are applicable for shortages in healthcare is: 3.b.3 Proportion of health facilities that have a core set of relevant essential medicines available and affordable on a sustainable basis. As the SDGs are supported by the United Nations and its member states, this creates broad support from countries worldwide.

The World Health Organization (WHO) is an agency related to the United Nations, working to promote health, keep the world safe and serve the vulnerable (WHO, n.d.). The WHO continually researches topics related to health(care) and also shares news articles which are relevant to health(care). An example of a relevant publication is about addressing the global shortages of medicines (WHO, 2016). In this publication the WHO addresses the shortage of essential medicines in recent years and increased frequency in documentation of this process. It also stresses the common denominator of these shortages, which is mainly the fact that these medicines are old, off-patent, difficult to formulate, have a tightly-defined shelf life, or only a few or a sole manufacturer(s).

Specific policies related to shortages in healthcare, associated with different health or governmental organisations are the following. The United States have established a Drug Shortage Program as part of the US Food & Drug administration (FDA) (Shukar et al., 2021). Manufacturers provide FDA most drug shortage information, and the agency works closely with them to prevent or reduce the impact of shortages. When a shortage is listed as current on the Drug Shortage Database, the FDA is aware of the supply situation and is working with the manufactures on efforts to mitigate the supply disruption. FDA also continue to work with

manufacturers on shortage prevention efforts for drugs not yet listed on the Drug Shortage Database (USFDA, 2024).

The EU in its turn has also established certain agencies and policies to tackle shortages issues. The European Commission has written several articles on drug shortages in the EU, aiming to prevent or mitigate potential critical shortages in the EU (European Commission, 2023). This article mentions measures aimed to improve availability of certain key antibiotics, as well as mentioning public procurement practices that support security of supply of medicines. Several practices that are proposed are preliminary market consultation, awarding contracts to multiple winners, joint procurement and ensuring that the duration of contracts is tailored to favour predictability of demand and long-term availability. Another example of the European Union trying to address the problem of shortages in healthcare is observed in the establishment of the European Directorate for the Quality of Medicines & HealthCare (EDQM). The EDQM lists several initiatives the EDQM undertakes to tackle drug shortages, such as a methodological guide to help select medicines at risk of shortages and a guide to be used to mitigate the negative impact of medicine shortages (EDQM, 2023).

**2.4 Theoretical framework**

Before moving on to the methodology, a framework for analysing will be presented. This framework is important for the results section, as different departments and product categories will be analysed. These departments and product categories were shortly introduced in the introduction of this report. The product categories were chosen, because drugs, PPE and diagnostics (equipment) are all used in clinical care of patients and the three departments were chosen as large amounts of literature exist on these three departments, as will be explained in more detail in chapter 4. Different departments of a hospital will be analysed in the results section, to look at differences in specific departments of a hospital, to see if differences exist between the causes and the handling of shortages in different departments. Potential differences can help different departments learn from one another, while similarities can reaffirm beliefs that a certain shortage is indeed caused by reason X or Y. The same applies to different product categories, because similarities and differences will be analysed thoroughly across all three product categories, drugs, PPE and diagnostics (equipment). The analysis of shortages in different departments and product categories will happen in a uniform way, which will make sure that conclusions drawn are similar regarding the reasoning. The framework that will be applied throughout this research is the following:

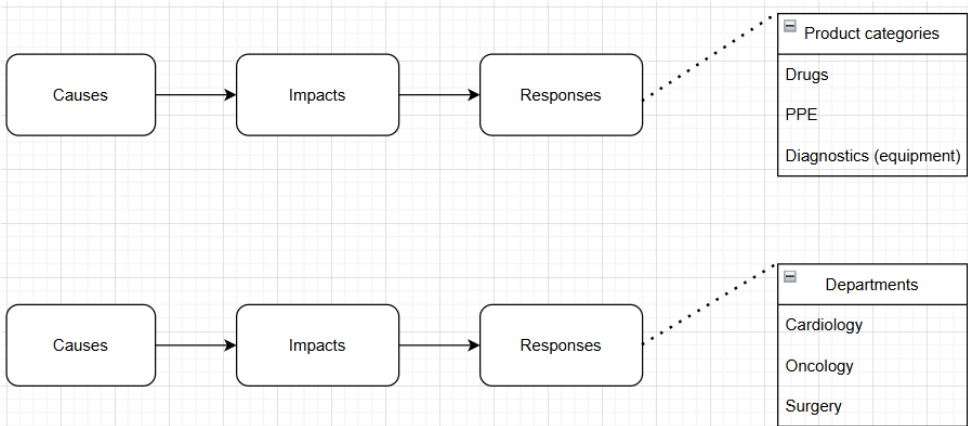


Figure 5: Theoretical framework applied in chapter 4 'Results'

For all different departments and product categories firstly the causes of shortages will be analysed, subsequently the impacts of these shortages will be analysed and lastly the responses

of buyers to these shortages will be analysed. By combining all causes, impacts and responses across departments and product categories afterwards, the typology containing similarities and differences across causes, impacts and responses will be presented.

### 3. METHODOLOGY

#### 3.1 Qualitative desk research

The research is mainly a qualitative desk research study to propose a generic typology of how buyers deal with shortages, however input from experts was collected to review and improve the proposed typology. After extensive literature review through desk research the typology is proposed, after which inputs from experts were gathered to refine the typology. These inputs from experts were collected through semi-structured interviews, which makes the collection of the input a form of qualitative research, to be exact a qualitative research of the type one-to-one interview. To summarise, the research is a combination of a qualitative desk research and one-to-one interviews.

To propose the typology, information gathered in the desk research is from a variety of sources. To be specific, three sources; academic articles, policy documents and secondary sources. The literature review looks at the key theoretical constructs on which the research in the results section will be built, as explained at the beginning of chapter 2. In the results section itself, information from all three sources will be referenced to, i.e. information from academic articles, policy documents and secondary sources, such as news articles and articles from literature related to purchasing and supply chain journals. To generate a clear overview about referencing to certain types of articles, abbreviations will be used. AA stands for academic articles, PD stands for policy documents and SS stands for secondary sources. Underneath, ‘Table 1’ has been added, where all sources used are referenced to, in combination with the corresponding abbreviation. In subchapters of chapter 4 ‘Results’, tables will be added comparing these sources and their usage. Per source used, these tables will indicate whether these sources provide novel insights or are simply confirming other sources, as well as providing examples of statements which are novel insights or supported in other literature (confirming). This will paint the bigger picture by implicitly mentioning that sources are confirmed by multiple sources or have novel insights. Additionally, at the end of the section of the departments and the section of the different product categories, after the theoretical framework containing causes-impacts-responses, a table with all the novel sources in that section will be added. These are the sources deemed as novel in the in-text tables. For every source with a novel insight that insight will be described and explained, to gain an understanding of all novel insights per section of the study.

Table 1: References used in chapter 4 ‘Results’

<b>Table of all references across different sources</b>		
<b>Academic articles (AA)</b>	<b>Policy documents (PD)</b>	<b>Secondary sources (SS)</b>
Abdelrahman et al., 2016 AA1	Association of American Medical Colleges, n.d. PD1	Behnam et al., 2020 SS1
Best & Williams, 2021 AA2	Eerste Kamer der Staten-Generaal, 2023 PD2	Fadavi et al., 2021 SS2
Cohen & van der Meulen, 2020 AA3	European Medicines Agency, 2024 PD3	Griswold et al., 2021 SS3
De Weerd et al., 2017 AA4	HM Government, 2023 PD4	Hsia et al., 2015 SS4
Dill & Ahn, 2014 AA5	Occupational Safety and Health Administration, 2024 PD5	Kapoor et al., 2020 SS5
Dranitsaris et al., 2017 AA6		McBride et al., 2013 SS6
Fox et al., 2014 AA7		McBride et al., 2022 SS7



Hilabi et al., 2023 AA8		Nelson, 2020 SS8
Jessop et al., 2020 AA9		Pickworth et al., 2020 SS9
Kamerow, 2020 AA10		Reed et al., 2016 SS10
Khot, 2020 AA11		Romito et al., 2015 SS11
Knezevic et al., 2022 AA12		Scholz, 2020 SS12
Leaven et al., 2017 AA13		Wiggins et al., 2014 SS13
Mazer-Amirshahi et al., 2014 AA14		
Patel et al., 2017 AA15		
Peeters et al., 2021 Part 1 AA16		
Peeters et al., 2021 Part 2 AA17		
Peeters et al., 2021 Part 3 AA18		
Shukar et al., 2021 AA19		
Ventola, 2011 AA20		
Verschuere & Blome, 2020 AA21		
Vos et al., 2016 AA22		
Walker et al., 2017 AA23		

To further delineate the concept of secondary sources, through these various secondary sources, evidence was collected on shortages in the healthcare sector. Evidence from secondary literature was reviewed across multiple causes of shortage, multiple product categories and multiple types of responses. Common themes established within the data led to creation of the typology of generic strategies to tackle shortages across product categories and shortage causes, which can be used by procurement experts. Data used in the qualitative desk research was from sources from several countries. Through qualitative research, one is able to reflect on the experience of subjects about a specific topic (Hennink et al., 2020). To relate this to this study, through qualitative research one is able to understand how to deal with (types of) shortages through the explanation and experience of the writer of an academic article or a secondary source.

Coding is another topic that is used in the desk research part of this study. Coding is used, because coding can help in labelling and organizing qualitative data, to identify different themes and relationships (Medelyan, n.d.). The specific type of coding that is used is template analysis. Template analysis involves the development of a coding ‘template’, which summarises themes identified by the researcher(s) as important in a data set, and organises them in a meaningful and useful manner (University of Huddersfield, n.d.). In the template analysis, codes are used that are expected to be relevant to the analysis. These codes can be changed in a later stage if proven to not be appropriate or of use. Once any a priori themes are defined, the first step of the analysis is to begin reading through the data, marking in some way any segments that appear to tell the researcher something of relevance to the research question(s). Where such segments correspond to a priori themes, they are coded as such. Otherwise, new themes are defined to include the relevant material and organised into an initial template, which is normally undertaken after initial coding of a sub-set of the data. This initial template is then applied to the whole data set and modified in the light of careful consideration of each transcript. (University of Huddersfield, n.d.).

The following example will pose as an insight into the actual coding that was used for this research. To analyse the causes, impacts and responses of shortages in different departments of a hospital, the following search terms were used to find sources, both academic and secondary: ‘causes of shortages in department X’, ‘impacts of shortages in department X’, ‘responses of

buyers to shortages in department X', 'hospital departments shortage', 'procurement hospital shortage'. In these different search terms 'department X' is a variable that can be changed to a specific department, e.g. oncology. Several interesting sources found through databases, such as PubMed, Scopus, Google Scholar, but also in journals and websites such as Healthcare Purchasing News and Health Service Journal, were put into a document, of which several sources were included into the thesis in a later stage. Sometimes through these keyword searches, other keyword searches were recommended by the site itself, an example of this being the recommendation of similar topics by Google Scholar. This helped in expanding the keyword search by including additional search terms.

Furthermore, elaborating on the concept of the typology itself, the tradition of developing typologies has been prominent in research, particularly within the fields of psychology and sociology, for decades. A typology is formed by grouping cases or participants into types on the basis of their common features and/or differences (Stapley et al., 2022). After the subchapters in the results chapter, the theoretical framework comparing causes, impacts and responses of buyers will be added. This will help generate an overview of similarities and differences specifically for the different departments as well as for the different product categories. Afterwards, the typology will combine these frameworks. The typology will as a result consist of common characteristics and differences related to different departments and product categories. These findings will firstly be presented textually, after which they will also be presented graphically.

### **3.2 Input from respondents**

To assess feasibility of the typology, experts' opinions were included, to possibly refine or confirm the proposed typology. To gather the opinion, a one-to-one interview with a procurement professional within the healthcare industry was scheduled, as this professional can help refine the typology from daily practice from their professional environment. Subsequently, two one-to-one interviews with procurement professionals in different sectors outside of the healthcare industry were scheduled, to assess whether the typology can be used outside of the healthcare industry as well. The one-to-one interviews were specifically held with Dutch procurement professionals, to assess whether a typology made from international sources can be applied into a Dutch context. The procurement professional within the healthcare industry is a tactical buyer working at Medisch Spectrum Twente (MST) in Enschede, also with past experience as a buyer for a food company in the eastern part of the Netherlands. The second professional, working outside of the healthcare industry, is a purchaser at a Dutch wholesaler. To be specific this purchaser has a history in procuring products of Asian and Mediterranean origine. The second procurement professional outside of the healthcare industry is a purchaser at an organization associated with preparatory work in the construction sector. The two purchasers that are not related to healthcare can assess the typology from a different point-of-view and potentially give additional insights, which might not have been reported by a purchaser from within the healthcare sector. This additional insight might help in creating a typology that is not merely aimed at the healthcare sector, but potentially even more broadly applicable.

One-to-one interviews are a type of qualitative research, which can specifically be of use when analysing a real-life context, or with exploration or identification of concepts or views (Hancock et al., 2007). The one-to-one interview is a specific type of qualitative research, it is mostly used as a valuable method of gaining insight into people's perceptions, understandings and experiences and can contribute to in-depth data collection (Ryan et al., 2009). In other words, the one-to-one interview is a great addition to qualitative desk research. To make sure that the

one-to-one interviews are similar independent of the respondent, an interview guide was established.

To extract the information from the respondents the setting of the one-to-one interviews were semi-structured. With a semi-structured interview, an interview with an outline of predetermined open questions is meant (Adams et al., 2015). If an interviewee answers a specific predetermined open question with an answer that is deemed significant by the interviewer, the interviewer is free to ask follow-up questions in a semi-structured interview. This is a good way to discuss a typology with respondents, as the discussion of the typology itself can be secured in the interview guide, however interesting remarks from interviewees can be followed up upon. As suggested with the phrasing ‘discussion of the typology’ the interviews will merely evaluate the typology and thus the data found in the desk research, instead of trying to gather initial data to put into the typology. In other words, the typology will be made, then evaluated with the respondents and potentially slightly changed due to input from respondents. The interview guide used in the interviews is the following:

Table 2: Questionnaire for the semi-structured interviews

<b>Questionnaire</b>
1. What experience do you have with procurement? What are your main responsibilities regarding procurement?
2. In what sector lies your experience with procurement?
3. Have you ever dealt with shortages of products in your specific sector? If so, with what kinds of shortages have you dealt?
4. How have you generally responded to a product shortage?
5. How has your organisation generally responded to a product shortage?
<u>Explain the typology</u>
6. Do you recognize these responses from practice?
7. Are specific responses mentioned not practically feasible?
8. Do you recommend any specific responses to be added into the typology?

Again, the inputs from the respondents are used to potentially slightly alter the typology, however the main body of the typology flows from the desk research. Any inputs from respondents that are deemed interesting and need a slight adjustment of the typology are reported back upon in chapter 6.

**4. RESULTS**

Specific shortages in different departments and different product categories will be analysed more elaborately, building on the explanations of shortages, scarcity, risk, resilience and healthcare policies in chapter 2. As mentioned, these will be analysed by using the theoretical framework, i.e. the flow cause-impact-response will be used per department and per product category. By using this framework, potential similarities and differences can be identified clearly. Regarding shortages of departments, cause-impact-response per department will be presented, while regarding shortages in product categories, firstly cause-impact will be presented, after which a separate section presenting responses of buyers will be added. After each subchapter, all sources used will also be analysed in a table based on novelty, as explained in chapter 3 ‘Methodology’. To reiterate, novel sources are sources that have an interesting insight that was not found in other sources up until that point. When sourcing are ranked as confirming, this means that in another section a source of similar content, confirming the

statement is used. Statements mentioned in a 'confirming' source are thus supported by other literature. This will help in observing similarities across departments and product categories, once this is needed for the typology.

#### **4.1 Variation of shortages and responses to shortages across departments**

Before analysing the causes, impacts and responses to shortages in the three product categories, first the causes impacts and responses to shortages across different healthcare departments will be analysed. That is, because these departments provide practical examples which are specific to a single department within the hospital, while shortages in product categories could be in all departments of the hospital. Additionally department shortages are generally from sources with a clinical perspective, while product category sources mostly are from sources with an academic perspective. The practicality of the clinical perspective will be analysed firstly, after which the academic perspective will also be incorporated with the analysis of product categories. Within healthcare, various departments exist. As medicine is such a broad subject, after graduation as a physician the possibility for physicians exists to specialize in a specific specialty or subspecialty of medicine, in this report also described as a department of healthcare. The American Association of Medical Colleges (AAMC) lists more than 135 of these medical specialties, some of the more renowned specialties being cardiology, neurology, oncology, internal medicine, anaesthesiology or surgery (Association of American Medical Colleges, n.d.). Large amounts of sources exist about disruptions of supply chains associated with specific departments of healthcare. Through research, most sources are found related to cardiology, oncology and surgery. These departments will independently be discussed, to look at causes of shortages, impacts and responses to these shortages.

##### **4.1.1 Cardiology department**

To briefly describe the department of cardiology, it specializes in diseases of the heart and blood vessels and manages complex cardiac conditions, such as heart attacks and life-threatening, abnormal heartbeat rhythms (Association of American Medical Colleges, n.d.). Shortages of PPE during COVID-19 were universal, in other words not associated with a single department. Whole hospitals experienced shortages in PPE, which also reflected on cardiology departments. An example of this is that the American College of Cardiology (ACC), the American Heart Association, and 11 other cardiovascular and healthcare societies issued a joint statement expressing concerns and seeking federal action “over the critical shortages of medical equipment, including ventilators, test kits and PPE, such as masks, face shields, and gowns, to address the public health crisis due to COVID-19 (Kapoor et al., 2020).

To deal with this shortage, hospitals recommended cardiologists to organize their teams to minimize redundant patient contact. This is a way to deal with a shortage not by increasing supply, but by reducing demand. Cardiologists should evaluate the need for laboratory evaluations, diagnostic testing, and patient in-hospital travel to minimize the use of personal protective equipment and healthcare worker exposure. The need for electrocardiograms and echocardiograms should be examined and clear guidelines should be set to ensure that these tests create true clinical value (Khot, 2020).

Additionally, the cardiology department was in a perfect position to work with pharmacists and healthcare professionals to implement safe and effective practice changes (Pickworth et al., 2020). Due to limited availability of drugs and resources, patient care had to be managed in a different way. Cardiology is a good example of a department where an illness can be treated in different ways. (Pickworth et al., 2020). Pickworth et al. proposed that shortage of drugs could also be managed by looking for different treatments of patients. By considering alternate

sources of treatment cardiologists are able to decrease the high demand of drugs that were in low supply.

Looking at different kinds of treatment to move away from drugs in short supply is especially important, because cardiovascular drug shortages are among the top five US drug shortages that are posing a threat to patient care and public health (Wiggins et al., 2014). As Wiggins has also proposed, when a drug shortage occurs, it requires modifications to prescribing, in other words substituting the initial drug by an alternative. Several factors have been shown to contribute to these drug shortages, including manufacturing delays, increased demand, medication discontinuations, and lack of raw materials. Other factors that contribute to drug shortages in cardiology are manufacturing and economic factors, although the two were not mutually exclusive and may have together influenced drug supply. Of the 127 drug shortages from 2010 to 2011 listed in the FDA report, the most common factors resulting in supply disruptions were problems at the manufacturing facility (Reed et al., 2016). Again, as a response Reed et al. proposes to look at alternative options for the drugs being in short supply.

Table 3: Novelty of sources in 4.1.1

Source	Novel	Confirming	Example
AA11	x		Cardiologists should evaluate the need for laboratory evaluations, diagnostics testing and patient in-hospital travel to minimize the use of PPE.
SS5		x	Critical shortage of medical equipment, including ventilators, PPE ... due to COVID-19.
SS9		x	A shortage of drugs should be managed by looking at different treatments for patients.
SS10	x		The most common factors resulting in supply disruptions were problems at the manufacturing facility.
SS13	x		Cardiovascular drug shortages are among the top five US drug shortages that are posing a threat to patient care and public health.

#### 4.1.2 Oncology department

To briefly describe oncology, it specializes in the diagnosis and treatment of all types of cancer and other benign and malignant tumours. This specialist decides on and administers therapy for these malignancies, as well as consults with surgeons and radiotherapists on other treatments for cancer (Association of American Medical Colleges, n.d.). Again, shortage in PPE was universal during COVID-19, and during the wave of COVID-19-infections, most of total PPE available went towards COVID-19-care. However, the shortage has also affected cancer care, where it is used for both patient and health-care worker protection. The use of chemotherapy-tested gloves, single-use disposable gowns, respirators or masks, eye protection, and closed-system transfer devices are recommended to protect nurses and pharmacists against unintentional exposure to antineoplastic drugs, and protective gear is required to care for patients with cancer who are in isolation or during certain procedures (Nelson, 2020). According to Nelson, lack of protective gear availability led to disruptions in oncology care. PPE shortages also impacted personnel availability (through illness, quarantine and reassignment to manage patient surges in other departments) in oncology, as nurses spend proportionately higher time in direct contact with patients.

Not only PPE was in short supply in oncology departments, but cancer drugs were as well. Oncology drug shortages often result in disruptions in the timing of chemotherapy treatments,

alterations in the dose or regimen administered, or even missed doses when alternative agents are unavailable (McBride et al., 2022). Drug shortage is an ongoing challenge for cancer centres both normally and also in a time of crisis. In normal situations cancer drug shortages have several impacts. In a study by McBride et al., delays in chemotherapy administration or changes in treatment regimens due to drug shortages were reported by 93% of survey participants; 85% of respondents reported increased costs, and 10% reported reimbursement challenges related to drug shortages. At 34% of represented institutions, at least 1000 hours of additional labour annually was needed to manage shortages (McBride et al., 2013). In times of crises this issue is mainly due to budget allocation to provide the necessary medication for the management of COVID-19 and its complications. The cancer drug shortage may have major negative impacts on patients' survival or quality of life. Even in a non-epidemic situation, intravenous cancer drugs topped the list of medication shortages. This might be due to the fact that these medications are more vulnerable to Good Manufacturing Practice (GMP) violations issued by the World Health Organization (WHO-GMP), U.S. Food and Drug Administration (CGMP), or European Union (EU-GMP) (Ventola, 2011). In addition, increased procurement time, scarcity of alternative providers, supply chain interruptions, and delays in delivery times may further impair access to biological and chemical oncology drugs over pandemic (Fadavi et al., 2021).

In 2018, the American Society of Health-System Pharmacists (ASHP) provided recommendations for managing drug shortages, including (1) formation of a working group, (2) validation of drug shortage, (3) formation of resource allocation committee, (4) patient prioritization, (5) finding and approving alternative medications or therapeutic equivalents, and (6) addressing ethical considerations for alternative choices. By following this guideline, health-care facilities can mitigate the impact of the viral pandemic on the provision of necessary medications and reduce its adverse effects on patient care (Fadavi et al., 2021).

Table 4: Novelty of sources in 4.1.2

Source	Novel	Confirming	Example
AA20	x		Even in a non-epidemic situation, intravenous cancer drugs topped the list of medication shortages.
SS2	x		By following this guideline, health-care facilities can mitigate the impact of the viral pandemic on the provision of necessary medications and reduce its adverse effects on patient care
SS6		x	The cancer drug shortage may have major negative impacts on patients' survival or quality of life.
SS7		x	Oncology drug shortages often result in disruptions in the timing of chemotherapy treatments, alterations in the dose or regimen administered, or even missed doses when alternative agents are unavailable
SS8	x		Lack of protective gear availability led to disruptions in oncology care

### 4.1.3 Surgery department

To briefly describe surgery, a surgeon has expertise in the diagnosis, treatment and support of critically ill and injured patients, particularly trauma victims and patients with serious infections and organ failure. In addition, these surgeons coordinate patient care among the patient's primary physician, critical care staff, and other specialists (Association of American Medical Colleges, n.d.). In addition to other departments in hospitals, PPE is also an essential part of surgery. During COVID-19, the virus was transmissible through aerosols. These aerosols were

generated by patients with COVID-19 during several surgical procedures, such as tracheostomy, upper airway procedures, endonasal procedures and laparoscopy. To tackle the risk of receiving COVID-19 through aerosols transmitted in surgical procedures, surgeons are recommended to wear several types of PPE. PPE was universally in short supply, which meant that measures had to be taken by surgeons for examples. Measures included sessional use of PPE, reusing it or using alternatives to standard PPE (Jessop et al., 2020). Reuse and decontamination of used PPE was also one of the short-term responses by other surgical departments (Griswold et al., 2021).

In addition to shortages of PPE in surgery, drug shortages are also present in the surgery department. The impact of drug shortages in surgery is mainly felt through shortages of anaesthetics. These are drugs used to anaesthetise patients for surgery. Two impactful shortages were the shortage of propofol and neostigmine (Romito et al., 2015)(Hsia et al., 2015). These drugs, often used to anaesthetise patients experienced national shortages in the US, which also reflected into shortages for individual hospitals. In response to this, hospitals had to find different types of anaesthetics to make sure that no surgeries were influenced negatively. Again, looking for a substitute product was a typical response to a product shortage, when looking at drug shortages in the surgery department.

Table 5: Novelty of sources in 4.1.3

Source	Novel	Confirming	Example
AA9		x	Measures included sessional use of PPE, reusing it or using alternatives to standard PPE.
SS3		x	Reuse and decontamination of used PPE was also one of the short-term responses by other surgical departments.
SS4		x	The impact of drug shortages in surgery is mainly felt through shortages of anaesthetics. These are drugs used to anaesthetise patients for surgery. Two impactful shortages were the shortage of propofol and neostigmine
SS11		x	The impact of drug shortages in surgery is mainly felt through shortages of anaesthetics. These are drugs used to anaesthetise patients for surgery. Two impactful shortages were the shortage of propofol and neostigmine

In addition to the three departments described above, of the three product categories researched throughout this thesis, some specific product categories are more applicable to specific departments within hospitals. For example, PPE is used throughout the hospital. PPE shortage was analysed in the specific departments above, however in all three departments the shortage of PPE throughout hospitals cascaded down to the specific department. Drug shortages are also analysed in this thesis, as drugs only used in specific departments exist. Examples are chemo in oncology or beta blockers in cardiology. However, diagnostics (equipment) shortages were not included in the analysis of the specific departments. That is, because diagnostics or radiology is a specific department of medicine. Sometimes also called diagnostic radiology, this specialty is concerned with diagnosis and treatment of specific diseases. Diagnostic radiology encompasses a variety of diagnostic and image guided therapeutic techniques, including all aspects of radiological diagnosis (nuclear radiology, diagnostic ultrasound, magnetic resonance, computed tomography, interventional procedures, and the use of other forms of radiant energy). Physicians studying diagnostic radiology are primarily hospital based and can specialize in a number of areas, including: vascular interventional; neuroimaging and

intervention; abdominal imaging and intervention; nuclear medicine; chest and cardiac imaging; paediatric imaging; and mammography (Association of American Medical Colleges, n.d.). In other words, shortages in diagnostics (equipment) are generally related to this specific department, which means that this is discussed in chapters 4.3 and 4.4.3. To summarize this section about shortages in different departments the framework of chapter 2.4 will be used.

Table 6: Causes, impacts and responses to shortage in different departments

<b>Department</b>	<b>Causes</b>	<b>Impacts</b>	<b>Responses</b>
<b>Cardiology</b>	<ul style="list-style-type: none"> <li>- COVID-19</li> <li>- Limited supply of drugs through manufacturing delays</li> <li>- Increased demand</li> <li>- Medication discontinuations</li> <li>- Lack of raw materials</li> </ul>	<ul style="list-style-type: none"> <li>- Shortage of medical equipment (ventilators, test kits, PPE)</li> <li>- Cardiovascular drugs being among the top five US drug shortages that are posing a threat to patient health and public health</li> </ul>	<ul style="list-style-type: none"> <li>- Reduce demand by minimizing patient contact</li> <li>- Evaluating need for diagnostic testing</li> <li>- Looking at alternative treatments (substitution)</li> </ul>
<b>Oncology</b>	<ul style="list-style-type: none"> <li>- COVID-19</li> <li>- Drug shortages through high demand</li> </ul>	<ul style="list-style-type: none"> <li>- Shortage of medical equipment (gloves, gowns, respirators and masks), also impacting personnel availability</li> <li>- Drug shortages leading to disruptions of chemotherapy</li> <li>- Alteration in dose and missed doses</li> <li>- Increased costs</li> <li>- Negative impact on quality of life and survival</li> </ul>	<ul style="list-style-type: none"> <li>- Patient prioritization</li> <li>- Reduce demand</li> <li>- Formation of a working group</li> <li>- Validation of drug shortage</li> <li>- Formation of a resource allocation committee</li> <li>- Patient prioritization</li> <li>- Finding and approving alternative medications</li> <li>- Addressing ethical consideration for alternative choices</li> </ul>
<b>Surgery</b>	<ul style="list-style-type: none"> <li>- COVID-19</li> <li>- National shortage in the US of propofol and neostigmine (anaesthetics)</li> </ul>	<ul style="list-style-type: none"> <li>- Impacting availability of surgeons, through aerosols that are spread in surgery</li> <li>- Negatively influencing surgeries, due to limited availability of anaesthetics</li> </ul>	<ul style="list-style-type: none"> <li>- Sessional use of PPE, reusing PPE, using alternatives to standard PPE</li> <li>- Looking for a substitute product when possible</li> </ul>



Table 7: Insights from novel sources about departments

Source	Novel insight
AA11	Cardiologists should evaluate the need for testing. If echocardiograms do not create clinical value, the test might not be needed. This is a way to reduce demand of PPE, personnel capacity and testing capacity. So even quite standard tests need to be reevaluated to bring down patient contact during pandemic situations.
AA20	Cancer drugs have a larger vulnerability to Good Manufacturing Practice, which means that even in a non-pandemic situation cancer drugs are vulnerable to shortages. Unavailability of cancer drugs directly impacts survival and quality of life of patients. Impacts of shortage in cancer drugs are clearly explained.
SS2	ASHP has provided six recommendations to manage drug shortages. Formation of a working group, validation of drug shortage, formation of resource allocation committee, patient prioritization, alternative medications and addressing ethical consideration for alternative choices. These recommendations can help in managing (cancer) drug shortages.
SS8	PPE shortages also impacted personnel availability (through illness, quarantine and reassignment to manage patient surges in other departments) in oncology, as nurses spend proportionately higher time in direct contact with patients in oncology. This is a clear description that patient contact is high in the oncology department.
SS10	Most drug shortages were created due to problems at the manufacturing facility. Reason of drug shortages (in this case related to cardiology) is clearly explained.
SS13	Cardiovascular drug shortages are among the top five US drug shortages that are posing a threat to patient care and public health. This clearly delineates that a cardiovascular drug shortage has a direct impact on patient care and public health.

## 4.2 Analysis of drug shortages

In literature related to shortages in healthcare, mainly articles regarding drug shortages are found. That is, because a direct link between patient welfare and drug shortages exists, as without specific drugs specific illnesses and patients cannot be treated. Drugs also account for a large part of total public sector health budget per country spent, being estimated at 40 to 60 percent. Drug shortage is a global issue, which affects low-, middle- and high-income countries. Many strategies have been developed by various countries to overcome this drug shortage problem, while the problem is accelerating. All types of drugs are liable to shortages, including several life-saving drugs, such as oncology medicines, antimicrobial drugs, opioids and cardiovascular drugs (Shukar et al., 2021). Furthermore, the pharmaceutical industry is highly regulated, as it's highly important to bring new, safe and effective medicines to the market (European Medicines Agency, 2024). Drugs need to be tested elaborately before coming to market, to ensure safety, as well as product conformity. Materials used to produce these drugs must be checked and are regulated as well, with drugs that are actually sold on the market are extensively tested by multiple authorities (European Medicines Agency, 2024).

To understand drug shortages, firstly the definition is of importance. According to Shukar et al. no standardized definition of drug shortage exists globally, exemplified in 26 unique definitions being reported by the EU and 56 definitions being found by the WHO worldwide. Existence of uniformity regarding definition of this topic is also very important, with drug shortages becoming a common problem in combination with the increasing awareness of this topic during the last decades (De Weerd et al., 2015). In the scientific environment, however, several definitions are widely-used. The American Society of Hospital Pharmacists defines drug

shortage as: “a supply issue that affects how the pharmacy prepares or dispenses a drug product or influences patient care when prescribers must use an alternate agent” (Fox et al., 2014).

There are various reasons for drug shortages, depending on the type of drug (Mazer-Amirshahi et al., 2014). However, overall drug shortages can be classified in three categories, supply issues, demand issues and regulatory issues (Shukar et al., 2021), as shown in figure 6 below.

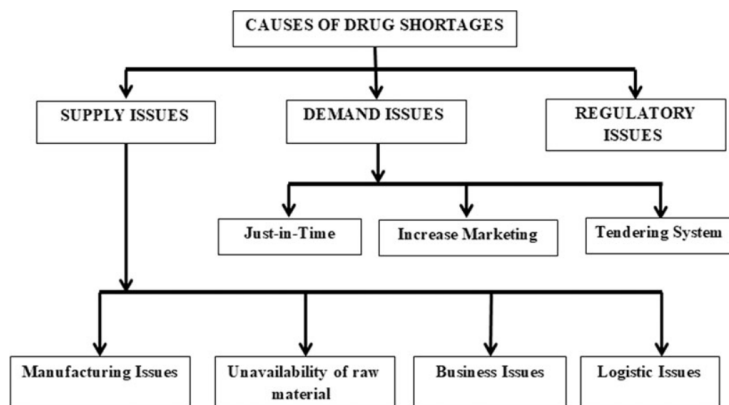


Figure 6: Causes of drug shortages (Shukar et al., 2021)

#### 4.2.1 Supply issues

Supply issues mean manufacturers are unwilling or unable to produce enough medicines to satisfy demand. It can be classified into four subcategories, i.e. manufacturing issues, unavailability of raw material, business issues and logistic issues. Manufacturing issues include quality problems and competing priorities. Quality problems are found through quality checks and inspections after manufacturing, often leading to recalls of medicines already dispatched into the market. Recalls can occur due to microbial contamination or unexpected reactions between products and containers amongst other reasons (Shukar et al., 2021). In 2012, 67% of total drug shortages were due to quality issues in the USA (Mazer-Amirshahi et al., 2014). Additionally, competing priorities can also lead to manufacturing issues. When a manufacturer produces a range of different drugs, these drugs can sometimes compete for the same raw materials, leading to shortages in the manufacturing of certain drugs due to production of other drugs.

Unavailability of raw material is another subcategory of supply issues in drug shortages. This subcategory is quite self-explanatory, as unavailability of raw material needed for manufacturing of a drug can lead to a shortage of the drug itself. It could be a shortage of active pharmaceutical ingredients (API), excipients or packaging materials. Most active pharmaceutical ingredients come from India and China, meaning that availability of these ingredients are very affected by potential political conflicts, animal diseases, trade disputes and other environmental conditions (Shukar et al., 2021).

Business issues are economic factors, such as little profit margin, small market size, consolidation, absence of maintenance and low procurement ability (Dill & Ahn, 2014). Several concrete examples of these business issues are a low market prices, or in other words, the existence of big competitors in the market as well as the difficulty of small suppliers having to compete with large branded already existing competitors in the market. Drugs with small market sizes, for example drugs for very rare and specific diseases are also vulnerable to shortage, as manufacturers prefer manufacturing drugs with a bigger market size and profit potential (Mazer-Amirshahi et al., 2014).

Logistic issues are also a subcategory of supply issues, created by transportation issues and drug supply chain management incompetency. Transportation issues can be created by bad weather, bad traffic or even large natural disasters (Mazer-Amirshahi et al., 2014).

#### 4.2.2 Demand issues

Demand issues can also lead to drug shortages, with this issue being divided into three subcategories, which are just-in-time, increase marketing and tendering system. Demand may be predictable or unpredictable. A well-established demand system can predict shortage caused by just-in-time (JIT) inventory, average demand growth and seasonal demand, but outbreaks, epidemics, and disasters are unpredictable (Walker et al., 2017). In low- and middle-income countries several specific demand issues exist as well, such as irrational use of medicine, lack of patients' education and prescription adherence leading to medication wastage (Walker et al., 2017). JIT inventory systems tries to align fixed raw materials from suppliers directly with the currently scheduled requirement (Shukar et al., 2021). With low financial budget, stakeholders purchase a fixed quantity of stock for a fixed duration that fulfils only the current needs, with no backup plan in place. This creates an increased risk of shortage in medicine (Ventola, 2011).

Another subcategory of demand issues is increased marketing. Increased marketing can both be predictable and unpredictable. Predictable marketing happens through increasing focus of professionals and the public towards a product. This can happen by companies in an unethical manner, trying to shift attention to a drug marketed by themselves, although this mainly exists in low-income countries without drug-related policies (Abdelrahman et al., 2016). Unpredictable marketing happens through environmental circumstances such as outbreaks, natural disasters or other incidents. Drug shortages might occur due to increased lead times, especially for drugs which are very specific regarding its manufacturing process (Dill & Ahn, 2014). A last risk lies in seasonal demand. Even though this is largely forecastable, it's not entirely. Examples are demands of cough syrups and antihistamines in winter (Mazer-Amirshahi et al., 2014).

A last subcategory is tendering system. Awarding a drug tender to a single manufacturer would put it in high risk of shortage, which has happened in both the USA and the EU. Low pricing of tenders can also lead to manufacturers leaving the market, leading to loss of competition and rising prices (Dranitsaris et al., 2017).

#### 4.2.3 Regulatory issues

Drug regulatory authorities are accountable for effective drug regulation to safeguard amongst other things drug safety and drug quality. Inflexibility in regulatory processes, lack of policies and unavailability of communication among stakeholders are mentioned as regulatory issues leading to shortage (Shukar et al., 2021). The absence of an uniform definition of drug shortage is also a regulatory issue in itself, which limits the ability to judge the presence of drug shortages. Drug shortages impact multiple stakeholders, such as the main stakeholder involved, the patients. Shortage of drugs leads to diminished available of sufficient care, which impacts the patients first and foremost.

Table 8: Novelty of sources in 4.2

Source	Novel	Confirming	Example
AA1	x		This can happen by companies in an unethical manner, trying to shift attention to a drug marketed by themselves, although this

			mainly exists in low-income countries without drug-related policies.
<b>AA4</b>		x	Existence of an uniform definition of this topic is also very important, with drug shortages becoming a common problem in combination with the increasing awareness of this topic during the last decades.
<b>AA5</b>	x		Business issues leading to shortages are economic factors, such as little profit margin, small market size, consolidation, absence of maintenance and low procurement ability.
<b>AA6</b>		x	Low pricing of tenders can also lead to manufacturers leaving the market, leading to loss of competition and rising prices.
<b>AA7</b>		x	Drug shortage is a supply issue that affects how the pharmacy prepares or dispenses a drug product or influences patient care when prescribers must use an alternate agent.
<b>AA14</b>	x		In 2012, 67% of total drug shortages were due to quality issues in the USA.
<b>AA19</b>		x	Causes of drug shortages can be divided into supply issues, demand issues and regulatory issues.
<b>AA20</b>		x	With low financial budget, stakeholders purchase a fixed quantity of stock for a fixed duration that fulfils only the current needs, with no backup plan in place. This creates an increased risk of shortage in medicine.
<b>AA23</b>		x	A well-established demand system can predict shortage caused by just-in-time (JIT) inventory, average demand growth and seasonal demand, but outbreaks, epidemics, and disasters are unpredictable.
<b>PD3</b>		x	The industry of medicines is highly regulated, as it's highly important to bring new, safe and effective medicines to the market

### 4.3 Analysis of PPE shortages

Personal protective equipment (PPE) shortages are mainly relevant since the COVID-19-pandemic. PPE is a critical component of healthcare settings, protecting workers from infections and as a result helping in infection control (Patel et al., 2017). PPE may include items such as gloves, safety glasses and shoes, earplugs or muffs, hard hats, respirators or coveralls, vests and full body suits (Occupational Safety and Health Administration, 2024). None of these items would normally have been very vulnerable to shortage, however this changed during the COVID-19-pandemic. Several reasons exist why in principle PPE is not vulnerable to shortage. PPE market supply is simply based on demand, which normally is quite stable and forecastable, as it simply can be related to the number of patients with infectious diseases, which is based on prevalence and potential growth trends. This creates a limited ability of the PPE supply chain to surge production, as stable demand leads to a focus on cost cutting strategies. This is also reflected in the fact that a significant proportion of the supply chain is produced off-shore, due to lower labour and material prices (Patel et al., 2017). Risks associated with this robust, offshore supply chain have been observed during the 2009 H1N1 Influenza pandemic and the 2014 Ebola virus epidemic, however the impact during the recent COVID-19-pandemic has been even larger.

Cohen & van der Meulen, (2020), have described four main factors to contribute to PPE shortages during the PPE shortage for US healthcare workers during the COVID-19-pandemic, as expressed in figure 7.

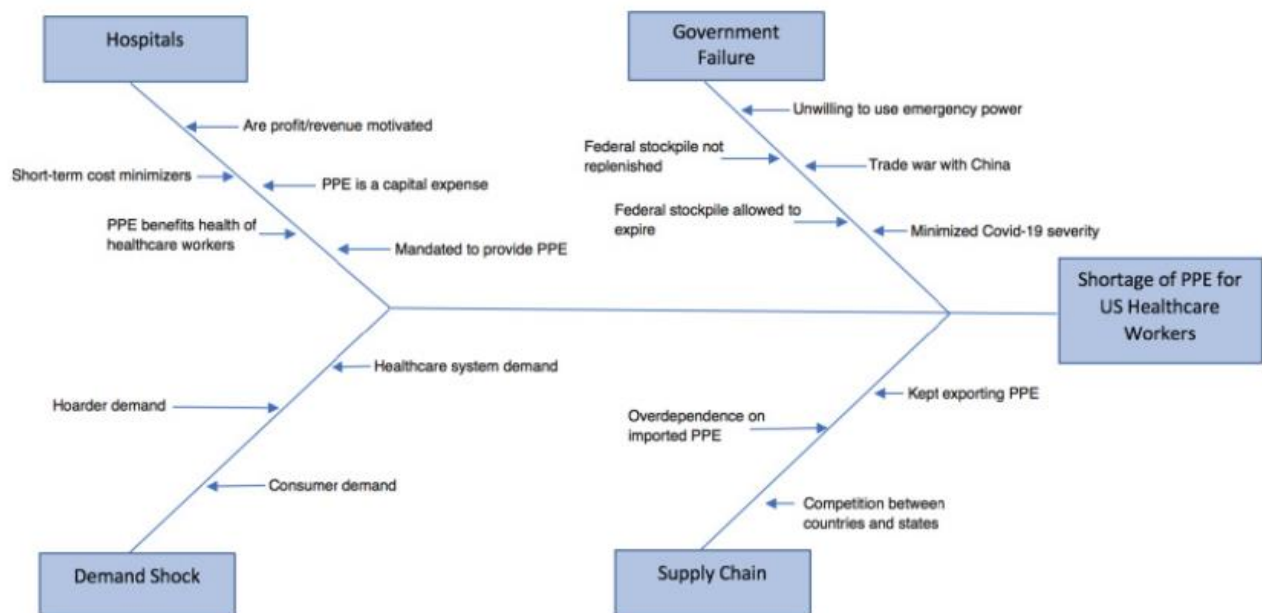


Figure 7: Factors contributing to PPE shortage (Cohen & Van Der Meulen, 2020)

The four factors contributing to the shortage, as per figure 7 (Cohen & Van Der Meulen, 2020) will now be outlined more elaborately. These factors arose from a number of processes and worked concurrently to generate severe PPE shortages in the US healthcare sector. In other words, it is important to understand that factors contributing to a general shortage, interact and amplify problems. Taking the example of figure 7, if only consumer demand was a factor, the shortage might not occur, but the fact that the healthcare system demand goes up, leads to a higher consumer demand and also hoarder behaviour, leading to a very large demand shock. Not only this demand shock is influencing the shortage however, as supply chains kept exporting PPE, instead of keeping it within the countries, etc. All these factors interplay to form a perfect storm.

According to Cohen & Van Der Meulen, The budgeting model used by hospitals is the first factor contributing to PPE shortage. This factor is explained as a structural weakness in the healthcare system, as employers (hospitals) are required to provide employees with PPE free of charge. Additionally, while other items used to treat patients such as e.g. catheters or medication are billed to the patient or insurer, PPE is a cost for the hospital itself. This leads to the conclusion that PPE is a cost for employers. While employees would want to receive as much PPE as possible, to ensure their own wellbeing, the employer wants to keep costs as low as possible, creating a conflict of interest. Hospitals function like other business, trying to pursue efficiency and cost minimization. This efficiency leads hospitals to adapt a just-in-time production, keeping nearly zero PPE inventories. In itself this does not create a problem during normal circumstances, however during crises such as the Ebola epidemic or the COVID-19-pandemic, with sharply increasing demand for PPE, it becomes problematic.

The second factor contributing to PPE shortage is the demand shock (Cohen & Van Der Meulen, 2020). The rapid increase in the demand for PPE by the healthcare system and the general public contributed massively to PPE shortage as well. Close to one-third of all hospitals

had no more face masks in March of 2020 and 13% of hospitals had run out of plastic face shields (Kamerow, 2020). The scale and severity of the crises also led to panic buying, hoarding and resales of masks and gloves among normal consumers. Already inadequate inventories were sharply reduced by this panicked buying. Two types of customers helped in exacerbating this demand shock. Firstly, worried consumers, but secondly, hoarders of e.g. N95 respirators intending to resell these respirators at inflated prices.

Government failure is the third factor contributing to PPE shortage (Cohen & Van Der Meulen, 2020). The market seemingly was not able to regulate itself and ensure sufficient supplies of PPE for hospitals, which meant that the government could have taken action. Coordinated domestic distribution and direct PPE procurement from international suppliers were options that could have been taken. The national stockpile was not maintained on a timely basis, leading to usage of expired PPE. The private sector sought guidance about accessing government inventories, however the government failed to provide any guidance. Several failures were also applicable to the US government, such as minimization of the severity and a trade war with China, however the issues described were applicable to other governments as well.

The breakdown of the global supply chain is the fourth and last factor contributing to PPE shortage (Cohen & Van Der Meulen, 2020). Incentives for hospitals to keep costs down had kept inventories low and driven sourcing to low-cost producers, especially China, which dominates the PPE market through low production costs and high quality of products. As China internally also dealt with the pandemic, Chinese demand also skyrocketed. As a result, China limited export of PPE, leading to a large disruption to the global supply chain of PPE. As the virus spread, other countries' demand also increased, against an ever-decreasing supply.

Table 9: Novelty of sources in 4.3

Source	Novel	Confirming	Example
AA3	x		... have described four factors to contribute to PPE shortage, i.e. hospitals, demand shock, government failure and supply chain.
AA10		x	Close to one-third of all hospitals had no more face masks in March of 2020 and 13% of hospitals had run out of plastic face shields.
AA15		x	PPE is a critical component of healthcare settings, protecting workers from infections and as a result helping in infection control.
PD5		x	PPE may include items such as gloves, safety glasses and shoes, earplugs or muffs, hard hats, respirators or coveralls, vests and full body suits.

#### 4.4 Analysis of diagnostic (equipment) shortages

Similar to shortages in PPE and in medicine, diagnostic (equipment) shortages are caused by supply chain issues. Several sources from table 1 are used in this section AA8 and SS1. As discussed in the conceptual framework, supply chain disruptions can be caused by internal and external factors. A large external factor of recent years has been the COVID-19-pandemic. During the COVID-19-pandemic, not only PPE was short in supply, but also diagnostic testing methods to test for COVID-19. Two main testing technologies were used to find COVID-19, molecular assays and immunoassays (Behnam et al., 2020). An example of the shortage of molecular assay tests is the shortage in the US, needing six million tests per week to twenty

million tests per day of molecular assay tests during the height of COVID-19, with only three to three-and-a-half million being available. Additionally, the global capacity at the time was 14 million to 16 million tests per week, which means that at some peak days, the US daily demand could be greater than the weekly global production capacity. With all countries needing these kind of tests, there seemed to be a global shortage in molecular assay tests. According to (Behnam et al., 2020) the constraints of producing higher amounts of supply of molecular assay tests lay in the five main activities in the process for delivering these tests: sample collection, logistics, test execution, data management and testing-capacity management. To effectively deliver lab-based molecular-assay tests the process must be executed harmoniously to maximize supply in a complex testing environment during the pandemic.

Not only external supply chain disruption were the reason of shortages in diagnostics (equipment), but also internal supply chain disruptions. An example of this is the shortage in MRI scans in middle- and low-income countries (Hilabi et al., 2023). Although magnetic resonance imaging (MRI) was invented in 1974, access to this innovative and clinically valuable imaging technique remains limited in developing/underdeveloped countries. External factors also come in to play, as this shortage is specific to low- and middle-income countries and hospital in these countries cannot help that there situated within these countries and not in high-income countries, which could be classed as an external factor. However, most factors found to be the reasons of this shortage in low- and middle-income countries are internal to the supply chain itself. Due to high acquisition costs, a lack of infrastructure, a continuous power supply, and the knowledge needed to maintain and operate the systems, MRI is generally restricted to developing nations (Hilabi et al., 2023). The lack of specialists in MRI physics and clinical applications continues to be a significant problem for developing countries. Although the health indices are still poor, many developing nations have recently seen economic transition with better living standards, an aging population, increased healthcare knowledge, and access to cutting-edge medical treatments. Acquisition costs, infrastructure and knowledge needed to maintain and operate the systems are internal factors of the supply chain leading to shortage in this instance. Acquisition costs is simply the cost of acquiring a MRI scan, which has to deal with the production costs of the scan and the price of the scan. Infrastructure is something that is also internal to the supply chain, with logistics and infrastructure of the supply chain being different with suppliers and OEMs being situated onshore or nearshore than them being situated offshore. Lastly, knowledge needed to maintain and operate the systems is also an internal factors, i.e. an operational problem at the buyer, as the buyer does not know how to operate and maintain the system.

Table 10: Novelty of sources in 4.4

Source	Novel	Confirming	Example
AA8		x	Not only external supply chain disruption were the reason of shortages in diagnostics (equipment), but also internal supply chain disruptions. An example of this is the shortage in MRI scans in middle- and low-income countries.
SS1	x		the constraints of producing higher amounts of supply of molecular assay tests lay in the five main activities in the process for delivering these tests: sample collection, logistics, test execution, data management and testing-capacity management.

## 4.5 Responses of procurement on shortages

Responses of buyers to shortages are very important in trying to overcome issues created by these shortages. Again, the responses to shortages are limited to responses to shortages in medicine/drugs, PPE and diagnostics (equipment).

### 4.5.1 Responses of buyers to shortages in drugs

According to the European parliament during the COVID-19-pandemic, guidelines for countries to avoid medicines shortages can be classed in four categories. These four categories are ‘showing solidarity’, ‘ensuring supply’, ‘optimal use of medicines in hospitals’ and ‘optimisation of sales in community pharmacies to avoid hoarding’ (Scholz, 2020). An overview provided in the article by Scholz, written for the European Parliament, has been added below in figure 8.

Showing solidarity	Ensuring supply	Optimal use of medicines in hospitals	Optimisation of sales in community pharmacies to avoid hoarding
<ul style="list-style-type: none"> <li>• Lifting export bans and restrictions</li> <li>• Avoiding national stockpiling</li> <li>• Avoiding that misinformation leads to improper use and unnecessary stockpiling</li> </ul>	<ul style="list-style-type: none"> <li>• Increasing and reorganising production</li> <li>• Ensuring manufacturing continues at full capacity</li> <li>• Implementing regulatory flexibility</li> <li>• Monitoring available stocks at national level</li> <li>• Ensuring necessary support to the wholesale sector</li> <li>• Fully enforcing the 'green lanes'*</li> <li>• Facilitating air freight and other forms of transport</li> <li>• Ensuring fair distribution of supply</li> </ul>	<ul style="list-style-type: none"> <li>• Equitable distribution of available medicines</li> <li>• Exchanging hospital protocols to treat patients</li> <li>• Considering alternative medicines on the basis of hospital protocols and national guidelines</li> <li>• Extending the expiry dates of medicines</li> <li>• Considering the use of magistral preparations or veterinary medicines</li> <li>• Encouraging clinical trials for medicines used off label*</li> </ul>	<ul style="list-style-type: none"> <li>• Introducing measures to reassure persons reliant on medication</li> <li>• Introducing restrictions on sales in community pharmacies</li> <li>• Limiting online sales of products at risk</li> </ul>

Figure 8: Guidelines to optimize supply and avoid medicines shortages during the coronavirus pandemic (Scholz, 2020)

These categories are specifically linked to countries and their involvement in managing supply shortages, however this should also be specifically related to procurement’s involvement. According to (Shukar et al, 2021) five strategies can be used to manage drug shortages: ‘informing prescribers and recommending alternative agents’, ‘contacting other suppliers for the short medicine’, ‘investing supply restoration and planning’, ‘substituting the prescribed medication’ and ‘updating the formulary’. Of these five strategies, ‘contacting other suppliers for the short medicine’ and ‘investing supply restoration and planning’ are mainly applicable to procurement. Procurement can help in managing drug shortages by trying to attain similar medicines from different suppliers or by making sure that supplies are actively and proactively planned and restored. Additionally, it’s deemed crucial to effectively manage contracts of suppliers in order to ensure accessibility and availability of essential medicines. This is in line with the preferred customer principle, which will be outlined in section 4.4.4.



#### **4.5.2 Responses of buyers to shortages in PPE**

According to academic literature, to make sure PPE supply chains are increasingly resilient regarding shortages, important factors in response are the importance of planning, the significance of collaboration and relationship building. Throughout previous pandemics little leadership and management learning existed, however during the COVID-19-pandemic created extensive learning opportunities (Best & Williams, 2021).

Firstly, an analysis of responses of organizations and governments. Before the pandemic, hospitals in Belgium were found to have simple sourcing procedures regarding PPE (Verschuere & Blome, 2020). According to Verschuere & Blome, all hospitals in their study were part of the ACAH (Purchasing Negotiation Centre for Hospitals). As PPE is sterile equipment, hospitals expect equipment to be conform specification requirements posed by the FAMPH and European authorities. Regarding suppliers, Belgian hospitals seemed to favour Belgian or European suppliers, as they were deemed more reliable due to presence on the European Public Market. Before COVID-19, hospitals felt no need to source from multiple suppliers as the hospitals were linked to a single supplier through contract. These contract were often revisited, due to the fact that PPE is a critical material that needs continuous replenishment. Most hospitals had an on-site or off-site buffer stock that was often replenished, as stock was limited due to lean principles (Verschuere & Blome, 2020).

During the global shortage of PPE during COVID-19, the Belgian government created Task Force COVID-19 (TF19), consisting of three foreign trade agencies. TF19 was responsible to carry out a search of potential suppliers from China for PPE. The sourcing process consisted of several phases. In the first phase, TF19 started to look for potential suppliers in China. In the second phase, TF19, after placing orders with suppliers, tried consolidating the market and custom flows, as many newly-formed PPE suppliers tried claiming a place in the market. TF19 also had to accompany certain administration in the purchase order process. TF19 aided in cultural and linguistic support with the fabricants and suppliers. Belgian hospitals were looking for new sources of supply, for which the help of TF19 was needed, as traditional routes of importation with their own suppliers were saturated due to the global shortage.

In other words, the response of buyers within the healthcare sector were different for the PPE shortage, than for shortages in medicines and diagnostics (equipment), which will be elaborated in 4.4.3. Normally, in the PPE market, there are no real examples of shortages. The main historical example of PPE shortage was created due to the global shortage as a result of the COVID-19-pandemic. As all countries and all healthcare institutions suffered from this same global shortage, normal procurement tactics to tackle shortage as explained in the reaction of buyers to shortage in medicines could not be used. Most countries used collective procurement agreements or task force, as is highlighted in the Belgian example with TF19 (Verschuere & Blome, 2020).

Similar buying approaches were used in other countries, such as in the following examples. The Netherlands has a similar taskforce, 'het Landelijk Consortium Hulpmiddelen' (LCH). This taskforce was created to 'bundle forces' (Eerste Kamer der Staten-Generaal, 2023). The mentioned goal of the LCH was to jointly procure and distribute different types of PPE, as a shortage is looming for healthcare personnel and do so without trying to make profit. The Dutch Ministry of Health, Welfare and Sport was responsible for the financial means to procure the PPE and tried making sure that the procurement prices were conform market prices. Healthcare institutions were free in trying to procure PPE for themselves, but if, through the global shortage, they were not able to do so, the LCH would serve as a back-up. The Dutch first chamber, in its research about the reaction of the Dutch government in creating the LCH, has mentioned that mistakes were made. In the future, the Dutch government should appoint healthcare procurement professionals to procure PPE, instead of simply employees of the

Ministry of Health, Welfare and Sport. Additionally, the First Chamber has stated that in the initial reaction all EU member states tried taking care of themselves, while a collective stance would have ‘made more sense’. In conclusion, the Netherlands also took a collective approach, however did so with aid from employees of the Ministry, instead of professional healthcare buyers. This is viewed as a mistake by the Dutch First Chamber.

Another example is the approach in the UK. Normally, the National Health Service (NHS) was responsible for procurement of PPE, however due to the skyrocketing demand during the early phases of the pandemic and enormous price inflation and limited supplies, normal market dynamics ceased to exist, as did the normal NHS procurement procedures (HM Government, 2023). To tackle the issues, the UK adopted an entirely new ‘open-source’ approach to procurement of PPE. The UK invited the industry to come to them, instead of the other way around. Through this approach, the UK received an enormous amount of offers from an enormous amount of different sources (24000 offers from 15000 different sources during the first 14 weeks). These offers were processed by 400 employees and subdivided in different streams, such as the UK Make workstream for UK-related sources and the China Buy workstream for offers from China. A High Priority Lane was also established, through which MPs, ministers and senior government officials could directly refer offers they received directly from different sources.

To conclude this section about responses of organizations and governments to shortages in PPE, in all instances a national approach was undertaken. During the chaotic first weeks of the pandemic, all countries reacted for themselves, almost choosing a ‘everyone for themselves’ approach. National taskforces were created, while countries frantically searched for different and new sources of PPE. In hindsight, most countries did not operate most efficiently, however in such unforeseen circumstances, most countries still support the way of action that was undertaken at that point in time. Individual buying initiatives did not really exist, as the global shortage was that large, that most suppliers directly supplied PPE to nation-wide buying initiatives.

In addition to responses of organizations and governments, an extensive study has also analysed the supply strategies and their consequences in the Netherlands, public procurement preparedness for future crises and specific learnings on public procurement preparedness for the Netherlands (Peeters et al., 2021)(AA16, AA17 & AA18). Specific actions taken by Dutch buyers to shortages in PPE during COVID-19 were guided by a national Dutch response. Multiple healthcare providers and departments, directorates, and committees from the government worked together to combat shortages of medical equipment. As a national response was implemented through cooperation across departments and providers, as well as a national outbreak management team (OMT), individual buyers did not play a specific role. However, looking at this shortage from a national point-of-view, some procurement lessons can be learned. Through international learnings, buyers are suggested to respond in the following way if a new pandemic were to be present (Peeters et al., 2021)(AA16, AA17 & AA18): the Netherlands should balance professionalization and regulations, i.e. make sure that legislation is flexible, so in cases of disastrous events there is ‘room to play’, however this is only possible if procurement is highly professionalized, because if not, a flexible legislation might lead to corruption and chaos. The combination between a flexible legislation and highly professionalized procurement leads to a good mix to deal with events such as COVID-19.

Additionally, a balance between knowledge and power should be existent. Responsibility and power lay within the government during the pandemic, however knowledge often lay with procurement professionals. This discrepancy led to an inability to deal with such unforeseen circumstances. In the future, if knowledge and power are aggregated, future pressures on the

supply chain can be tackled in a more efficient way. Tackling this discrepancy can be done by shifting knowledge towards power, or shifting power towards knowledge.

Lastly, the Netherlands should balance what is to be done currently and what is to be done in the future. This will help the Netherlands in tackling future pressures on the supply chain. The Netherlands should not try and reach for the stars, but should tackle issues one at a time. An example given by (Peeters et al., 2021) is that it does not make sense to have high safety stocks, if no system or organization for distributing these stocks during crises is in place. In other words, it is important for procurement to understand the interrelated nature of changes, as well as changing issues in the right order.

#### **4.5.3 Responses of buyers to shortages in diagnostics (equipment)**

According to Behnam et al., (2020), to bridge the supply-demand gap several measures can be taken, both in the short-term and in the medium-term. Three short-term measures that could be taken to prevent shortages in diagnostic tests during COVID-19 are establishing visibility into testing capacity, maximizing existing laboratory capacity and establishing new laboratory capacity. By having a clear view of unused testing capacity waste can be eliminated, ensuring a more effective production process. Additionally, local laboratories might not be fully utilizing installed equipment. Unlocking this available capacity starts by compiling a full inventory of the installed equipment base, and subsequently calculating total theoretical laboratory capacity, given installed equipment base. This allows companies to address and locate bottlenecks, for example by hiring additional personnel in stages of the testing process. Lastly, new laboratory capacity can be established by opening up new laboratories, as demand for the products is quite predictably high during the foreseeable future (as this was situated during the pandemic). Two medium-term measures are scaling up the production of closed-system cartridges and proprietary agents. This is because original equipment manufacturers (OEMs) could not supply the total demand in cartridges and proprietary agents. Another medium-term measure is exploring alternate testing protocols and technologies.

Additionally, several procurement professionals have addressed successful strategies that were used during shortages of reagents and other patient testing methods, as well as plans that were undertaken by these professionals to plan for future supply shortages (Knezevic et al., 2022). Successful strategies, undertaken to mitigate the effect of shortage in patient testing supplies by procurement professionals were having a well-defined existing supply chain structure with clearly identified roles within the supply chain. It incorporates the ability to activate an enterprise supply-chain management command centre populated with key leadership and resources who can provide the necessary support, coordination, escalation, and communication of any ongoing issues. Another is the existence of long-term relationships with trusted vendors. These relationships can help in the supplier communicating the fact that specific products are highly demanded or in limited availability. Additionally, laboratories should have excess stock to be able to deal with increased demand and laboratories should diversify risk by making sure that not all materials are sourced from the same region or country. A last way to deal with supply shortages of patient testing methods is pro-actively looking at product innovations. An example mentioned (Knezevic et al., 2022) is that the Mayo Clinic looked at 3D printing of specific patient testing methods.

Strategies undertaken to mitigate the effect of shortages of patient testing supplies by the Yale-New Haven hospital were trying to secure supplies from other suppliers or using alternatives, as well as trying to decrease internal demand.

Several prospective changes implemented to plan for future supply shortages are also mentioned, even though these might still be broad or vague. Some of these prospective changes to plan for future supply shortages are: internal development of equipment, implementation of

automation in laboratories, quality control, trust building with local suppliers, increasing size of supply chain, centralized command centre or system for supply chain, Identifying the right resource for the right patient for the right purpose and capacity expansion to meet growing needs of customers.

#### 4.5.4 Responses of buyers to shortages across product categories

Common themes that are established in multiple product categories, in other words themes that can be applied to medicine/drugs, PPE and diagnostics (equipment), are the following: government intervention was present both in medicine shortage and in PPE shortage. Emphasis on working with various suppliers and stakeholders is also something that was mentioned both in medicine shortage and PPE shortage. Furthermore, a principle that is similar across product categories is the preferred customer principle. Preferred customers are customers that are preferred by suppliers, which means that this customer will receive preferential treatment. When shortages exist and only certain customers can be supplied with drugs, suppliers will prefer to supply preferred customers than other customers (Vos et al., 2016). It's very important to attain this preferred customer status as a result. This is also applicable to PPE shortages and diagnostics shortages.

Another thing that gets mentioned in multiple categories is strategic inventory management. Various inventory management applications are eliminating waste, optimizing the usefulness of inventory and fulfilling the customer needs (Leaven et al., 2017). These applications and this tool is not applicable to a single product shortage in healthcare, but to all product shortages. By maintaining a buffer stock in your inventory, unforeseen shortages due to demand spikes can be tackled at first. By serving demand from your excess stock, this creates extra time for the institutions to look for different suppliers to fulfil future demand. Additionally, if a supply chain disruption occurs, this excess demand will again buy time to find different suppliers without leading to stockouts at first. In the same reasoning, contract management is an important tool. By making sure that you contract suppliers in flexible contracts, adjustments in supply volumes can be made if needed, for example during crises.

A last thing that is often used as a solution to shortages in all categories related to healthcare is not from the buying point-of-view, but from a production point-of-view. Capacity should be increased to make sure that demand is met by an increased supply (Abdelrahman et al., 2020). Related to this, novel technology should be implemented and innovations should be incorporated, to make sure that the production process is more efficient in meeting demand, again by trying to increase supply.

Table 11: Novelty of sources in 4.5

Source	Novel	Confirming	Example
AA1		x	Capacity should be increased to make sure that demand is met by an increased supply
AA2		x	Throughout previous pandemics little leadership and management learning existed, however during the COVID-19-pandemic created extensive learning opportunities.
AA12		x	The Mayo Clinic looked at 3D printing of specific patient testing methods.
AA13		x	Another thing that gets mentioned in multiple categories is strategic inventory management. Various inventory management

			applications are eliminating waste, optimizing the usefulness of inventory and fulfilling the customer needs.
<b>AA19</b>		x	Five strategies can be used to manage drug shortages: ‘informing prescribers and recommending alternative agents’, ‘contacting other suppliers for the short medicine’, ‘investing supply restoration and planning’, ‘substituting the prescribed medication’ and ‘updating the formulary’
<b>AA21</b>		x	Most hospitals had an on-site or off-site buffer stock that was often replenished, as stock was limited due to lean principles.
<b>AA22</b>	x		When shortages exist and only certain customers can be supplied with drugs, suppliers will prefer to supply preferred customers than other customers.
<b>PD2</b>		x	The mentioned goal of the LCH was to jointly procure and distribute different types of PPE, as a shortage is looming for healthcare personnel and do so without trying to make profit.
<b>PD4</b>	x		To tackle the issues, the UK adopted an entirely new ‘open-source’ approach to procurement of PPE. The UK invited the industry to come to them, instead of the other way around.
<b>SS1</b>		x	To bridge the supply-demand gap several measures can be taken, both in the short-term and in the medium-term.
<b>SS12</b>	x		According to the European parliament during the COVID-19-pandemic, guidelines for countries to avoid medicines shortages can be classed in four categories. These four categories are ‘showing solidarity’, ‘ensuring supply’, ‘optimal use of medicines in hospitals’ and ‘optimisation of sales in community pharmacies to avoid hoarding’.

To summarize this section about shortages in different product categories the framework of chapter 2.4 will be used.

Table 12: Causes, impacts and responses to shortage in different product categories

<b>Product category</b>	<b>Causes</b>	<b>Impacts</b>	<b>Responses</b>
<b>Drugs</b>	<ul style="list-style-type: none"> <li>- Manufacturing issues</li> <li>- Unavailability of raw materials</li> <li>- Business issues</li> <li>- Logistic issues</li> <li>- Demand issues</li> <li>- Regulatory issues</li> </ul>	<ul style="list-style-type: none"> <li>- Delays in (chemotherapy) administration</li> <li>- Increased healthcare costs</li> <li>- Negative impacts on patient survival and quality of life</li> <li>- Disruptions in treatment regimens</li> </ul>	<ul style="list-style-type: none"> <li>- Reduce demand by minimizing patient contact</li> <li>- Find and approve alternative medications</li> <li>- Formation of working groups to manage shortages</li> </ul>
<b>PPE</b>	<ul style="list-style-type: none"> <li>- Hospital budgeting models leading to JIT-inventory</li> </ul>	<ul style="list-style-type: none"> <li>- Lack of essential protective gear for healthcare workers</li> <li>- Increased risk of infection among healthcare staff</li> </ul>	<ul style="list-style-type: none"> <li>- Reuse and decontamination of PPE</li> <li>- Using alternative</li> </ul>

	<ul style="list-style-type: none"> <li>- Demand shock during pandemics</li> <li>- Government failure to manage supplies</li> <li>- Breakdown of global supply chains during COVID-19</li> </ul>	<ul style="list-style-type: none"> <li>- Disruptions in patient care, especially in high-risk departments like oncology and surgery</li> </ul>	<ul style="list-style-type: none"> <li>protective equipment</li> <li>- National and international procurement efforts</li> </ul>
<b>Diagnostics</b>	<ul style="list-style-type: none"> <li>- Supply chain disruptions due to external factors like COVID-19</li> <li>- Insufficient global production capacity for necessary diagnostic tests</li> </ul>	<ul style="list-style-type: none"> <li>- Inability to meet testing demands during pandemics</li> <li>- Delayed or inaccurate diagnosis, affecting patient outcomes</li> </ul>	<ul style="list-style-type: none"> <li>- Increase global production capacity</li> <li>- Prioritize testing resources for high-need areas</li> <li>- Develop alternative testing methods</li> </ul>

Table 13: Insights from novel sources about product categories

Source	Novel insight
AA1	Increased marketing can be predictable and unpredictable. Predictable marketing happens through increasing focus of professionals and the public towards a product. This can happen by companies in an unethical manner, trying to shift attention to a drug marketed by themselves. In other words, a shortage can occur due to increased marketing, creating a higher demand.
AA3	Four main factors contributed to PPE shortages during the COVID-19-pandemic, these factors being hospitals, government failure, demand shock and supply chain. These four factors in itself created a shortage, however they also have a reinforcing effect. In other words, in itself these created a shortage, however when merged together it created a 'perfect storm'.
AA5	Drug shortages might occur due to increased lead times, especially for drugs which are very specific regarding its manufacturing process. In other words, when drugs are very specific or specialized (which is often the case) lead times might increase, which leads to shortages for hospitals.
AA14	Drug shortages are often due to quality issues (drugs need to be of a specific quality standard). Drugs with small market sizes (for example for rare illnesses) are also liable to shortages. Risks also lie in seasonal demand, for example cough syrup during winter. This source lists several diverse causes of drug shortages.
AA22	When shortages exist and only certain customers can be supplied with drugs, suppliers will prefer to supply preferred customers than other customers. This source introduces the preferred customer principle.
PD4	To tackle the issues, the UK adopted an entirely new 'open-source' approach to procurement of PPE. This gives an example of a government response to PPE shortage, in which case the UK Government wanted the industry to come to them instead of sourcing PPE from manufacturers itself.

SS1	This source gives three short-term and two medium-term measures to bridge the supply-demand gap, in other words it proposes several responses of buyers to deal with shortages.
SS12	Four guidelines for countries to avoid medicines shortages are proposed in this source. These guidelines are more on a country-wide level than on a procurement-level, however it has valuable additional insights which might be incorporated in larger scale responses.

## 5. TYPOLOGY

### 5.1 Proposed typology

In this section the proposed typology will be outlined. The typology will look at common characteristics and differences of shortages and responses across product categories and departments, first by describing these textually and subsequently by displaying the typology graphically.

#### 5.1.1 Shortages and responses across departments

Factors and responses to shortages vary by department within healthcare, yet there are notable similarities and differences across product categories. This helps in answering research sub question 4.

**Cardiology:** Common shortages include PPE and drugs, with responses such as minimizing redundant patient contact, evaluating the necessity of diagnostic tests, and exploring alternative treatments. The focus here is on optimizing the use of available resources and finding substitutes.

**Oncology:** Oncology departments face shortages in PPE and cancer drugs, with responses involving managing chemotherapy timing, dose alterations and ensuring adequate protective gear. This department requires careful management of treatment schedules and protective measures due to the critical nature of cancer care.

**Surgery:** In surgery, shortages in PPE and surgical equipment are prominent. Responses include reallocating resources and sourcing alternative supplies. The approach in surgery is more about prioritizing urgent procedures and resource allocation.

Similarities can be found in the types of shortages, which are in all departments in PPE and in drugs. A response to shortages similar in both cardiology and surgery is looking for potential replacement drugs for drugs that are especially risky.

#### 5.1.2 Underlying factors that cause shortages across product categories

Underlying factors causing shortages in the healthcare sector are divided into supply issues, demand issues, and regulatory issues. This helps in answering research sub question 1.

**Supply Issues:** These arise from manufacturing problems and quality issues, which are common across all product categories including drugs, PPE, and diagnostics. Additionally, unavailability of raw materials is a significant factor affecting drug and diagnostic equipment shortages. Economic factors such as low profit margins and small market sizes predominantly affect drug shortages, while logistic challenges like transportation disruptions are a universal issue impacting drugs, PPE, and diagnostic equipment.

**Demand Issues:** Just-in-time inventory systems affect all product categories, creating vulnerabilities during sudden demand spikes. Increased marketing efforts primarily influence drug shortages, while tendering systems that limit flexibility are common in drug and PPE shortages.

Regulatory Issues: Inflexible regulatory processes and lack of coherent policies impact all product categories, contributing to drug and diagnostic equipment shortages. Poor communication among stakeholders is particularly detrimental in managing PPE and drug supplies.

Shortly summarizing similarities and differences in factors causing shortages across the three product categories, starting with similarities:

- Manufacturing problems and quality issues (drugs, PPE and diagnostics)
- Logistic challenges such as transportation disruptions (drugs, PPE and diagnostics)
- Vulnerability due to JIT inventory systems (drugs, PPE and diagnostics)
- Poor communication among stakeholders (drugs, PPE and diagnostics)
- Low profit margins (drugs, PPE)

Several differences in responses are also found:

- Small market sizes and increased marketing efforts are specific to drugs
- Significant impacts from global events such as COVID-19 causing demand shocks and supply chain disruptions are specific to PPE
- Unavailability of specific active pharmaceutical ingredient and complex supply chain requirements for specialized equipment are specific to diagnostics (equipment)

### **5.1.3 Responses of buyers across product categories**

Buyers respond to shortages in various ways depending on the product category, though some responses are common across categories. This helps in answering research sub question 3.

Drug Shortages: Responses include informing prescribers about alternative drugs, contacting other suppliers, investing in supply restoration and planning, substituting prescribed medications, and updating formularies. These responses are highly specific due to the critical nature and diversity of drugs.

PPE Shortages: During the COVID-19 pandemic, national task forces were formed for centralized procurement and distribution, sourcing from multiple suppliers, and ensuring adequate inventory levels. Similar to drug shortages, ensuring diversified supply sources and maintaining strategic inventory levels are key.

Diagnostic Equipment Shortages: Responses involve establishing visibility into testing capacity, maximizing existing laboratory capacity, scaling up production of critical components, and exploring alternate testing protocols and technologies. Like PPE, centralized efforts and increased production capacities are crucial responses.

Shortly summarizing similarities and differences in responses across the three product categories, starting with similarities:

- Diversification of supply sources (drugs, PPE and diagnostics)
- Maintaining buffer stock to manage spikes in demand (drugs, PPE and diagnostics)
- Centralized procurement efforts and government intervention (PPE and drugs)
- Preferred customer status (drugs, PPE and diagnostics)

Several differences in responses are also found:

- Informing prescribers about alternative drugs, updating formularies and specific substitution strategies are specific to drugs
- Formation of national task forces, centralized distribution and focus on international sourcing and logistics are specific to PPE



- Establishing visibility into testing capacity, maximizing existing laboratory capacity and exploring alternative testing protocols and technologies are specific to diagnostics (equipment)

### 5.1.4 Graphical display of proposed typology

In this graphical display of the typology, before inputs from experts, the common characteristics of underlying factors causing shortages across product categories, responses of buyers to shortages across product categories and shortages and responses across departments will be displayed. This display will help in summarising the textual content of the typology elaborated in chapters 5.2.1, 5.2.2 and 5.2.3.

	Drug shortages	PPE shortages	Diagnostics (equipment) shortages
Minimizing redundant patient contact			
Evaluating necessity of diagnostic tests			
Exploring alternative treatments			
Managing chemotherapy timing			
Dose alterations			
Ensuring adequate protective gear			
Reallocating resources			
Sourcing alternative supplies			

Figure 9: Shortages and responses across departments

	Drug shortages	PPE shortages	Diagnostics (equipment) shortages
Manufacturing problems and quality issues			
Logistic challenges and transportation disruptions			
Vulnerability due to JIT inventory systems			
Inflexible regulatory processes and lack of coherent policies			
Poor communication among stakeholders			
Low profit margins			
Small market sizes			
Increased marketing efforts			
Significant impacts from global events such as COVID-19			
Unavailability of specific raw materials			
Complex supply chain requirements for specialized equipment			

Figure 10: Underlying factors causing shortages across product categories

	Drug shortages	PPE shortages	Diagnostics (equipment) shortages
Diversification of supply sources			
Maintaining buffer stock to manage spikes in demand			
Centralized procurement efforts and government intervention			
Preferred customer status			
Informing prescribers about alternative drugs and formularies			
Formation of national task forces and centralized distribution			
Establishing visibility into testing capacity			
Maximizing existing laboratory capacity			
Exploring alternative testing protocols and technologies			

Figure 11: Responses of buyers to shortages across product categories

In general several responses are found to be used across all department and across all three product categories. These are thus the generic strategies to be adopted by procurement experts to tackle shortages in the healthcare sector:

- Diversification of supply sources
- Maintaining buffer stock to manage spikes in demand

- Preferred customer status with suppliers
- Sourcing alternative supplies
- Exploring alternative treatments in cooperation with medical personnel
- Reallocating resources in conversation with medical personnel

However, these responses can also be specified, to situations where a specific response (figure 11) is applicable to a specific cause of a shortage (figure 10). These two figures are combined, to gain an overview for which cause a certain response is usable. This overview is added as figures 12.1 and 12.2. To be able to gain a good overview of this interplay between responses and causes, abbreviations are used, but the specific causes and responses are in the same order as in figure 10 and figure 11. Due to the width, figure 12 will be split into two tables.

	Manufacturing problems	Logistic challenges	Vulnerability due to JIT	Inflexible regulatory processes	Poor communication	Low profit margins
Diversification of supply sources	█	█			█	
Maintaining buffer stock		█	█			
Centralized procurement efforts			█	█	█	
Preferred customer status	█					█
Alternative drugs and formularies						
National task forces				█		
Visibility into testing	█					
Maximizing capacity						
Alternative testing protocols	█					█

Figure 12.1: Responses to specific causes of shortages pt. 1

	Small market sizes	Marketing efforts	Impact from COVID-19	Unavailability of materials	Specialized equipment
Diversification of supply sources			█	█	█
Maintaining buffer stock			█		
Centralized procurement efforts			█	█	
Preferred customer status	█				
Alternative drugs and formularies			█	█	
National task forces				█	
Visibility into testing					
Maximizing capacity					█
Alternative testing protocols			█	█	

Figure 12.2: Responses to specific causes of shortages pt. 2

In figures 12.1 and 12.2 above responses to specific causes of shortages can be found. To give an example of figure 12.1, if manufacturing problems lead to shortages within the supply chain, diversification of supply sources is a good response to try to tackle this shortage. Figures 12.1 and 12.2 give several generic strategies to respond to several different causes of shortages.

Several important findings can be found in figures 12.1 and 12.2. Not all findings will be discussed, however some especially remarkable findings will now be discussed more elaborately. The first remarkable finding is that all responses are appropriate for the cause of shortage ‘Impact from COVID-19’. This can clearly be explained, however, as during COVID-19 the shortages were so large and widespread, that all responses of buyers to shortages were tried to handle these shortages. Another interesting finding is the responses to the cause ‘Manufacturing problems’. Four different responses are appropriate for shortages with this exact cause, however some responses that are seemingly logical are not applicable according to literature. When shortages occur due to manufacturing problems the responses diversification, being a preferred customer, visibility into testing and alternative testing protocols are appropriate, however logically one might assume that maintaining buffer stock would also be a good response to manufacturing problems, as with buffer stock a company might not be impacted by manufacturing problems. The reason that maintaining buffer stock is not classified

as a appropriate response might be the fact that not all products that have a shortage due to manufacturing problems are able to have buffer stock, for example because of limited shelf life.

Two other remarkable findings are the fact that no response is really appropriate for the cause ‘marketing efforts’ and that ‘small market sizes’ has only one appropriate response. Regarding ‘marketing efforts’, from literature there seems to be no appropriate response of buyers. That is, because for this specific cause only this cause of a shortage has been mentioned, but no response has been proposed in literature. From logic, when a manufacturer has a higher marketing effort to try to sell more of its products, creating a higher demand and thus a shortage, some response might still be appropriate, for example diversification of supply sources, becoming a preferred customer, or alternative drugs or formularies. All these responses might enable a hospital to secure products, even though a shortage might occur due to increased marketing. In addition to the fact that no responses are found to be appropriate for increased marketing, in literature only a single response for the cause ‘small market sizes’ is to be found. When a market size is small (for example due to the fact that a very specific drug is needed for a rare illness), lead times will increase, leading to a shortage of the product in that specific market. Only being a preferred customer is deemed as an appropriate response in that case. This makes sense, however, as the other 8 responses are not probably not applicable to this specific cause of a shortage. In other words, if for a very specific illness a very specific drug is needed, which has a larger lead times and thus a shortage, the only thing that a hospital can try to do is becoming a preferred customer of the manufacturer, which might decrease the lead times for this hospital specifically.

### **5.1.5 Insights from the evaluation interviews**

The purchasing professional working as a tactical buyer in a hospital mentioned that all six strategies to be adopted to tackle healthcare shortages presented in the typology in this thesis were applicable in practice. The professional addressed that in the hospital that he worked for, all six strategies generally were used, mentioning that the hospital in his case mainly used ‘diversification of supply sources’ and ‘sourcing alternative supplies’. When discussing potential missing factors in the typology, i.e. strategies used in the hospital, but not mentioned in the typology, this procurement professional mentioned some examples, which were mainly related to his experience working for a hospital, but also related to his past employment as a purchaser for a company in the food sector.

Regarding shortages, the presence of such an alliance creates two advantages. The first is the fact that a buyer buying large volumes from a supplier, while also being a large supplier of care in the eastern part of the Netherlands, leads to suppliers really valuing this alliance. In other words, indirectly this alliance leads to a preferred customer status as a buying alliance, purely through size. The second advantage is through a principle, similar to the sixth principle mentioned in the typology (‘reallocating resources in conversation with medical personnel’). Through the presence of the buying alliance, when a hospital associated with the alliance has a shortage of a particular product, but another hospital associated with the alliance has not got this same shortage, products can be allocated from the hospital with a surplus to the hospital with the shortage. An important sidenote that has to be made regarding previous statement is that this solution is merely good for highly local shortages and not for shortage with a wider scope. For this solution to work, hospitals nearby must have the product in shortage in stock, or this shifting around of products will not work. However, generally, through these two advantages, the formation of an alliance can thus be included as a strategy to tackle shortages from a buying perspective.

From past experience related to the food sector this professional also mentioned threatening with fines and changing ingredient proportions. Threatening with fines is an option as a short-term solution for shortages, as it will secure either the product or a sum of money for the buying company, however it is not a long-term solution, as suppliers might be incentivized to stop the relationship. Changing ingredient proportions in a product is an option in the food sector, as per an example given by the professional. It was mentioned that sometimes if an ingredient is in shortage, a little less of this ingredient gets put into the final product. This is quite similar to substitution, but not completely, as a smaller amount of this single ingredient gets put into the product. So, merely a part of this ingredient gets substituted. To give an example, most ingredients in the food sector have a percentage range, e.g. 4-6% of the total product, and if normally 6% of the total product is this specific product, but this product now faces a shortage, the company can also decide to merely have 4% of the total product consisting of this specific product. As threatening with fines is merely a short-term solution and changing ingredient proportion is solely related to the food sector, these strategies will not be added to the final typology.

The second purchasing professional working as a purchaser for a Dutch wholesaler has mentioned several strategies used, in addition to the strategies already mentioned in the typology. This purchaser mentioned that four of the strategies mentioned in the typology were common in their daily purchasing practice. These four are the first four strategies mentioned in the typology, as the last two are specific to medicine and as a result not applicable to a wholesaler. A minor remark was mentioned about the third strategy 'preferred customer status with suppliers'. The respondent mentioned that the wholesaler not only aims to become a preferred customer with its suppliers, but due to the market share of this wholesaler, suppliers generally also want to become a preferred supplier of this wholesaler. In other words, it's more an interactive concept than merely the buyer wanting to becoming the preferred customer. This interactivity also helps the buying firm in dealing with potential shortages.

Another concept mentioned in the interview is specific to the wholesaling market. The wholesaler tries to mitigate the risks of a potential product shortages, by making sure that it has multiple suppliers with multiple alternatives for the same product. In other words, by having multiple suppliers supplying multiple brands of the same product, a shortage in a single supplier or of a single product brand is relatively less important.

The third purchasing professional working as a purchaser in an organization associated with preparatory work in the construction sector has mentioned that the strategies mentioned in the typology were very common for them, with some minor remarks. To be specific, the four strategies non-specific to medicine were applicable to their buying practice. Again, a remark was made about the third strategy 'preferred customer status with suppliers'. Again, this buyer preferred a strategic partnership with the supplier and making sure that through the relational aspect the supplier would allocate product to them as a buying firm. Other strategies from this organisation involved with making doors for homes, is recollecting returned doors, disassembling them, and using parts that are prone to shortages in new doors, instead of trying to order these parts from a supplier.

Lastly, a strategy mentioned by this purchasing professional is explained by viewing yourself as a supplier as well. To elaborate, when your own supplier is facing a shortage through a specific reason, you can decide to supply your own customers with an unfinished product. To relate this to the door market, if a specific lock in a door is facing a shortage, the organisation can decide to supply its customers the door without this lock, leaving the customer to find a lock supplier on its own. This principle can also be translated to other markets, for example the

wholesaling market, because a wholesaler can decide to only supply ingredients to customers, instead of a finished product, due to shortage of a single ingredient in this finished product. This strategy, however, is not applicable to healthcare, as drugs, PPE and diagnostics (equipment) simply are procured as finished products.

## **6. CONCLUSION AND DISCUSSION**

### **6.1 Conclusion**

The three interviews have led to several changes to the proposed typology. A new and final typology is established, serving as a conclusion to this thesis. This final typology is based on the proposed typology, in combination with feedback given from respondents. This has led to a more elaborate typology, also addressing which strategies presented in the typology are specific to healthcare or possibly applicable beyond solely the healthcare sector. The strategies below are strategies to be adopted by procurement experts to tackle shortage, in other words these are the strategies found through literature research and interviews that answer the research question of this study.

#### **Strategies to be adopted by procurement experts to tackle shortages are the following:**

General strategies to tackle shortages

- Diversification of supply sources
- Maintaining buffer stock to manage spikes in demand
- Forming a strategic partnership, in which suppliers are viewed as preferred suppliers from a buying perspective and buyers are viewed as preferred customers from a supplier perspective
- Sourcing alternative supplies
- Forming a buying alliance

Strategies to tackle shortages specific to healthcare

- Exploring alternative treatments in cooperation with medical personnel
- Reallocating resources in conversation with medical personnel

Changes made, when compared with the proposed typology are that the strategy ‘preferred customer status with suppliers’ has been changed to ‘forming a strategic partnership, ... from a supplier perspective’, as feedback mentioned that in practice organisations tend to look from a relational point of view, which also incorporates the view of the buying firm, as a relationship is two-sided. Additionally, forming a buying alliance has been added as a general strategy, as buying alliances can help in tackling shortages through two advantages mentioned in chapter 5.1.5. The strategies presented in the typology above can help purchasers in dealing with shortages, both within and outside of the healthcare sector. This research has build upon existing research on underlying factors causing shortages and responses of buyers to shortages, specifically in three product categories in the healthcare sector. By zooming out and looking at common characteristics, the typology presented above was created, to give purchasers extra tools to deal with product shortages, as the strategies presented in the typology are proven useful both in theory and in practice.

The 7 general strategies presented in the typology are found through literature research and input from respondents. All 7 will be explained more elaborately.

- To tackle shortages a good response for buyers is diversification of supply sources. When a shortage exists buyers can look at other suppliers or supply sources to make sure that they still have access to the product. Buyers should keep options open to make sure that different options and suppliers are available.
- Sometimes demand might rise due to various reasons. An example could be the seasonal demand of cough syrup mentioned before, which mainly happens during the winter period. When buyers know that every winter a higher demand exists for cough syrup, they might anticipate beforehand and make sure that buffer stock of cough syrup exists, going into the winter. That way, a shortage might be prevented thanks to this anticipation of buyers.
- A strategic partnership between supplier and buyer might help buyers in securing products prone to shortages. If supply is not sufficient to provide all buyers, a supplier might give preference to buyers it has a good relationship or partnership with. Having a strategic partnership can help buyers in attaining products in shortage. Having a strategic partnership with a single supplier is contradictory to the response 'diversification of supply sources', however if a single supplier can assure that you as a buying firm are preferred over other buyers, diversification might not be necessary. In other words, buyers should evaluate per product if a diversification strategy or if a strategic partnership strategy is needed.
- Sometimes a specific product has alternatives that work similarly. If this is the case, buyers can decide to switch to an alternative, if the original is in short supply. Buyers should evaluate products to gain knowledge of potential risks and availability of alternatives.
- Forming a buying alliance is related to forming a strategic partnership. That is, because by forming a buying alliance buyers can create a stronger position in relation to a supplier. By making sure that volumes ordered are larger, the supplier might consider the buying party an important buyer, which leads to this buyer taking preference over other buyers. Forming a buying alliance can thus potentially lead to this buyer being a preferred customer, simply through volume ordered.
- Exploring alternative treatments in cooperation with medical personnel is similar to sourcing alternative supplies. However, this specific response differs from sourcing alternative supplies because sometimes in healthcare the opinion of medical professionals must also be incorporated. To give an example, a buyer might see a drug that is a good alternative for another drug that is prone to shortage, however this alternative drug might have side effects when combined with other often prescribed drugs that the original drug does not have. This might not be known to a buyer, but is known to a medical professional. So for specific products the input of a medical professional is absolutely necessary.
- Reallocating resources in conversation with medical personnel is the last response of buyers. When PPE is in short supply in the cardiology department, but not in the surgery department, on paper it might make sense to replace this PPE from surgery to cardiology. However, before acting on this, the opinion of medical personnel must be incorporated, as these employees know the actual situation from practice. For example, surgery might have a large amount of surgeries planned, for which extra PPE is needed, which is why PPE cannot be replaced to another department within the hospital. So procurement and supply chain can only act in correspondence with medical personnel.

Furthermore, a reflection must be made on the sources used during the results section of this thesis. As briefly mentioned before, a distinction between healthcare department analysis and product categories analysis must be made. Both section of this report try to find causes-impacts-

responses for shortages, however (insights from) sources differ between these sections. The section about the different healthcare departments and causes-impacts-responses for the shortages in these three different departments is mainly from sources with a clinical perspective. Shortages are analysed from practice in these instances, with clear clinical examples. Responses are mostly used in practice. For the section about the different product categories this is different. Shortages are often analysed from theory in these instances, which is a major difference with the section about departments. That is, because a lot of policy documents can be found regarding this section, which means that the responses are proposed by e.g. governments instead of proven in practice.

## **6.2 Implications**

This thesis has implications both for literature and for practice. Regarding literature, vast amounts of literature on shortages in healthcare existed, in all three product categories and departments analysed in this thesis. Literature existed on underlying factors causing shortages in drugs (Mazer-Amirshahi et al., 2014), underlying factors causing shortages in PPE (Cohen & van der Meulen, 2020) and underlying factors causing shortages in diagnostics (equipment) (Behnam et al., 2020). Additionally, literature existed on responses of buyers to shortages in drugs (Shukar et al., 2021), responses of buyers to shortages in PPE (Peeters et al., 2021) and responses of buyers to shortages in diagnostics (equipment) (Knezevic et al., 2022). However, no literature existed creating an overview of underlying factors causing shortages and responses of buyers to these shortages across the three product categories drugs, PPE and diagnostics (equipment). By moving beyond looking at a response to a shortage within a specific product category or a single healthcare department, potential best-practice responses from independent product categories within healthcare can be gathered, which can as a result be used in different product categories as well. In other words, the thesis adds to existing literature in stating (through extensive literature research) that different types of shortages can be dealt with in similar ways. The creation of an overview of underlying factors causing shortages and responses of buyers to shortages across these product categories is thus a novel approach. Furthermore, the results found through the literature research are combined into a figure, which presents specific responses of buyers to specific causes of shortages (figures 12.1 and 12.2). For example, a shortage caused by X can be responded to in ways A, B and C. An extensive combination of specific types of responses to specific types of causes of shortages was not present in theory either.

Additionally, the thesis has also an implication for practice. The thesis serves buyers with the possibility to look at generic responses to shortages in specific product categories and in a specific sector. Seemingly proven in different product categories in this specific sector, responses might also be tried in new product categories, not analysed in this thesis, both within and outside of the healthcare sector. In other words, this thesis is able to generate a new insight for procurement professionals, which might be an addition to the way procurement professionals currently handle shortages associated with their specific products and product markets and sectors. Again, figures 12.1 and 12.2 give actual responses for buyers to take when shortages caused by specific reasons occur. So if a buyer is able to find the cause of a shortage, this buyer knows what response to have, based on the findings of this research from literature and interviews.

### **6.3 Limitations and future research**

Several limitations to this research exist. The first limitation is the size of the dataset used to gather the results. It could have been more extensive, to gain a better grasp of the actual situation in literature. A larger sample size gives a more realistic and reliable portrayal of reality. However, due to time constraints, the sample size was the size it was. The same reasoning applies to the sample size of the semi-structured interviews. With more time, a larger sample size could have been made to collect a larger amount and a more diverse set of experts' opinions. Again, due to time constraints, the sample size was decided to be as large as it was. Future research should aim to retrieve even more data from academic articles, policy documents and secondary sources. Another limitation lies in the fact that all interviewees were working for (healthcare) organisations in the eastern part of the Netherlands. This does not create a problem in itself, as the insights were still very valuable, however it does create a limitation, as it does not eliminate the risk of regional preferences, so for future research the recommendation is that respondents from all parts of the Netherlands are incorporated. Following this reasoning, the fact that all interviewees are from the Netherlands is also a limitation. It does create a good overview in case of answering the research question in a Dutch context, however to also move beyond borders interviewees from other countries should also be included. The limitation lies in the fact that the interviewees' input is not transferable to a foreign context.

Other important limitations lay in the literature in the dataset itself, as for example most articles about shortages in PPE were about the shortages during COVID-19. In other words, the existence of COVID-19 and related literature had such an enormous impact on existing literature, that during data searches mostly data about COVID-19 related shortages would appear. Further research could be done by dividing literature about shortages related to COVID-19 and other shortages. This creates separate types of research, which are distinctively different. A last limitation of this research lies in the fact that literature is often overlapping. In this thesis, three product categories were used, i.e. drugs/medicines, PPE and diagnostics (equipment). However, generally these are not distinctive product categories in research. For example, some drugs are used both as separate drugs, as well as diagnostics, such as radioactive imaging agents (Josephson & Rudin, 2013). These drugs are strictly speaking drugs and as a result fall within the product category 'drugs' in this research, however they are also used to trace pathogens in radioactive imaging, which means that these could also be classified as being part of the product category 'diagnostics'. The dividing line is sometimes thus very blurry, which is a limitation of this research. In further research, researchers should move beyond product categories and simply speak of shortages of products in healthcare, to eliminate this limitation.

Lastly, also future research exist which is not related to the limitations of this study. For example, by analysing even more product categories, except for the three used in this study, or by analysing even more hospital departments, except for the three used in this study. Another type of future research might look beyond hospitals, while remaining within healthcare, also incorporating other healthcare institutions such as general practitioners or nursing homes. While the main aim of this research was to find generic strategies, in this study also some specific strategies to specific causes of shortages were found. Future research could maybe elaborate on this, by looking at even more causes of shortages or other specific responses that might be useful in practice.

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