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Inventory management in hospitals: a case study at UZ Leuven (department of radio pharmacy)

CONFIDENTIAL

Project Master's Thesis submitted by
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with a view of getting the degrees

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Master in Business Engineering, professional focus

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Foreword

In this research project, I will study the procedure of receipt, storage and removal of inventories at the radiopharmacy department of UZ Leuven. On top of the analysis of the current procedure and its issues, I will develop a suggestion solution by means of a VBA tool and a suggestion for further developments of the system.

After finishing a group project last year in this department, my interest in the inefficiencies that are still in place in many hospitals today was risen. For my master's thesis, I contacted the department again and after a discussion of several issues they were facing, this project was chosen because of its close link to one of my majors of supply chain management. Furthermore, I could also adopt the insights gained from my second major of corporate finance.

As I felt like my suggestion solution would improve the department's performance, thereby decreasing time losses and inconvenience for personnel members, I was truly motivated to write this master's thesis. However, the realization of this helpful tool for the personnel members would not have been possible without the data provided by the department.

Therefore, I would like to express special thanks to the main contact person for the project, dr. Kim Serdons, as well as the other staff members that have replied my emails and completed the questionnaire to prioritize the issues: Sofie Raets, Julie Vancraeynest and Marva Bex. Apart from the contact persons at the hospital, the main supervisor for this thesis, prof. Pierre Semal from UC Louvain, provided me with helpful insights and constructive feedback, for which I would like to thank him. Additionally, the supervisor from KU Leuven, prof. Monique Snoeck, is also thanked for willing to be a part of this project and her presence and questions at the oral defense. Finally, I thank Estelle Tonon, the coordinator of my double degree programme for her efforts into informing me about the master's thesis guidelines. I am also grateful for the support from my environment, in particular friends and family, throughout the execution of the research project.

Sofie De Block

13/08/2018, Paal-Beringen

Contents

1. Introduction

The topic of this research was chosen as a succession of an earlier research project in the radio pharmacy department during the course of 'Seminar operations management' thought at KU Leuven. These research projects in hospitals have gained importance with rising pressure from governments and society on hospitals in general to limit costs without harming quality provided to patients. Hence, efficient and effective management of hospitals has become incredibly important. The main objective of this text is to develop an improved process of receipt and storage of products in the radio pharmacy department of UZ Leuven. This hospital has a special characteristic, namely the fact that it is a university hospital and therefore it is involved in research and education on top of providing health care.

In order to have a more general idea about the complexity of the hospital, some general company information is provided first, followed by a bit more detailed information about the department itself. The general company information includes information concerning the organization, financials, human resources and vision for the future of the hospital. The latter is especially important as it indicates how the hospital wishes to address the challenges in the health care industry that were mentioned above. Human resources cannot be disregarded in the healthcare industry either, as it is a particularly labor-intensive industry in which the quality provided strongly depends on the skill of workforce. The financial information provided in this text is rather limited due to the lack of financial reporting that is made publicly available by the hospital. The information provided in these first two sections is therefore mainly based on internet sources provided by the hospital itself as well as external internet sources.

After the company and department introduction, the as-is process of receipt and storage of goods is thoroughly discussed, based on procedure documents provided by the department. Additional focus is given to the type of inventory that is held by the department, comprising of two key points. First, the products are categorized based on an incomplete product list provided by the hospital, thereby obtaining essential information on suppliers. Secondly, a description of raw materials, work-in-progress, finished goods and goods for the purpose of maintenance, repair and operations is provided.

Before starting the analysis of the as-is process, the literature is reviewed from several points of view. First, an idea on why some level of stock is held by companies in general is developed. Secondly, the literature concerning inventory management in firms in general is considered, followed by a special point of attention of expiring products. Finally, a review of the inventory

management systems that are often used in hospitals will be discussed. In addition, special attention will be given to DMAIC and lean management, as the involvement of people is essential in the industry and lean management was set as one of the focuses of the hospital's business practices in the vision for the future. For the literature review, sources used are journal articles as well as books and a few internet sources.

After the literature review, the as-is process will go through the DMAIC cycle. Therefore, the issues in the current system are first defined by means of a few interviews with the contact person for the project which were further completed by a questionnaire that was distributed to all personnel members involved in the procedure. The questionnaire serves as a basis for the prioritization of the defined issues, focusing on three aspects that are affected by the issues, being the financial results of the department, the inconvenience for personnel members and the quality of patient care and research. Consecutively, the issues are quantified and measured when possible with information that was provided from the interviews as well. In a third step, the issues are analyzed: in order to identify the root causes of these issues, an Ishikawa diagram, better known as the fishbone diagram is used. From the insights gained from the Ishikawa diagrams as well as the literature review, a first step towards an improvement of the as-is procedure is developed. The solution consists of a visual basic application in Excel. However, this solution is not perfect due to restricted professional programming skills and a consistent lack of data to develop a complete inventory model. Therefore, in the final step of controlling, the reader can find a discussion on how the solution provided can be used in the future to measure the room for improvement on the different aspects. It will therefore generate some key performance indicators that can be used to further improve the system in the coming years. Suggestions for future improvements are discussed in the conclusion as well as some personal opinions about the way these should be handled.

2. General company information

UZ Leuven, the university hospital of KU Leuven in Belgium, serves patients from all over Belgium and even from abroad. Moreover, it is the largest Belgian hospital with 1,995 available beds in April 2018 (Informatiesteunpunt zorg en gezondheid, 2018). The first roots of the hospital stem from 1080 and the link with the university exists since 1426. However, the official inauguration of UZ Leuven took place in 1928 (UZ Leuven, 2018a). After the split of KU Leuven into KU Leuven and UC Louvain in the seventies, the hospital was one of the pioneers in Belgium in the integration of different medical and paramedical departments in one single hospital, which obviously benefited the quality provided in health care (UZ Leuven, 2018b). Today, the hospital's mission comprises three key points: qualitative healthcare, research and education (UZ Leuven, 2018c). To achieve its goals, the hospital consists of four campuses spread around the city of Leuven (UZ Leuven, 2018d). Altogether, in 2017, they served over 35,000 oncological patients, they took care of over 60,000 emergencies, they performed more than 300 transplantations and they executed almost 60,000 surgical procedures (UZ Leuven, 2018e).

2.1 Organization

The hospital is organized in several departments, in particular, 150 medical departments. The board of directors with chairman Prof. Dr. Wim Robberecht, consists of both medically educated people as well as people with a background linked to business. The executive director of the hospital is Prof. Dr. Marc Decramer (UZ Leuven, 2018f). For the daily management, he is supported by several directors, that just like the board of directors have both business and medical backgrounds.

When investigating the legal forms of the three university hospitals in Flanders, there is little consistency that can be found. UZ Gent is organized in the legal form of a public organization that is part of a public university and is not required to publish its annual accounts. UZ Antwerpen is organized in the legal form of a private not-for profit organization and its annual accounts for 2016 were retrieved from the national bank of Belgium. UZ Leuven, the hospital under study here, is organized as a private organization that is part of a free university and no financial accounts could be found. (FOD Volksgezondheid, 2018; Nationale Bank van België, 2018)

2.2 Financials

In general, Belgium spends around 10% of its GDP on healthcare, resulting in a budget of €139 million granted to the seven Belgian university hospitals in 2013. This budget is divided among the university hospitals according to the number of doctors in spe and the number of internship supervisors. The hospitals are advised to spend 60% of their budget on human resources, 25% on research and development and the remaining 15% on education and training. The RUZB, which is the umbrella organization of the university hospitals, has highlighted that the budget is rather small compared to foreign hospitals in return for their realized turnover, which was €3.2 billion in 2013. Furthermore, the organization has expressed its concerns that the ongoing savings by the Belgian government on healthcare spending could negatively affect the quality offered by healthcare institutions. (Raad van Universitaire Ziekenhuizen van België, 2014a)

As a consequence of ongoing complaints from the industry, the Belgian government has established a consultation of all parties involved in 2014, including the RUZB. The goal of the consultation being to discuss the problems of the current system, such as complex regulations and little transparency in operational and financial reporting. Concluding from the consultation, the future improvements of the system should be based on accountability, value for money by further integrating the medical and non-medical policy, without losing the focus on quality while dealing with the rather difficult economic situation of ongoing savings. (Raad van Universitaire Ziekenhuizen van België, 2014b)

UZ Leuven has realized a turnover of €760 million and profit around €15 million in 2012, resulting in a profit margin of 1.97%, compared to a profit margin of 1.21% for UZ Antwerpen and 1.71% for UZ Gent (De Tijd, 2012). Unfortunately, no further financial information specifically for UZ Leuven can be given as no financial report for UZ Leuven was found. However, the financial report of 2016 for UZ Antwerpen can be used to discover which aspects are important in the balance sheet of university hospitals and to assess its liquidity, solvability and profitability.

When reviewing the balance sheet, one can immediately recognize that tangible fixed assets are the most important part of the fixed assets. Indeed, hospitals generally own large buildings and highly valuable technological equipment. The intangible fixed assets and financial fixed assets on the contrary are of minor importance. Concerning the current assets, receivables are a substantial part and remarkably, little value is kept in inventories. From the liability side, UZ Antwerpen has a debt-to-equity ratio of 0.42. Hence, with a general guideline of not having a

debt-to-equity ratio that exceeds 2, there are no solvability concerns. Moreover, the debt consists mostly of short-term payables to suppliers as well as to human resources. As these current liabilities are less than half the current assets, reflected by a current ratio of 2.16, there are also no liquidity concerns. Finally, from a profitability perspective, one can conclude that UZ Antwerpen did not realize any operating profit in 2016 nor in 2015. The key operating costs are purchasing of inventories and payment of salaries. The lack of profitability might be attributed to the too low budget of €105 million granted by the government as was described above. However, as was stated in the introduction, it might also help to improve inventory management in hospitals in order to boost profitability. (UZ Antwerpen, 2017)

2.3 Human resources

In order to serve all patients' needs, the hospital employed 10,444 employees in 2016, corresponding to 7,904 full-time equivalents. One should note that these figures include the employees of Z.org KU Leuven, a separate organization which works closely together with UZ Leuven and is therefore considered as a true partner. As is shown in Figure 1, 16% of the

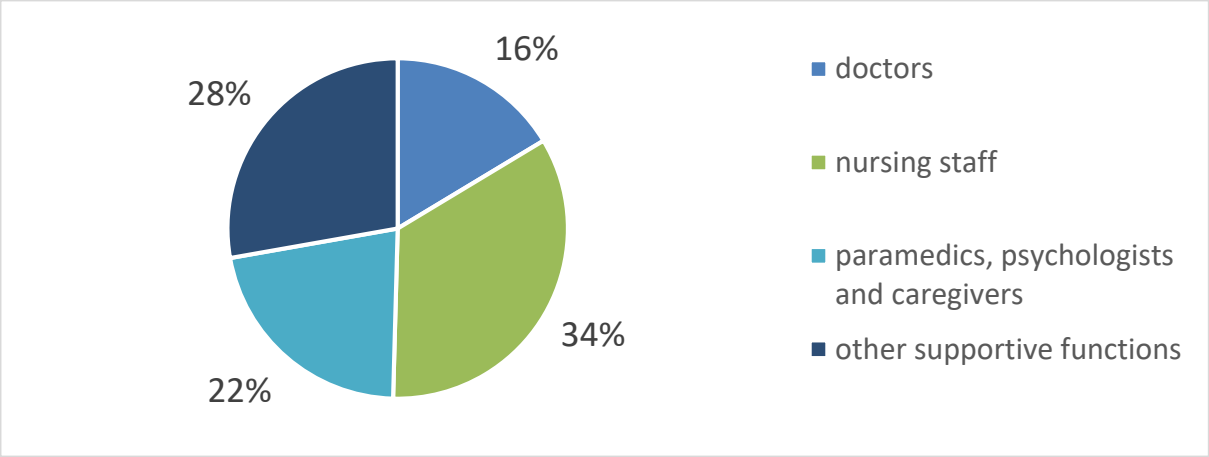

Figure 1: graph of human resources UZ Leuven (retrieved from http://jaarverslag.uzleuven.be/2017-in-cijfers/)

employees are doctors, 34% is nursing staff, 22% are paramedics, psychologists and supportive caregivers. The remaining part are supportive functions in business aspects such as administration. In general, the university hospitals have a significantly higher number of doctors compared to regular hospitals. In fact, the percentage of doctors working in UZ Leuven equals the average of 16% in university hospitals, whereas the average percentage in regular hospitals equals 12%. The majority of the workforce is female, with only about one fourth of the workforce being male (UZ Leuven, 2018e). A final important remark is that a substantial part of the medicine students are trained in the university hospitals rather than in regular hospitals, which is of course logical since the link with the university is simply closer

(Agentschap Zorg en Gezondheid, 2016). As a result of their excellent labor environment, the hospital was certified with a top employer certificate in 2017 (UZ Leuven, 2018g).

2.4 Vision for the future

Healthcare institutions nowadays face two main challenges. On the one hand, patients and society in general have increasing expectations concerning medical possibilities and expect qualitative care at all times and in all conditions. On the other hand, governments experience pressure on budgets, causing savings in investments and budgets for healthcare institutions. Consequently, a strong vision is needed to be able to keep responding to society's needs, even though resources might become more restricted. UZ Leuven's vision for the future consists of seven key focuses on top of the desire for an improved financing system, which was already discussed above as one of the goals of the consultation conducted in 2014. These seven key points will be discussed below.

A first focus of the policy for the future is value creation by innovating the care models. The hospital is convinced that innovation can be boosted by creating a bottom-up organization in which hierarchy is of minor importance. Furthermore, it is believed that gathering big-data will further contribute to the value that can be created, as opportunities might be detected more easily. Finally, the emphasis on 'patient empowerment' will remain an important aspect throughout everyday operations.

In order to be able to innovate, clinical research is a key factor and it is thus no surprise that boosting research is incorporated in the development plan of the hospital. More specifically, the Clinical Trial Center will serve as a coordinating organization for information sharing, financial streamlining and human resource management. Furthermore, in the future, medical ethics will remain an essential point of discussion and should not be disregarded.

Thirdly, the hospital wishes to tighten the collaboration with the university, especially focusing on the research and development of diagnostic and therapeutic techniques. More specifically, the interaction will be developed thanks to a ground-breaking integration of the hospital and the faculty of biomedical sciences through a one billion investment in the Health Sciences Campus.

A fourth emphasis in the policy development plan is networking and community building with other hospitals as well as with the political world. Fifthly, the hospital will continue to focus on attracting and developing talented workforce by means of open communication and constructive feedback. The sixth focus is internationalization: stimulating international career

opportunities and exchanges, being able to help more foreign patients that need specific treatments with specific technology and sharing expertise with organizations in development aid.

A final yet not unimportant point of attention will be further optimization of business practices. However, one should highlight that this is not a goal in itself, but rather a way to achieve the company's mission of qualitative healthcare, research and education. Because of the fact that the financing of hospitals is decided at the political level, the aforementioned networking focus is even more important. From a more operational point of view, the hospital wishes to achieve greater efficiency levels through lean management and automation of processes where possible. Furthermore, a simplification of administrative processes in which the company seeks to decrease costs without giving in on quality will be required in the future, as pressure to decrease costs in the industry is rising. It is exactly to this last emphasis of the policy plan that was set out in 2015 that this research will contribute. (UZ Leuven, 2015)

3. Radio pharmacy department

The specific department under study throughout this research project is the radiopharmacy department of UZ Leuven, which is led by Prof. dr. Guy Bormans and is part of the Nuclear Medicine and Molecular Imaging division led by Prof. Dr. Koen Van Laere. Apart from the radiopharmacy staff, the nuclear medicine division also comprises of research staff including PhD and postdoc students, a medical consultant, medical physics staff, technologists at a research, clinic and radiopharmacy level, residents-in-training and administrative and scientific assistance personnel. The main contact persons for this work were dr. Kim Serdons, who is part of the radiopharmacy staff, and Sofie Raets, who is a technologist at the radiopharmacy level and hence works closely together with the radiopharmacy staff. (Nuclear medicine and molecular imaging, 2018a)

Like any department in the university hospital, the Nuclear Medicine and Molecular Imaging department is involved in all four aspects of university hospitals: health care, research, education and community service. From the health care point of view, the focus is on optimization of diagnostic imaging through PET and SPECT scans as well as of providing optimal therapy. The division further highlights that research and knowledge transfer should be complementing one another. Through its close link with the university, the hospital seeks to educate students by providing them with specific problem-recognition, -formulation and -solving skills on top of factual knowledge. The last aspect of community service is sought through sharing of expertise with governments, organizations and companies. Through all of these four aspects, stimulating human skills, professional expertise and a sense of responsibility combined with continuous education are essential points of attention in the division's personnel management. (Nuclear medicine and molecular imaging, 2018b)

4. Defining the current situation

4.1 Description of As-is procedure

Before starting the description of the current procedure for the goods receipt and storage in the radio pharmacy department, a distinction is made between several types of products that will have a different storing procedure. A first group of products are the solvents and solids. Solvents are defined by Rhodes & Croft (1978, p.181) as *"The constituents of a solution that are present in larger amount, or constituents that are liquid in the pure state, in the case of solutions of solids or gases in liquids"*. Secondly, a group of commonly used goods such as microbiological growth media will require a different procedure. A third group of products are the non-radioactive reference compounds and specific radiolabeling precursors (KU Leuven Radiopharmaceutical research, 2018). Simply put, as the names indicate, these are products that are added to other substances with the goal of labeling them (European Medicines Agency, 2009). Fourthly, the sterile materials that are retrieved from the internal hospital pharmacy comprise another group of products.

A first step in taking care of the incoming goods is checking whether the goods are intact and whether the goods are of desired quality. The information on orders that were placed is kept manually in the People Soft folder and when the order is received, the order is crossed out. An abstract of this folder is shown in Figure 2. The values that are looked for when the order is received are highlighted. Even though there is rarely a lack of quality, it happens more often that only a part of the order and thus not the full amount is being supplied.

Aanvraagnr: 721293 - BEX Req. date: 23-05-2018 Page 1 van 2
Bestelunit: 1645 - FD GHB 3/0 * E901 PET-RADIOPHARM. Status: Doorsturen
Project :

Setid	Artikel	Omschrijving	Aantal	Verpak.	Bedrag	Leverdatum
POSET	LA7175	LABCOAT ADV SPP WHITE ELAST L - 25/DS	10,00	DS	79,86 EUR	30-05-2018
	Leverancier:	0000008786 - VWR INTERNATIONAL		Lev.ref.:	113-1147	
	HATS	: 100 - AFDEK-EN PROTECTIE-MATERIAAL				
	ATS	: 020 - AFDEK- & PROTECTIEMATERIAAL : STAF				
	SUBATS	: 060 - ANDER AFDEK-& PROTECTIEMATERIAAL STAF				
	REQ-ID	: [illegible]				
POSET	LA7176	LABCOAT ADV SPP WHITE ELAST XL - 25/DS	5,00	DS	81,80 EUR	30-05-2018
	Leverancier:	0000008786 - VWR INTERNATIONAL		Lev.ref.:	113-1148	
	HATS	: 100 - AFDEK-EN PROTECTIE-MATERIAAL				
	ATS	: 020 - AFDEK- & PROTECTIEMATERIAAL : STAF				
	SUBATS	: 060 - ANDER AFDEK-& PROTECTIEMATERIAAL STAF				
	REQ-ID	: 0001732063 Lijn: 2				
POSET	LA7177	SHOECOVER ANTISKID PP LAMINATED WHITE - 400/DS	5,00	DS	66,67 EUR	30-05-2018
	Leverancier:	0000008786 - VWR INTERNATIONAL		Lev.ref.:	113-8287	
	HATS	: 100 - AFDEK-EN PROTECTIE-MATERIAAL				
	ATS	: 020 - AFDEK- & PROTECTIEMATERIAAL : STAF				
	SUBATS	: 050 - SCHOENOVERTREKKEN				
	REQ-ID	: 0001732063 Lijn: 3				
POSET	111872	COVERALL MAX SF WIT COL/BO ELAST M, 25 STKS/DS	5,00	DS	109,02 EUR	30-05-2018
	Leverancier:	0000008786 - VWR INTERNATIONAL		Lev.ref.:	113-1085	
	HATS	: 100 - AFDEK-EN PROTECTIE-MATERIAAL				
	ATS	: 020 - AFDEK- & PROTECTIEMATERIAAL : STAF				
	SUBATS	: 060 - ANDER AFDEK-& PROTECTIEMATERIAAL STAF				
	REQ-ID	: 0001732064 Lijn: 1				
POSET	111873	COVERALL MAX SF WIT COL/BO ELAST L, 25 STKS/DS,	4,00	DS	109,02 EUR	30-05-2018
	Leverancier:	0000008786 - VWR INTERNATIONAL		Lev.ref.:	113-1086	
	HATS	: 100 - AFDEK-EN PROTECTIE-MATERIAAL				
	ATS	: 020 - AFDEK- & PROTECTIEMATERIAAL : STAF				
	SUBATS	: 060 - ANDER AFDEK-& PROTECTIEMATERIAAL STAF				
	REQ-ID	: 0001732064 Lijn: 2				
POSET	111875	COVERALL MAX SF WIT COL/BO ELAST 2XL, 25 STKS/DS	2,00	DS	102,85 EUR	30-05-2018
	Leverancier:	0000008786 - VWR INTERNATIONAL		Lev.ref.:	113-1088	
	HATS	: 100 - AFDEK-EN PROTECTIE-MATERIAAL				
	ATS	: 020 - AFDEK- & PROTECTIEMATERIAAL : STAF				

Figure 2: extract of folder PeopleSoft

After being crossed out in the general order folder, the received products are registered in lists per type of goods. A depiction of these registration lists can be found in Appendix 1, A & B. Note that for the fourth product category, the sterile materials from the internal pharmacy, the products are even registered on a separate list per product (Appendix 1, C).

After the completion of the registration, an orange sticker is put on all the products except on the sterile materials from the internal pharmacy, indicating that they are waiting for the required identification and/or documentation. The solvents and solids with an orange sticker that do not need to be cooled are stored in a strong box. On the other hand, those goods that do require to be kept at certain temperatures are stored in a fridge. The frequently used goods with an orange sticker are put in a regular rack. The precursors and references are put in a freezer or in a closed container in a fridge. As the sterile materials do not need any identification and/or documentation, these are immediately stored in their place of use in case there is available space to put them, if not, they are stored in one of the stockrooms.

The storing procedure for the sterile materials is finished now. However, the other products have to wait until the required identification and/or documentation is retrieved. When the identification requirements which can be found in the folder 'product identification' and the documentation requirements such as the certificate of analysis which can be found in the folder 'analysis certificates' are fulfilled, the responsible personnel member signs the QA in the registration lists and the orange sticker is replaced by a green sticker, meaning that the product is ready for use.

On top of the green sticker, some products get another sticker with more detailed information about the product. The sticker that is put on solids and solvents contains information on lab number and expiration date, as is shown in Figure 3. However, some of these products will be due earlier because they can only be used until a certain period after the opening of the packaging. For example, anhydrous solvents for synthesis reactions only have a one-month shelf life after their first use. Therefore, they get a sticker as is shown in Figure 4 and the third line is filled in when the product is used for the first time. The products that are subject to a shortened shelf-life after opening are listed in the form of the overview of products with a limited shelf life after

Figure 3: sticker for solids and solvents

Figure 4: sticker for anhydrous solvents for synthesis reactions

opening, which is revised every three years. The limited shelf life terms are 1 month, 3 months or 1 year, making it possible to use these stickers. However, if there were more possibilities, the use of stickers would not be efficient anymore. An overview of the last revision stemming from 2016 can be found in Appendix 2. The precursors and references also get a sticker with information on their expiration date. Concerning the frequently used goods, there is only one type of products, namely the microbiological growth mediums, that get an extra sticker indicating that their growth-enhancing functions have been tested.

After having a green sticker and an extra sticker if required, the products are stored again waiting to be used. The solvents and solids are moved to the stockrooms, except the ones that need to be cooled. The latter are immediately put in the place where they will be used. The same applies for the frequently used goods and the precursors and references.

For the use of products, the department tries to adopt the first-in-first-out method by putting the products that are stored in the back, as is done in for example supermarkets. In this way, the expiration of products is avoided. However, a regular check of the inventories' expiration dates is necessary to prevent expired products from being used. For the solvents and solids, the inventory is checked every three months and those products that will expire in the next three months are highlighted in red. In addition, those products that expire in three months are ordered at the same time of the inventory check. For the precursors and references, an excel file is used to indicate the expiration dates of all the products in the inventory. Finally, for the sterile materials, a similar approach is adopted as for the solvents and solids: the products that will expire within three months are listed and this list is hung up in the stockroom.

In a final step of the inventory procedure, the products that are expired get a red sticker before being temporarily stored until they can be removed in the right way, as the department is dealing with radioactive substances. However, the procedure of removing products will not be included in the scope of this research.

4.2 Type of inventory

Before entering the review of the literature and the analysis of the issues in the current procedure, it is important to identify which types of inventory are held by the department. From a list of products that was provided by the department, the 228 different products can be categorized. However, one should note that the department personnel had been working on the list only recently and therefore it is not complete yet. One can distinguish eight head product categories. The broadest category is the laboratory, analysis material and chemical products,

with category code 320 and contains 153 different products. For a complete overview of the product categories that were identified from the incomplete products list, being the Head ATS, the ATS and the SUBATS, the reader is referred to Appendix 3. In the categorization, the reader can find the codes, names and number of products in each category.

The 228 products that were categorized before, are supplied by 37 vendors. Some of these suppliers produce products from multiple product categories, whereas others such as Acros and Avery Zweckform only deliver products from within one category or even only one product, like Clippard Europe SA. VWR, the major supplier, is the only supplier for products from head ATS 100 and is especially important for product categories 320-10-126 and 320-80-110. As was already indicated above, some products are delivered from the internal hospital pharmacy instead of directly from an external supplier. In Appendix 4, an overview of the number of products supplied by the suppliers per product category is depicted. These insights will be particularly helpful in the tracking of performance of suppliers and assessing their impact on the management of inventories at the level of the department.

Apart from the categorization of products as was established above, one should also look at whether the inventories consist of raw materials, work-in-progress or finished products. When assuming that the finished product that is produced by the department is a service rather than a product, one can state that the products in the inventories are raw materials and work-in-progress inventories that will be combined in order to provide patient care and conduct research. For example, when the department wishes to prepare a certain therapy for a patient, personnel members will use shoe covers, sleeve covers, various substances, a bottle and a cap, and so on. When this therapy dose is ready to be used, it is not held in the department any longer. Therefore, we can assume that no inventories of finished goods are held by the department itself. Instead of stating that the products are raw materials and work-in-progress in the provision of services, one could also identify them as MRO inventory, being goods for maintenance, repair and operations. However, in this case, the MRO inventory rather consists of racks, dustbins, cleaning materials, etc.

To continue the analysis of the types of inventories that are held, two remarks have to be considered. First, many of the products held by the department can only be ordered in certain quantities because the suppliers pack them in this way. Therefore, for these products, a certain level of safety stock is always available above the stock that is needed to fulfill the demand in each order cycle. Moreover, many products are critical in the daily operations of the hospital and a stockout would cause a failure to operate. Therefore, the department tends to keep rather

high levels of safety stock for these items. However, for some products, substitutes are available in case they are depleted. For example, multiple kinds of sleeve protectors are held in the department's inventory so when one of these runs out, the personnel members can still operate in a safe manner. As a consequence, for these products, it is possible to keep levels that are lower than the cycle stock. Another product that can be substituted are the shoe covers that exist in multiple sizes. When for example size 38 is out of stock, the personnel members can simply wear size 39 for once. Yet, when all sizes are depleted, the continuity of operations is endangered. (Reference for business, 2018)

5. Literature review

Investopedia defines inventory management as the process of ordering, storing and using all kinds of goods within a company. Inventory is both an asset and a liability, as it will be used to fulfill the customers' demand, yet it also carries risk. In general, the larger the corporation, the more complex the management of stocks will become, and the better information systems will be required to deal with these complexities.

The review of the literature will start with a general introduction on the management of inventory systems in companies, by answering the crucial question of why companies hold inventories. As the review continues, the content will become more and more specific to the healthcare industry and in particular inventory management in hospitals. Special attention will also be given to dealing with products that expire, as this is especially important in the department for which a suggestion solution is the goal of this research. For the purpose of being complete, all well-known models are included. However, one should note that many of them will not be applicable in the department under study as they require information that is especially hard to retrieve on many cost parameters or the models are simply too complicated to be implemented in a department where there is no model in place yet. Another reason could be that a deep integration with suppliers is needed to establish the model, hence they become impossible to be implemented. Because of the aforementioned problems with many of the models discussed, a deeper focus will be put on lean management, which was already set as part of the vision for the future in the hospital's business practices. This approach seems the most applicable in the department under study as the involvement of people is essential in the healthcare industry. To end the literature review, several ways to address and improve the procedure will be discussed, leading to the conclusion that DMAIC will be the approach used to continue this research.

5.1 Why do companies hold inventory?

A first general question one should ask is why a company holds inventories and what factors will affect the size of the stock. Therefore, the incentives for keeping stocks will be discussed here below.

A first aspect is the fact that a company cannot order products and have these delivered at the same time. Hence, inventories serve as a buffer between the rhythm at which a supplier can deliver the products, the rhythm at which the company itself uses the product and the rhythm at

which the clients, patients in the case the company considered is a hospital, will need the product.

A second key reason to hold inventory is to deal with variability and uncertainty in the rhythms mentioned above. Customer demand, or patients' needs, will vary depending on many factors and are especially hard to predict. In addition, suppliers might not be able to respect delivery terms because of problems with machines, personnel, quality, etc. The company itself might also face constraints in the use of products in inventories, such as expiration dates in the case of the department under study.

Finally, the level of inventories will also strongly depend on costs associated with inventories. One can distinguish four types of costs associated with inventories. The first group are the ordering costs, including handling costs as well as transportation costs. Secondly, when purchasing a product, there are purchasing costs, which might for example be smaller when a larger number of products is ordered and accordingly, a discount is granted. Thirdly, keeping inventories is not for free: space is being used, opportunity costs arise due to the negative effect on the cash cycle such that the capital cannot be invested elsewhere, products decrease in value the older they get, or even expire and become worthless, registration and storing of goods requires personnel members' time and so on. On the contrary, when there is a shortage, costs will also arise making up the fourth and last group of costs associated with inventories.

5.2 Inventory models

Now that the incentives of holding inventories have been established, the literature review will be continued with the many ways to manage inventories. Decisions in inventory management include the desired size of the stock, the time at which the companies decide to order and which quantities to order, how to track the inventory levels and so on.

A first well-known model to decide on how much to order and when, is the Economic Order Quantity Model (EOQ-model) which was first developed in 1913 by F.W. Harris. The model is based on a trade-off between ordering costs and holding costs, thereby minimizing the total costs associated with inventories. The power of this model lies in its simplicity and elegance of a root-square formula which is depicted below (Erlenkotter, 1990).

$$EOQ = Q^* = \sqrt{\frac{2*D*C_o}{C_h}}$$ with

D: annual demand, assumed to be constant and known

Q*: fixed quantity ordered

Co: cost per order

Ch: cost to hold one unit for one period

However, it must be emphasized that the model's assumptions, like a known and constant demand and a supplier that respects its delivery terms at all times, are especially unlikely in the real world of corporations nowadays. It is thus no surprise that a variety of enhancements has been developed throughout the years, softening these assumptions and making the model more practically applicable (Lambrecht, 2006).

As the Economic Order Quantity is not optimal when the demand is known yet not constant, an optimal algorithm using dynamic programming was developed. In 1958, Wagner and Whitin established the Wagner-Whitin algorithm in which nor the demand nor the inventory holding costs are constant (Wagner & Whitin, 1958). Even though this algorithm leads to an optimal solution for deterministic yet dynamic demand, it requires quite some computations. Yilmaz (1992) argues that its difficulties to be applied in practice stem from the fact that the costs for many different possibilities have to be assessed. Moreover, the costs are only minimized over the planning horizon: there is no overall long-term cost minimization for the company.

As a consequence, several heuristics were developed that are quite close to the Wagner-Whitin algorithm and deviate only slightly from the optimal cost level. A first example is the Silver-Meal heuristic, which is based on a cost minimization for each order cycle. Secondly, the incremental order quantity algorithm is based on a trade-off between ordering and incremental holding costs (Yilmaz, 1992). Saydam and Evans (1989) have assessed that the Silver-Meal heuristic is seventeen times faster than the Wagner-Whitin algorithm, while the deviation from the optimal cost level was only found to be 1.6%. They also showed that the Silver-Meal heuristic is both faster and achieves a lower cost level than the incremental order quantity model, which they refer to as the incremental part-period algorithm (Saydam & Evans, 1989).

Another problem that arises from the EOQ model is that sometimes, it is simply not possible to order the cost-minimizing quantity because the suppliers are only willing to supply a certain amount or a multiple thereof. A model that can be applied to manage inventories is the minimum order quantity (MOQ) system, in which the buyer either orders nothing at all, or the minimum order quantity set by the supplier. The system is especially useful in industries where products become obsolete and in industries where orders would otherwise be too small and too frequent. As the suppliers provide less flexibility to their clients in this system, they often compensate this by not charging a fixed order cost and only charging the purchasing cost per item. (Zhao & Katehakis, 2006)

As the previous two techniques, EOQ and MOQ, might become especially complicated in case the company orders a wide range of products and they might all require different optimal quantities, or the suppliers might require different minimal quantities, the ABC analysis can contribute to a simplification of the ordering process by decreasing attention to products that are less important to the company's bottom-line. The products are classified based upon their annual use value and their amount and thus the space they use in storage. A-products are those products of which you hold least, yet they contribute most to your bottom-line. Therefore, these products should be tightly controlled and efficiently managed. C-products on the contrary demand less attention as they are less valuable to company sales and profit even though they comprise most of the inventory space. B-products are all products that fall in between the two previous classes. An important remark to make is that the annual use value is the key factor in the categorization, which might not be the ideal and only classification factor that is important, especially with companies that offer over thousands of products to their customers. Just like for the EOQ-model, many enhancements have been developed to the ABC-analysis approach, taking more criteria into account, depending on the specificities of the industry, the company and the customers. However, obviously these models become more complex and require more technical ingenuity to be solved, hence many heuristics have been established with the purpose of decreasing the complexity (Ramanathan, 2004).

As was mentioned above, the economic order quantity model as well as the aforementioned algorithms and heuristics disregard uncertainty regarding demand and supplier delivery terms, also referred to as lead times. In order to have a buffer against a higher than expected demand or a delay in delivery, companies often decide to hold some level of so-called safety stock. Hence, the company is protected against stockouts. However, it will be extremely costly to protect against all levels of increases in demands and delays in deliveries. Therefore, a typical approach is to determine a service level, indicating the accepted number of stockouts. Apart from the service level which is an indication of the percentage of replenishment cycles without a stockout, a company can also decide to implement a certain fill rate that additionally reflects the volume of the stockouts. In general, the higher the service level or fill rate, the more safety stock will be held and the less stockouts will occur. Accordingly, a trade-off is made between the costs of dissatisfied customers and the costs of keeping more inventory. (King, 2011)

Whereas the former models focus on the optimal quantities being ordered, the just-in-time approach focuses on reducing inventories to a minimum as a part of the key objective to diminish all types of waste in a company. As the name clearly suggests, in a just-in-time system,

the products are delivered at the time and in the exact quantity they are needed. The just-in-time approach has been found to provide companies with advantages of shortened lead times, reduced inventory levels and increased asset turnover. However, these results can only be achieved thanks to a highly efficient internal coordination between numerous departments as well as a well-integrated communication with external suppliers and clients. Moreover, a beneficial just-in-time system requires all the steps to be just-in-time, from purchasing to selling. Therefore, inventory reduction should not be regarded as a goal but rather as a result of a total just-in-time approach in order for the strategy to be successful. (Claycomb, Germain & Dröge, 1999)

There are two approaches that go beyond the just-in-time system in terms of integration between supplier and buyer by engaging in agreements and contracts. The first one is called vendor managed inventory (VMI) and unlike in the EOQ-model which is based on a total cost minimization for the buying party, the VMI approach aims at a coordination between both parties that remain independent. By comparing uncoordinated scenarios to scenarios with VMI and scenarios with complete vertical integration (in which both parties are no longer independent firms), Bookbinder, Gümüs and Jewkes (2010) found that total system costs are lowest with complete vertical integration. Furthermore, even though in most VMI agreements either the vendor or the customer are better-off, total supply chain system costs can be decreased by moving from an uncoordinated situation to a VMI. In order to agree on a VMI with the prospects of one party being worse-off yet achieving a total system cost saving, a compensation from the party that is better-off is suggested (Bookbinder, Gümus & Jewkes, 2010).

Next to VMI, a second approach is called consignment inventory. The difference between the two approaches is that in VMI, the products are owned by the buyer as soon as the vendor decides to replenish whereas in consignment inventory, the products are owned by the vendor until they are used. However, the products are still stored at the buying firm and this firm keeps control over the replenishment decision. The advantage for the supplier is that it can reduce its holding costs, as they can store as much as they want at the buyer. For the buyer, the benefit results from the fact that they can delay payments until they use the products, and that they do not have to take into account lead times (Gümüs, Jewkes & Bookbinder, 2008).

Valentini and Zavanella (2003) describe a particular consignment stock policy, in which an s,S model is used. Recall that s and S denote respectively the minimal and maximal stock that should be in place. Hence, the supplier will monitor the inventories of the buyer and make sure the inventory level stays between s and S. Accordingly, the buyer does not pay when the

inventory is replenished but when the inventory is used. The main difficulty in this s,S consignment inventory model is the definition of s and S levels as well as the necessity of information sharing on demand and consumption between buying and supplying firm.

A final inventory approach that has been receiving more attention recently is lean management. Whereas just-in-time focuses merely on efficiency, lean uses the efficiency created to add value (Kettering University Online, 2016). Hence, apart from the objective of minimizing inventories, lean also focuses on improving firm performance and customer satisfaction (Womack et al., 1990). Studies on lean production generally found a positive effect on financial performance as well as operational performance, including inventory leanness. However, mixed results are found concerning the direct effect of inventory leanness on financial performance (Hofer, Eroglu & Hofer, 2012). The industry, characterized by products, technologies, supply and demand, is a strong factor in the viability of inventory leanness. However, in general, the relationship between inventory leanness and firm performance is positive and concave, implying that an optimal level of inventory leanness exists (Eroglu & Hofer, 2011). Yet, Isaksson and Seifert (2014) found that the majority of companies in their sample still had not reached this optimal level, meaning that an increase of leanness can still pay off.

5.3 Dealing with expiring products

As the department that comprises the scope of this research deals with expiring products, a thorough analysis of the difficulties of managing inventories of those products will be needed. In an environment with perishable products, two challenges exist for the analysis of inventory management for companies in general. First, demand for a particular product can change as the product ages because of decreased quality, decreased utility and so on. Second, the suppliers can decide to charge higher prices for fresher products and give discounts on products that will expire sooner. (Karaesmen et al., 2011)

Nahmias (1982) considers products with fixed as well as random lifetime. Fixed lifetime products are products that are of equal value as long as they have not expired, yet after expiration, their value immediately drops to zero. Using a simple EOQ model with deterministic demand, the order size should be equal to the minimum of the optimal order size (Q*) and the size that makes sure that demand will be fulfilled without products expiring. However, when the company is dealing with uncertainty due to stochastic demand, defining the optimal policy is much more complicated. Fries (1975) developed a model in which a single product expires a certain number of periods after arrival in the inventory. The model includes a continuous

probability distribution for demand as well as costs for ordering and holding products, shortages, and disposal of expired products.

With fixed lifetime products, it is also possible to adopt a continuous inventory review system, as was developed by Weiss (1980) assuming a Poisson demand process. However, due to strong and rather unrealistic assumptions such as zero lead times, the optimal solution turns out to be ordering when there are no items left in inventory that have not expired. Moreover, in order to implement a continuous inventory management system, more innovative technologies and systems, such as Radio Frequency Identification (RFID) technology, is needed. Even though these technologies are likely to reduce outdating costs, they require some investment to be implemented (Karaesman et al., 2011).

In addition, Veinott (1960) showed that for fixed lifetime products, it is best to use a FIFO policy, meaning that products that expire first are used first. Nahmias (1985) highlights that using FIFO minimizes the number of products that are likely to expire before being used. On the contrary, in case the utility of the products decreases as the expiration date approaches, LIFO might be a better option. As this is not the case for the products used in the department that comprises the scope of this research, literature on the ordering policies under LIFO product use are disregarded here. Apart from fixed lifetime products, Nahmias (1985) additionally discusses random lifetime products, which are products that do not have an exact expiration date. For example, products with an exponential decay might require a different approach in inventory management and control. However, these products are not part of the scope of this research either.

5.4 Inventory management in hospitals

As was established in the section on why companies should hold some level of inventories, many types of costs are associated with inventories. With regard to the current pressure on hospitals to reduce costs, Norris (1988) emphasizes that too often, hospitals only take into account unit costs when trying to improve their financials. Accordingly, one should obtain insights on delivered costs, being all costs associated with inventories and procurement as were stated above, when setting out procurement strategies.

Dellaert and Van De Poel (1996) have studied the global inventory control in the academic hospital of Rotterdam. Initially, the hospital applied a R,s,S rule for every individual item, with R being the length of the review period, s being the order level and S being the order-up-to level. By replacing this strategy with an EOQ strategy, both inventories and ordering costs were

decreased. Finally, they extended the EOQ strategy to a R,s,c,S model in which the calculation of the parameters followed from the more intuitive EOQ strategy rather than calculating them in a sophisticated yet complicated way.

As the elaborated EOQ models as well as the heuristics discussed above are rather complex, they are believed to be too complicated to implement in the department under study here. Therefore, they will not be considered in the review on the management of inventories in the healthcare industry below.

Landry and Beaulieu (2010) have studied the inventory management systems used in hospitals. They emphasized that avoiding stockouts is especially important in the healthcare industry as it endangers the primary mission to provide care to patients. As a consequence, they highlight that this industry is particularly likely to overstock. In the study, they have identified two types of inventory systems: perpetual systems and periodic systems. Whereas in the former, the inventory status is up-to-date at every moment, this is not the case in the latter. However, in order to achieve a completely up-to-date inventory status, every transaction must be registered. On the other hand, in the periodic system, inventories will have to be counted at given points in time to assess the amount to be re-ordered. Hence, in the choice between a perpetual and periodic system, there is a key trade-off between the time required to register every transaction and the time required to count the inventories. Technologies used in hospitals for the purpose of perpetual inventory management are keyboards, biometric readers, bar codes and RFID-enabled cards. In addition, Landry and Beaulieu (2010) reviewed four periodic methods used in hospitals throughout the years, leading to the finding that the two-bin system performed best on three aspects: the average inventory level turned out to be lowest without harming service levels, the personnel could focus best on their primary activity of taking care of patients and the need for storekeepers was limited. (Landry & Beaulieu, 2010)

In a first step towards an integrated supply chain management in a hospital, Kim (2005) implemented a vendor managed inventory system thanks to experts employed by the supplier to be responsible for the inventory control in the central warehouse. As the experts took over this task from the pharmacists, inefficiencies were solved, inventory costs were decreased, and the pharmacists could again focus on their primary services. However, this approach requires excellent information sharing considering the use of products by all the wards.

Consignment inventory found its way to the health care industry due to fiscal concerns. One of the first implementations is found in Colorado, when Carlisle, a laboratory supplies dealer told

three local orthopedic surgeons that they would replace the hip implants when they were used. It should be highlighted that these materials are high cost - low volume items, causing that hospitals were hesitant to hold large inventories before the implementation of consignment inventory. The consignment approach has proven to be especially useful with fast-moving and wide-ranging inventories. However, Carlisle argues that suppliers should not forget to primarily focus on providing a qualitative service by making sure that there are no stockouts, that they know exactly what is needed by the buyers and so on. (Fenton & Sanborn, 1987)

Wang, Lee and Chang (2012) have studied a more recent implementation of consignment inventory management in a hospital associated with a university in Taiwan. A first implementation for some products had decreased holding costs as well as improved flexibility in cash management for procurement. Therefore, the desire to extend the consignment inventory to as many products as possible was raised by the hospital. In particular, the research concerns a single-manufacturer-single-buyer consignment agreement, in which the manufacturer produces only one, yet a perishable product. The model that is developed is based on a coordination between supplier and buyer in which the production batch and replenishment lot size are determined simultaneously, taking into account the capacity of the warehouse at the buyer location.

Research of Just-in-time approaches in the healthcare industry was conducted by Jarrett (1998). Just like Norris (1988), Jarrett (1998) argues that governments have put pressure on decreasing costs through price control efforts rather than improving operational efficiency. Furthermore, the research highlights that a zero inventory JIT approach would not be a wise decision, as it is simply impossible to exactly estimate the volume of products that will be required to take care of patients at every point in time. In addition, the delivery of defect-free products is also extremely hard to establish and requires excellent information sharing between supplier and hospital. A limited buffer is therefore suggested to deal with this uncertainty and responsibilities that are in the hands of health care institutions.

As was already briefly discussed in the general literature review section, Eroglu and Hofer (2011) have assessed the effects of inventory leanness on firm performance in different industries. More specifically, inventory leanness was measured in terms of the Empirical Leanness Indicator (ELI), an indicator that is based on a comparison of inventory leanness in equally sized firms within a specifically defined industry. They have defined nine possible relationships between firm performance and inventory leanness. The results include some

industries that are closely related to the health care industry. Below, these related industries are described according to the SICCODE description:

- The pharmaceutical preparation manufacturing industry: “Establishments primarily engaged in manufacturing in-vivo diagnostic substances and pharmaceutical preparations (except biological) intended for internal and external consumption in dose forms, such as ampoules, tablets, capsules, vials, ointments, powders, solutions, and suspensions.” (SICCODE.com, 2018).
- The surgical and medical instrument manufacturing industry: “Establishments primarily engaged in manufacturing medical, surgical, ophthalmic, and veterinary instruments and apparatus (except electrotherapeutic, electromedical and irradiation apparatus). Examples of products made by these establishments are syringes, hypodermic needles, anesthesia apparatus, blood transfusion equipment, catheters, surgical clamps, and medical thermometers.” (SICCODE.com, 2018).
- The surgical appliance and supplies manufacturing industry: “Establishments primarily engaged in manufacturing surgical appliances and supplies. Examples of products made by these establishments are orthopedic devices, prosthetic appliances, surgical dressings, crutches, surgical sutures, personal industrial safety devices (except protective eyewear), hospital beds, and operating room tables.” (SICCODE.com, 2018)
- The medicinal and botanical manufacturing industry: “Establishments primarily engaged in (1) manufacturing uncompounded medicinal chemicals and their derivatives (i.e., generally for use by pharmaceutical preparation manufacturers) and/or (2) grading, grinding, and milling uncompounded botanicals.” (SICCODE.com, 2018)

For all these related industries, an inverted U-shape relationship was found between inventory leanness and firm performance. This suggests that an optimal level of inventory leanness does indeed exist for these industries. However, whereas in the pharmaceutical preparation manufacturing industry and the surgical and medical instrument manufacturing industry the optimal firm performance is achieved with an inventory leanness above the industry average, the opposite is true for the surgical appliance and supplies manufacturing industry. In the latter industry, the optimal firm performance is achieved with inventory leanness below industry average. Finally, for the medicinal and botanical manufacturing industry, the average inventory leanness in the industry turns out to be the firm performance optimizing level. However, it should be remarked that for this last industry, only nine firms were included in the research, which might have biased the results (Eroglu & Hofer, 2011).

Consecutively, Isaksson (2014) found that for pharmaceutical products, inventory leanness of raw material and work in progress is linearly related to financial firm performance. For finished pharmaceutical goods, an optimal level of inventory leanness exists. However over 90% of firms have not reached this level yet. For medical equipment on the other hand, a linear relationship exists for work in progress as well as finished goods. For raw materials that are used in the manufacturing of medical equipment, an optimal inventory level exists too and just like for the finished pharmaceutical goods, less than 10% of the firms have reached the optimal level. An overview can be found in Table 1. Isaksson further highlights the positive effects of increasing ELI by one standard deviation on the EBIT/sales ratio, which are additionally summarized in Table 1.

	Pharmaceutical products			Medical equipment		
	RM	**WIP**	**FG**	**RM**	**WIP**	**FG**
% of firms not at optimal level	Linear	Linear	90,20%	92,50%	Linear	Linear
change in ebit/sales by one st.dev. increase in ELI	7,63%	5,69%	4,95%	4,07%	5,29%	7,55%

Table 1 : summary of results from Isaksson (2014)

A specific research on lean learning in a hospital was conducted by Ballé and Régnier (2007). Throughout the research, they emphasize that lean thinking can benefit patients thanks to its focus on customer satisfaction, safety and decreasing lead times. Furthermore, they argue that the healthcare industry is known for its high level of employee involvement, which is one of the absolute necessities to develop lean thinking and learning. As they went through the incremental lean thinking improvement process, they discovered that the management of storage capacity and inventories was at the heart of many other problems that were found. Specific problems concerning the management of inventories that were discovered are overstocking causing products to expire, understocking causing stockouts, multiple holding points and unsafe storage space. As a consequence, they state that the hospital was essentially depending on the diligent yet not flawless checks of inventories by staff. To solve these issues, staff would need to understand demand and consumption of the products and consequently define inventory levels. As a result of this understanding, they can then implement a supermarket approach, in which every product is attributed one fixed storage location that is clearly tagged, and a FIFO approach is used by putting new inventories in the back of the attributed storage locations. (Ballé & Régnier, 2007)

5.5 How to continue the project?

Throughout the years, many tools and techniques have been developed to implement a problem solution or to improve procedures.

A first tool is the PDCA cycle, better known as the Shewhart or Deming cycle and finds its use in continuous improvement processes. The acronym PDCA stands for Plan, Do, Check, Act. It was first developed by Shewhart in 1939, who emphasized that *"the cycle draws its structure from the notion that constant evaluation of management practices, as well as the willingness of management to adopt and disregard unsupported ideas, is key to the evolution of a successful enterprise."* (Johnson, 2002). However, it was Deming that established implementation of the PDCA cycle in the real world when he suggested its adoption by Japanese firms in the 1950's. The first step of planning follows when management recognizes an opportunity. Rather than trying to do it right immediately in the second step, this approach rests on the idea of doing something which is perhaps not right from the beginning, yet a lot can be learned from its execution in the check phase. The fourth and last step of acting is essential as in this step, the improvements are realized. (Johnson, 2002)

A second tool is RADAR and is used as part of the excellence model methodology to assess organizational performance in a structured way thanks to its matrix structure. The excellence model methodology states that business results can be improved through focusing on customer satisfaction, employees and impact on society. Just like in lean management, the involvement of people is key in this methodology. The matrix comprises five interconnected steps, being Results, Approach, Deploy, Assess and Refine. More specifically, after setting the desired results, a set of approaches is developed and consecutively deployed in a systematic way to be implemented. Through thoroughly monitoring and analyzing the results delivered by the approaches, the approaches are finally assessed and refined.

Thirdly, DMAIC is an approach that uses facts in a systematic way to manage projects, thereby being result-driven. In a first step, the project is clearly defined, and the issues are prioritized in order to establish on which issues the focus should be set and which issues can be ignored. A second step is to measure the key process characteristics, followed by an analysis of the key causes of the defined issues that are of great priority. The latter can be done in several ways. For example, by a root-cause search using a fishbone diagram, also known as Ishikawa. In this technique, effects are attributed to six classes of causes: manpower, machinery, materials, methods, measurement and mother nature. These six classes are also referred to as 6M

(American Society for Quality, 2018). The fourth step is to improve the process by focusing on improvement of the measured key process characteristics. Finally, in the fifth step the process is controlled, and the benefit created is tried to be sustained. Therefore, companies often implement key performance indicators to keep tracking and controlling the key process characteristics. (Sokovic, Pavletic & Kern Pipan, 2010)

6. DMAIC for the main issues in the as-is procedure

6.1 Defining the issues

The very first step of controlling the amount and quality of the goods causes a first problem to arise: when the suppliers have failed to meet the obligations in the order, the personnel members will highlight it in the general folder. As was indicated before, it often happens that only part of the amount was delivered. Therefore, personnel members must remember and check regularly if there are orders or parts of orders that still have not been received. Consequently, they have indicated that it occasionally happens that they forget about goods that were not delivered after a while.

A second point of inefficiency is that the order first has to be found in the general folder, and then a registration on another list is required, even though some of the data that need to be filled in in the registration list, such as product and supplier, are also in the general folder. As this is all done manually, the searching and registering can be time-consuming.

A third aspect one should look at when developing a solution is the facilitation of the identification and document requirements, that are now listed in folders on paper and again require quite some time to be retrieved. Additionally, remembering which products still need identification or checking it in the registration lists is another inconvenience for personnel members. Furthermore, after the required identification and documents are retrieved, multiple stickers exist, and they are put on the products manually, which could cause human errors. However, it should be emphasized that the system with the stickers in a certain color is especially clear: orange for products that have arrived but are waiting for approval to be used, green for goods that can be used and red for expired products.

Concerning the use of products, it is clear that products are stored as much as possible in their place of use. If it is not possible to store them in this place, or there is no space left in the place of use to store the products, they are kept in stockrooms. However, especially when a product has several places of use, this might become tricky as there is little overview on the amount of product that is left in the department. On the other hand, as was discussed in the literature review, using the FIFO-approach in the case of products with an expiration date has proven to be the best approach, unless the products gradually decrease in value as the expiration date approaches.

With respect to the inventory checks that happen on a three-month basis for most products, the contact person has indicated that in fact, as some of the products expire within one month, as is

shown in Appendix 2, the personnel members check these products more regularly. However, again this can be a time-consuming activity particularly when there are several places of use for one single product. They have additionally emphasized that human errors do occur when counting the stock in order to assess what number of products should be re-ordered. For example, for the microbiological growth mediums, they estimate that one in ten times, the number of mediums counted is incorrect.

Finally, one should look at the overstocking and understocking problem in this specific department. The personnel members highlighted that products seldomly have to be removed because they have expired. In total, they estimate that less than five percent of products has to be thrown away. Moreover, this comprises mostly products that have been opened but not fully used before they expire. One can compare it to a bottle of milk, which will expire one week after its first opening, yet one might not be able to empty the bottle within one week. The cost of overstocking is thus rather small. On the contrary, they did indicate that they are pressured to keep their inventory levels at a rather low level due to storing space constraints. Therefore, the risk of stockouts obviously increases.

As the previous problems were established thanks to the consulting of literature and interviews with the main contact person, Kim Serdons, a need for further prioritization of problems was established through a questionnaire. The exact eight issues that were included in the questionnaire are the following:

1) When products arrive, they have to be found in the PeopleSoft folder, checked and registered in the registration lists. This is all done manually.
2) When (part of) an order is not received, this is not registered in any way. The personnel members simply try to remember it.
3) The documents and identification required before a QA signature can be placed has to be checked over and over again until everything is in place.
4) There is little overview of the total amount of a product in inventory as some products are kept in stockrooms as well as in their place of use.
5) Checking the inventory for expired products and products that will expire in the next period is time-consuming and errors occur in the counting.
6) When the products have been approved for use, multiple stickers exist, such that sometimes the wrong sticker is on the wrong product.
7) Products expire before being used (overstocking).
8) Stockouts occur (understocking).

In order to better understand the importance and urgency of each of the aforementioned issues in the as-is procedure, the personnel members that deal with the procedure on a daily basis were asked to assess the impact of the problems on three criteria that are in accordance with the hospital's vision for the future. For each of the problems and criteria, they were asked to assign a number between 0 and 5, with zero meaning that the problem does not affect the criterium at all and five meaning that the problem strongly affects the criterium, thereby indicating that finding a solution to this problem would substantially improve the performance of the factor. The three factors are the following: general financial performance of the department, ability to provide qualitative patient care and quality of research, and inconvenience and time lost for personnel members.

Note that the general financial performance is important for the pressure from governments to cut budgets, the quality of patient care is essential as it is the primary mission of a hospital and the personnel satisfaction is needed to keep and attract talented workforce, which is also one of the parts of the vision for the future. Finally, the personnel members were also asked to identify other problems they face and to assess their importance on the three criteria. The full questionnaire can be found in Appendix 5.

In Figure 5, the average rating for every problem and every aspect is revealed. As the response to the questionnaire was rather low and the average is always affected by outliers, the median rating is also included in Figure 6. Finally, in Figure 7, the average and median sum of all aspects are depicted per problem, which is especially useful in to define the overall importance of each of the issues. For a complete table of all the separate rankings, the reader is referred to Appendix 6.

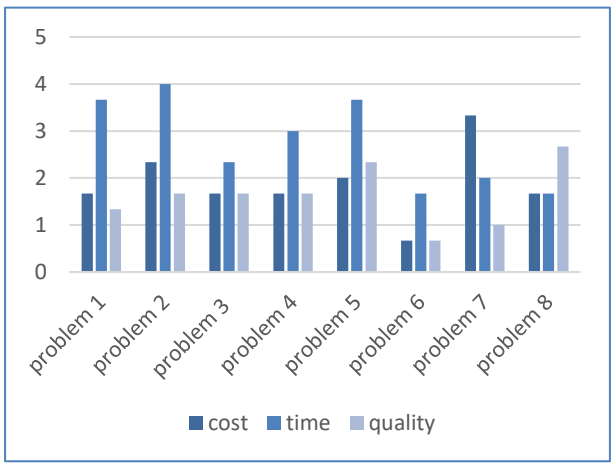

Figure 5 : avergae rating from questionnaire

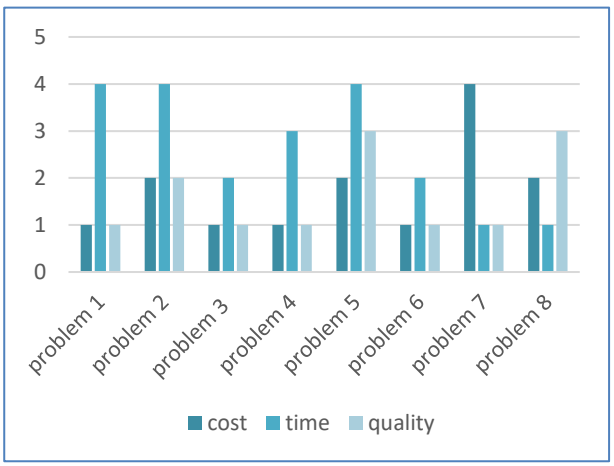

Figure 6: median rating from questionnaire

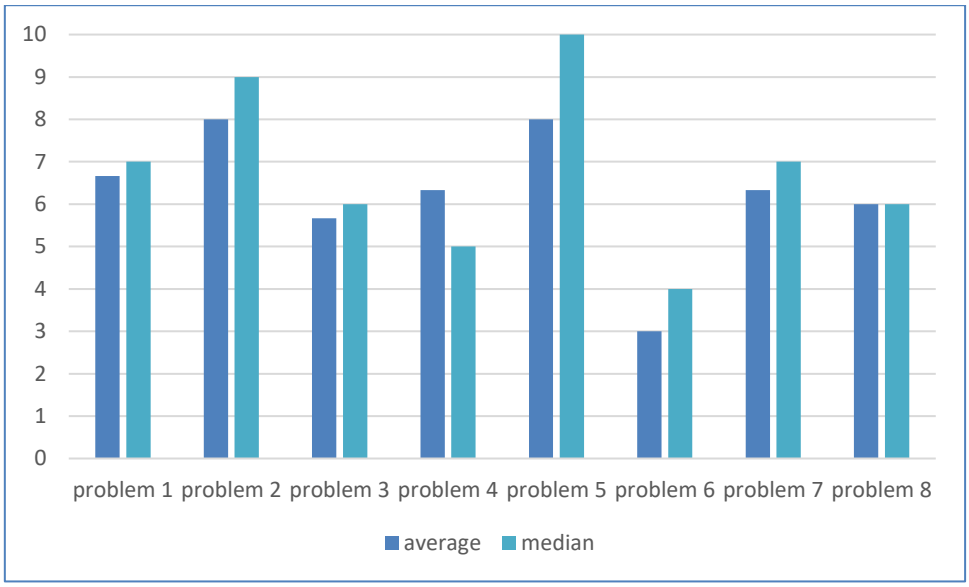

Figure 7: Average and median rating sum of all aspects per problem

In general, the results show that time and inconvenience for personnel member is the most affected factor for the first six issues. The seventh issue, being overstocking, is most likely to affect the department's financial performance. The eight issue on the other hand, is especially important for the quality of health care and research. For the second aspect, being inconvenience and time lost for personnel members, the second issue is ranked highest. Furthermore, this combination of problem and aspect got the highest average rank out of all average rankings, meaning that the personnel members would truly value a solution for the lack of overview of missing supplies. However, the first, fourth and fifth problem also receive an average ranking above three. On the contrary, with respect to the third aspect, being quality of patient care and research, no average rank above three was found. The highest average rank is 2.67 and is found for the eighth issue of understocking. When summing the ranks for the three aspects on all problems, one finds that problem 2 and 5 are essential, followed by problem 1 and 7. Problem 6 turns out to be the least important overall.

6.2 Measuring the issues

Now that the importance of the issues according to the personnel members is assessed, the research continues by quantifying the issues. The measurements are mostly focused on the aspect, being cost, time or quality, that was indicated to be most affected by the issue in the questionnaire. The measuring will start with the problems that were indicated to be most important and further continue in decreasing importance.

As was found from the questionnaire, problem 2 and 5 are absolutely essential. The second issue, being the fact that when (part of) an order is not received, this is not registered in any

way and hence, the personnel members simply try to remember it, is a source of inconvenience as well. The personnel members estimate that a rough 10% of orders are either not received on the date promised by the supplier, only partly received or received without having the promised quality. Concerning the fifth issue on checking the inventory for expired products and products that will expire in the next period, the time lost is estimated to be approximately an hour a week. In addition, according to estimations, in 1% of countings, errors occur. Even though this percentage is rather small, one should take into account the importance of decreasing these errors, as it is absolutely unacceptable that expired products are used in the healthcare industry.

Next in line are problem 1 and 7. For the first issue of manually looking for the right order, checking the order and registering it in the correct list, the questionnaire has revealed that this issue creates substantial inconvenience for personnel members. It is estimated that looking for the order takes around five minutes. With approximately two products arriving every day, and assuming 300 working days per year on which deliveries are received, personnel members lose 3000 minutes, equal to 50 hours so over 6 working days of 8 hours per year on this issue.

Whereas this first issue is particularly important from a time point of view, the seventh issue is rather affecting the financial performance of the department. In the end, the department has paid for the products and when they expire before being completely used, this is a loss of value. The prices of the products that expire from Appendix 2, are shown in Table 2.

Product	**Price**
Methylmagnesiumbromide 3.0M in diethylether 100 ml	€ 37.20
Dibromomethaan-D_2	€ 33.00 / 250g
Fosforpentoxide (P_2O_5)	€ 13.30 / 100g
Acetonitrile (ACN) watervrij 100 ml	€ 66.00
Dimethylsulfoxide (DMSO) watervrij 100 ml	€ 61.00
1,2-dichloorbenzeen (DCB) watervrij 100 ml	€ 70.00
N,N-dimethylformamide (DMF) watervrij 100 ml	€ 60.00
Tetrahydrofuran (THF) watervrij 100 ml	€ 59.00

Table 2 : prices of expiring products (retrieved from www.sigmaaldrich.com)

Recall that the expiration period starts when the products are opened, not when they are produced at the supplier. These prices were retrieved from the website of Sigma Aldrich, the supplier of these specific products. The website also indicates the available quantities. Unfortunately, for most of the products, 100 ml is the smallest possible order quantity. Only the first product in the table, Methylmagnesiumbromide 3.0M in diethylether, can also be

ordered in smaller quantities. However, the price of a quantity of 50 ml is € 41.20, being more than twice as expensive per ml compared to ordering 100 ml. This option would only pay off in case more than 50% of the product has to be thrown away due to expiration. The second option is to order 4x25ml at a price of € 44.30. This option is more likely to be beneficial for the department's financial performance.

With respect to problem 3, 4 and 8, a quantification is somewhat more difficult. Recall that problem 3 refers to the waiting for the documents and identification required before a QA signature can be placed in the registration form. Problem 4 on the other hand refers to the lack of overview of the total amount of a product in inventory as some products are kept in stockrooms as well as in their place of use. Both of these thus mostly cause inconvenience for personnel members, but they do not really cause valuable time losses. Problem 8, being stockouts, was indicated to affect the quality of patient care and research provided by the department. However, the department contact person, Kim Serdons, has indicated that it rarely happens that a product is depleted. Moreover, as was explained above, sometimes, substitute products are available for some goods, diminishing the criticality of these goods. Finally, as problem 6 was not ranked highly at all in the questionnaire, one can conclude that the sticker system is actually performing quite well and changing this is not a priority. Therefore, it will not be further measured nor analyzed and improved. The solution developed will additionally reflect the sticker system.

6.3 Analyzing the issues

The third step of the DMAIC cycle is the thorough analysis of the issues that were defined and measured in the previous two steps. For this purpose, cause and effect diagrams as was developed by Ishikawa will be established for the essential issues. Recall from the literature review that this method tries to categorize issues as being a consequence of one of the 6M, being man, machine, materials, method, mother-nature and measurement. The issues will be considered in the same order as in the measurement section.

When considering the inconvenience for personnel members resulting from missing deliveries, the first aspect that should be taken into account is mother nature or simply the environment the department is facing: the fact that suppliers sometimes do not meet their obligations is out of the control of the department, yet it is an important cause of the issue at stake here. Accordingly, apart from the suppliers not meeting their obligations to deliver at a specific moment in time, the materials can also be lacking quality and in this case, the inevitable

discussion about whether this is an error at the supplier level or at the buyer department level will arise. In case the expected products have not been delivered or they lack quality, the method used is that individual personnel members try to remember everything without sharing information. From the man point of view, the problem with the method becomes even more clear: people simply forget as it is part of being a human being. In addition, they are not skilled to develop another system as they are primarily trained in providing health care and conducting research. Consequently, no software system is in place keeping track of what is ordered, what has arrived and what is still missing, which is the machine point of view of the issue. Finally, a measurement problem also arises from the fact that supplier performance cannot be assessed, although it could be helpful in both future negotiations and in aforementioned types of discussions on which party caused quality problems. The Ishikawa diagram for this issue of missing supplies is depicted in Figure 8.

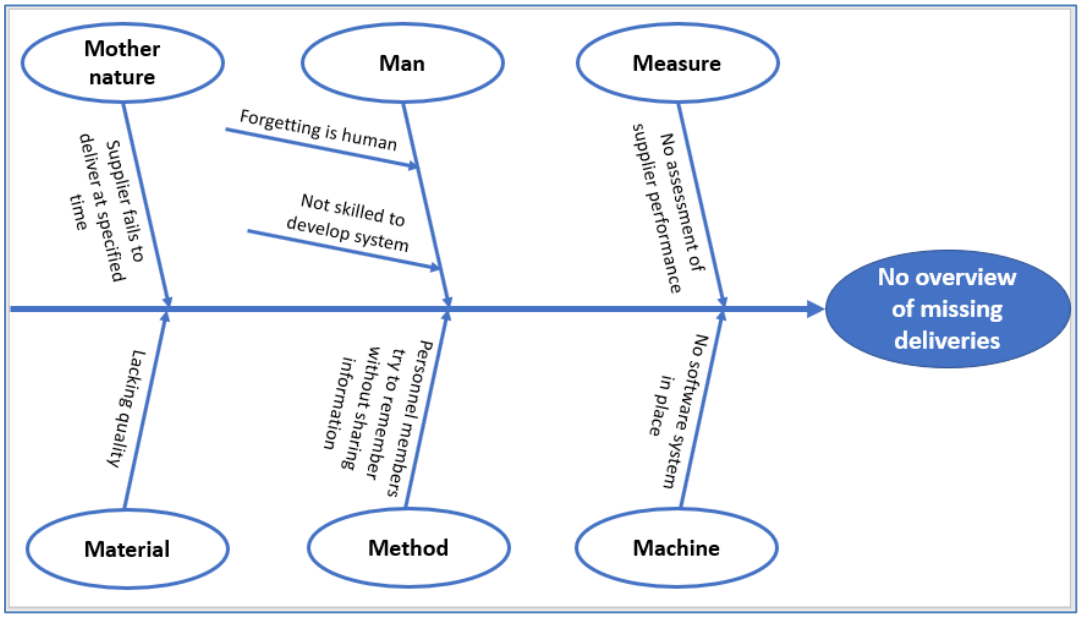

Figure 8: Ishikawa diagram problem 2 from questionnaire

The second issue to consider is the lack of overview of expired products and products that will expire. Again, inevitably, mother nature causes that some products cannot be held forever. The current method used is periodically inventory checks on products that will expire in the next period, which is time-consuming as was indicated in the measurement section. Moreover, due to the human aspect once again, errors will inevitably occur. First, when the list of products that will expire in the next period is established and second when expired products have to be removed, they can be overlooked or the wrong products that have not expired yet could be accidentally removed. Finally, again there is no IT system in place and the method fully relies on human beings for its execution. Therefore, the department also has no idea about what is

thrown away due to expiration, hence it is impossible to evaluate the level of overstocking in the department. The Ishikawa diagram for this problem of expiring products, which was the fifth issue in the questionnaire, is shown in Figure 9. Note that for this issue, no material cause was found in the analysis.

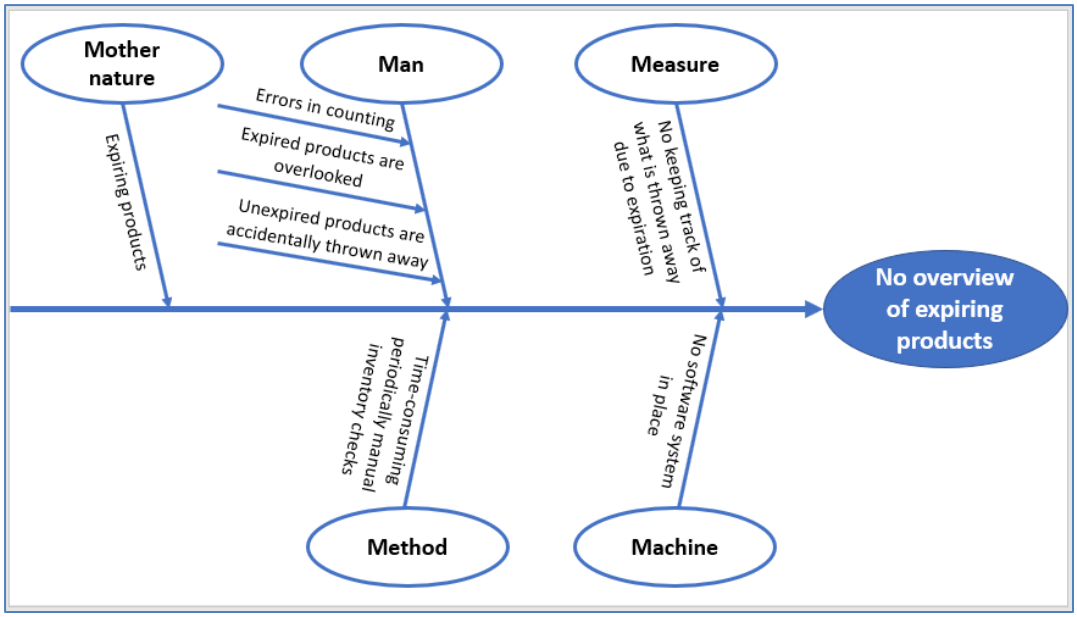

Figure 9: Ishikawa diagram problem 5 from questionnaire

The third issue is the time lost due to the registration of incoming supplies. The issue is caused mostly by method and machine, yet like many issues in this labor-intensive industry, this issue does also contain a human aspect. More specifically, the method comprises a double registration: the ordered products are registered first and when they arrive they are crossed out

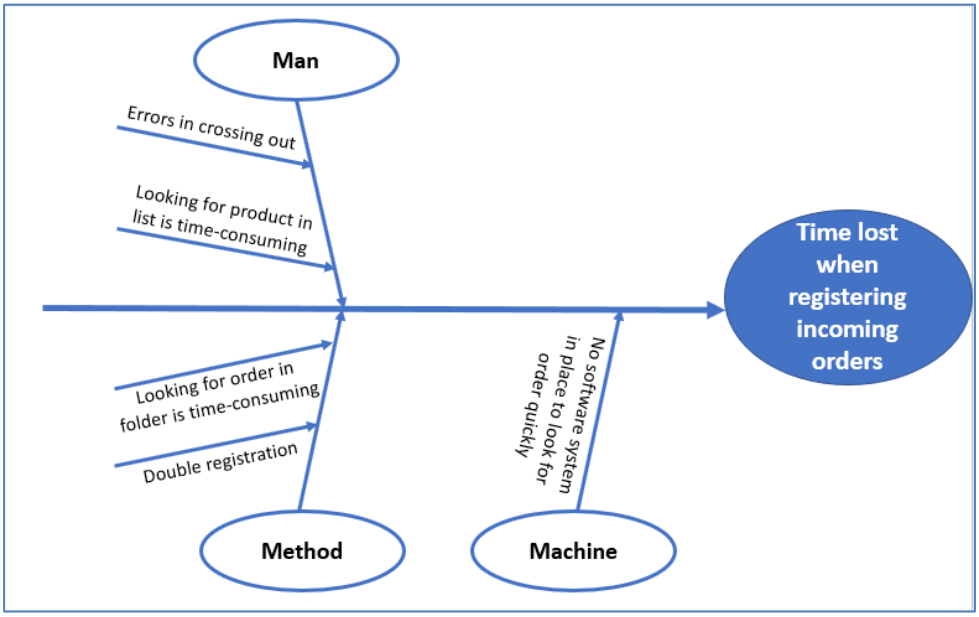

Figure 10: Ishikawa diagram problem 1 from questionnaire

and registered again on another list depending on the type of product. Moreover, finding the orders and crossing them out is time-consuming for personnel members and again errors occur. Again, there is no IT system in place to quickly look for the orders when they arrive. One can find a visual representation of the Ishikawa diagram of this first problem from the questionnaire in Figure 10.

For the seventh issue from the questionnaire, being the fact that products sometimes expire before being used, the environment, mother nature in the 6M approach, plays an essential role. As was established in the previous section, it is often the case that suppliers do not offer smaller quantities than the ones that are currently ordered by the department. In addition, when they do offer smaller quantities, these might be too expensive compared to the current quantities supplied. Apart from the environmental causes arising from suppliers, the lack of measurement of what is used by the department and what is thrown away also plays a crucial role in the overstocking issue. This lack of measurement mainly results from the fact that there is no IT system in place to track use and waste as a result of the personnel staff that is not trained in developing IT solutions. For a visual representation of the root cause search of this issue, the reader is referred to Figure 11.

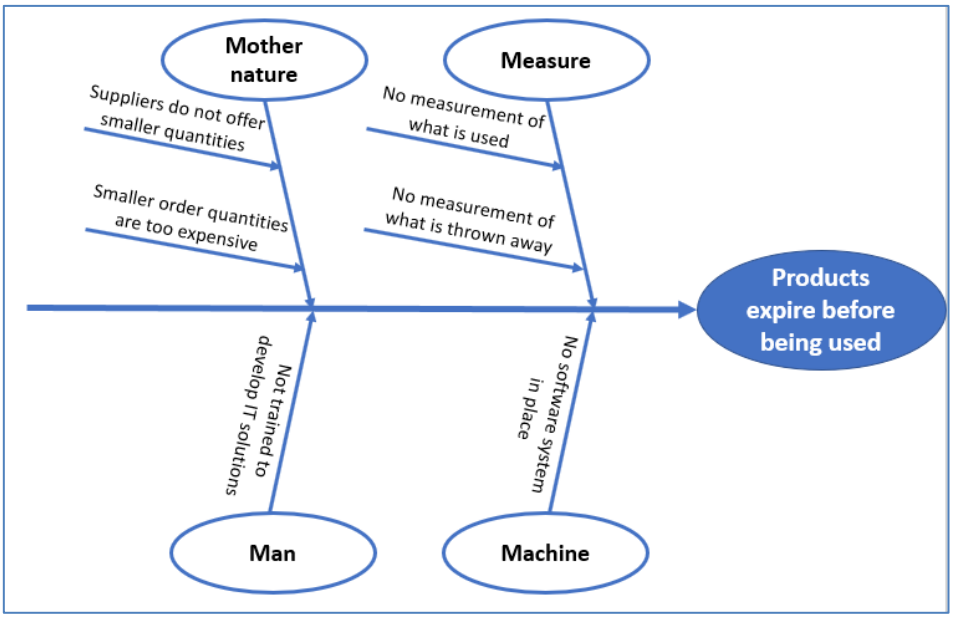

Figure 11: Ishikawa diagram problem 7 from questionnaire

Even though the quantification of the remaining issues were not possible to be executed in the previous section, their analysis is still essential to improve the complete procedure. However, as for problem 8 of stockouts, the personnel members have clearly emphasized in the interviews that stockouts rarely occur, this problem will not be further analyzed. Moreover, problem 6

received the lowest average rating on all three aspects (time, cost and quality) in the questionnaire, hence it will be disregarded as well. Therefore, the analysis continues with the third issue from the questionnaire, being the waiting for QA signatures, and results in the Ishikawa diagram that is depicted in Figure 12. The waiting for the QA signature is needed because the material cannot be used until the signature is placed. From a machine point of view, there is no software system in place that keeps tracking the documents and identifications that have already been gathered and those that are still missing. As there is no system in place, personnel members check over and over again which documents are missing in the current method, causing double work for personnel members.

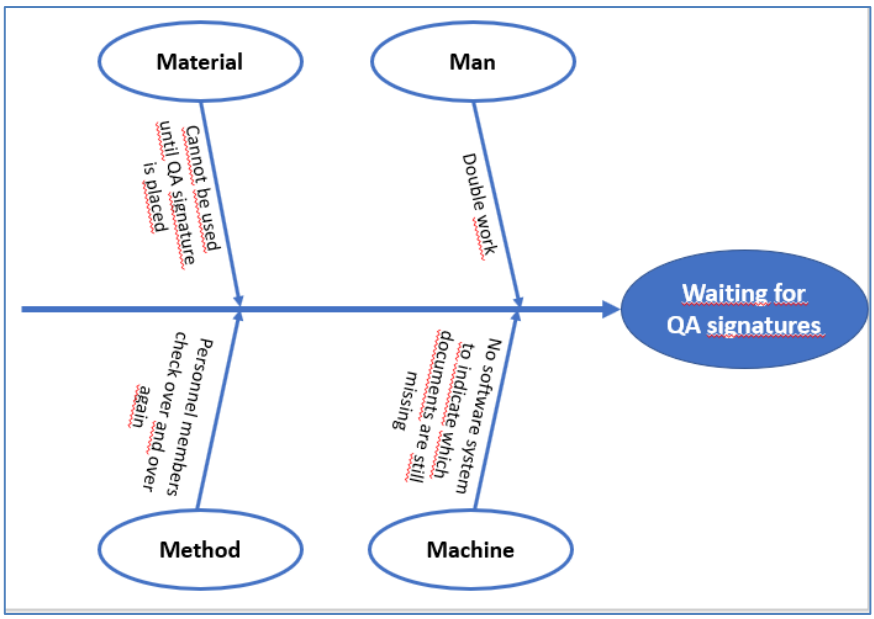

Figure 12: Ishikawa diagram problem 3 from questionnaire

Finally, with respect to problem 4 from the questionnaire, being the lack of overview of what is in stock, a first key cause has already been indicated: the stock is kept in the stockrooms as well as in the place of use of the products. This is the case because the space in the stockrooms nor the places of use are sufficient space to store the full cycle stock for the products. This is likely to be the consequence of too high levels of cycle stock held by the department out of fear for stockouts. Finally, it must be emphasized that the lack of measurement of demand for the products causes that an optimal inventory model with a certain service level to indicate the accepted level of stockouts cannot be developed. The Ishikawa diagram for this issue can be found in Figure 13.

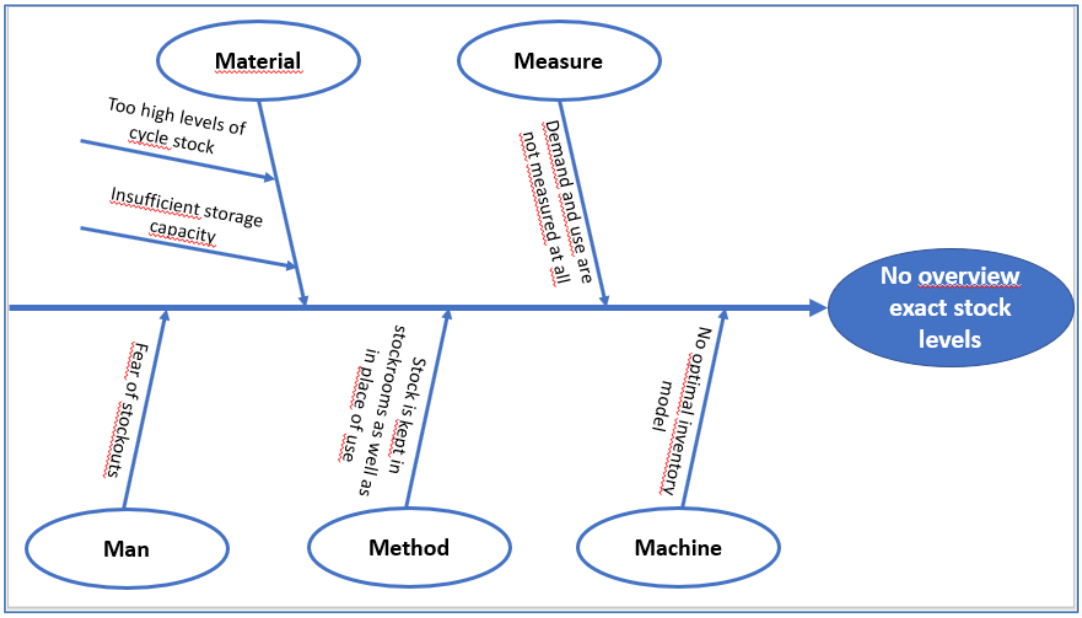

Figure 13: Ishikawa diagram problem 4 from questionnaire

Now that the six issues from the questionnaire that were indicated to be essential have been analyzed, the research project will continue with the development of an integrated solution in the next section.

6.4 Improve the procedure

For the purpose of improving the current procedure and (partially) solving the aforementioned six included issues, an Excel Workbook was developed using VBA. The code of the program was developed with the help of De Groot (2017). Here below, the program and its uses are shown and explained. In addition, the limitations and remaining issues will be thoroughly discussed.

First of all, when the workbook opens, the user is directed to an overview of all possible sheets. This overview is depicted in Figure 14. When the user wants to go to the overview of all orders, he or she simply clicks on "Overzicht bestellingen". In every sheet of the workbook, another link is provided to go back to the initial overview, by clicking on 'Terug naar hoofdblad'. This is shown in Figure 15.

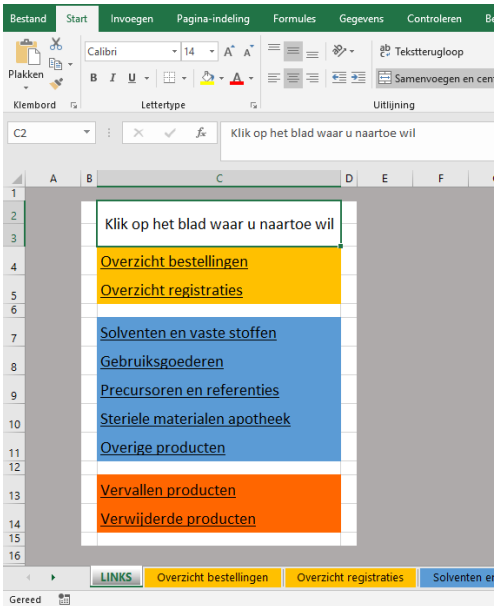

Figure 14: overview of sheets

As stated above, in the first sheet of 'Overzicht bestellingen', the user can find an overview of all orders. We see in Figure 15 that the orders that were shown in the extract of the PeopleSoft Folder are included. However, in reality, more lines will be shown in this sheet. For clarity purposes, it was decided to show the procedure using only a few lines.

Aanvraagnr	Req.Date	Verwachte leverdatum	Artikel	Omschrijving	aantal	leverancier	lev.ref
721293	23/05/2018	30/05/2018	111875	COVERALL MAX SF WIT COL/BO ELAST 2XL,25 STKS/DS	2	VWR International	113-1088
721293	23/05/2018	30/05/2018	LA7175	LABCOAT ADV SPP WHITE ELAST L-25/DS	10	VWR International	113-1147
721293	23/05/2018	30/05/2018	LA7176	LABCOAT ADV SPP WHITE ELAST XL -25/DS	5	VWR International	113-1148
721293	23/05/2018	30/05/2018	LA7177	SHOECOVER ANTISKID PP LAMINATED WHITE -400/DS	5	VWR International	113-8287
721293	23/05/2018	30/05/2018	111872	COVERALL MAX SF WIT COL/BO ELAST M,25 STKS/DS	5	VWR International	113-8085
721293	23/05/2018	30/05/2018	111873	COVERALL MAX SF WIT COL/BO ELAST L,25 STKS/DS	4	VWR International	113-8086

Terug naar hoofdblad
Ontvangst registreren
Bestellingen toevoegen

Figure 15: return to overview of sheets in sheet 'Overzicht Bestellingen'

Whereas in the as-is procedure, the personnel members had to check the People Soft folder for the right order, and then copy the order information in the right registration list, this is now achieved by a click on the blue button 'Ontvangst registreren' and a user form, which is depicted in Figure 16. The user form contains several fields in which values can be chosen or have to be entered manually. First, the article number can be entered by using a drop-down list. In order to make sure that the reader does not have to look for too long when the sheet contains more lines, the orders are sorted from earliest to latest expected delivery date ('Verwachte

leverdatum') and consecutively the article numbers are ordered alphabetically every time the workbook is opened. In addition, the user can enter the first letters or numbers from the article number in the field itself to decrease the number of options provided in the drop-down list. As it could be possible that the same product was ordered twice, the user additionally needs to enter the order number which is found in column 'Aanvraagnr'. With these two values, one single line in the list can be found and hence the product can be registered. In case the user wants to double check if the right order is being registered, he or she can always click on 'Toon info' to get the information on article number, article description, supplier and supplier reference number. When the user clicks this button and the article number or order number are not entered yet, a warning message will pop up indicating that the program can only show the information when the article and order number are completed.

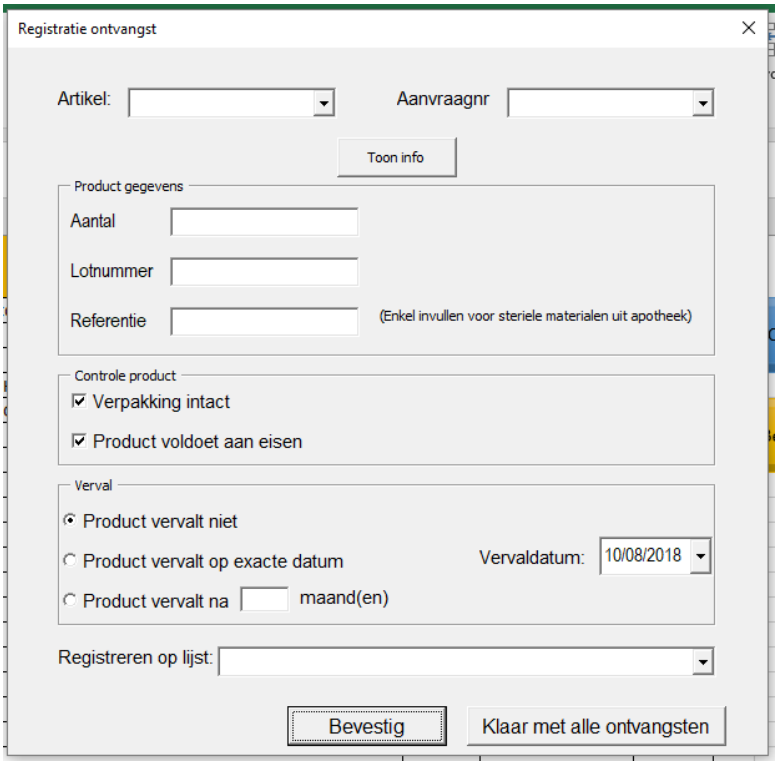

Figure 16: user form to register an incoming order

Now that the user has indicated the order he or she wants to register, the product data are gathered. The number of products that are received are counted and entered in 'Aantal:', the lot number is entered in 'Lotnr'. In case the product is a sterile material from the internal hospital pharmacy, the reference number of the product also needs to be entered in 'Referentie'. Consecutively, just like in the current procedure, the product packaging is checked for damages and also the product itself is checked for quality defaults. As the personnel members have

indicated that it rarely occurs that products are damaged or of insufficient quality, the two check boxes are automatically checked when the user form opens, and the user can un-check them consciously if necessary. Next, the information regarding expiration is gathered using three option buttons that are mutually exclusive. Either the product does not expire, or it expires on a prespecified date which is then entered in the date picker on the right, or it expires a number of months after being opened for the first time. As most products do not expire, the user form will always open with the first option highlighted. Finally, the reader indicates whether this product should be registered as a solvent and solid, as a frequently used good, as a precursor and reference, as a sterile material from the internal pharmacy or as a remaining product.

When the user then clicks ‘Bevestig’, the registration is confirmed, and the information is copied to the ‘Overzicht registraties’ sheet that keeps track of all the registrations that have been established as well as to the right registration list. In case the delivery contained less units than expected, the received number is distracted from the expected number in column ‘aantal’ and the remaining number turns red. Hence, problem 2 of no overview of missing deliveries is now solved. If the delivery is complete, the row is deleted from the sheet ‘Overzicht bestellingen’. The user form appears again, and the user can keep registering products. When the user wants to finish all the registrations, he or she clicks ‘Klaar met alle ontvangsten’. Next, the user is asked to enter his/her name and in all the established registrations, the name is put in column ‘Ontvanger’.

Apart from the blue button ‘Registratie ontvangst’, the sheet also contains a yellow button ‘Bestellingen toevoegen’. The goal of this button is to add all the orders that are in the People Soft folder. However, as it was impossible to directly program in the People Soft system as an external party, the button now simply jumps to the first empty row such that the orders can be pasted there. A possibility would be to fill this in when orders are placed or to have the IT staff program the orders into the file directly from the People Soft system. However, this falls beyond the scope of this research.

In conclusion, with this first part of the procedure, the personnel members can decrease the search time in the People Soft folder that was required before, diminishing issue 1 from the questionnaire. Moreover, they do not have to write down information that was already in the folder, and they only enter information that was not there yet. Furthermore, instead of writing their name every single time, they only have to enter this once. However, adding the orders still is difficult and time-consuming, yet solutions for this issue have been proposed.

After the registration of the products in the right registration list, the as-is procedure states that the required identification and documentation needs to be gathered before the products can be used. In this case, an orange sticker is placed on the product. To have a clear overview of which products are still waiting for identification and/or documentation, thereby partially solving problem 3, one can see in Figure 17 that the field of 'identificatie documentatie' is orange when it is empty, or yellow when part of the identifications and documentations are ok yet not all of them.

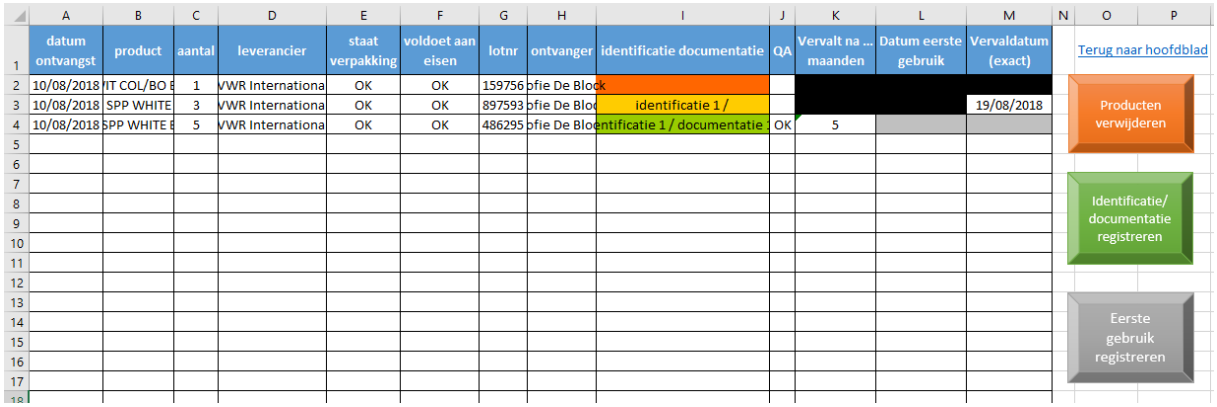

Figure 17: color use of field 'identificatie documentatie' and expiration data

When a user wants to add an identification or documentation, the user can simply click on the orange or yellow field and then on the green button 'identificatie/documentatie registreren'. The user is then asked if he wants to continue and if yes, to enter the identifications and documentations by separating them with '/'. Finally, the user is asked whether the QA signature can be placed or not. In case the user agrees, the field will turn green, just like the sticker that will be put on the product and 'OK' will be put in the QA column. If the field is already green and the user tries to add another documentation or identification, an error message will pop up stating that all the required documents and identifications are already in place. Unfortunately, it was not possible completely solve this problem, as there was no access to the folder in which the documentation and identifications needed for each type of product is found. Hence, this is another room for future improvement: when the user wants to add identification or documentation, the program could provide information on what is needed for that particular product such that again time losses created by looking for this in the folder 'identificatie/documentatie' are reduced. In this case, the question of whether the QA signature can be placed also becomes redundant.

As was described above, the registration of the products consists of entering information with respect to the expiration of the product. The use of the colors explained next is also shown in

Figure 17. In case the product does not expire, columns ‘vervalt na … maanden’, ‘datum eerste gebruik’ and ‘vervaldatum (exact)’ will be black. For products that have a prespecified expiration date, the last column contains this date and the other two are again black. When products expire after a certain number of months after being opened, this number of months is indicated in the first column, the other two columns are grey this time. For these products, a registration at the time of their first use is achieved by the grey button ‘Eerste gebruik registreren’. A window pops up in which the date of today is set. The user can agree with this date or change it when necessary. However, when for example a line in the registration list contains 4 bottles, only the first one is opened. Therefore, a new line is created when the first use is registered and here, one can find the date of first use and the exact expiration date, assuming that one month consists of 30 days. This is depicted in Figure 18. Every time the Excel file is opened, the expiration dates in all registration lists are checked and highlighted in red when the product has expired.

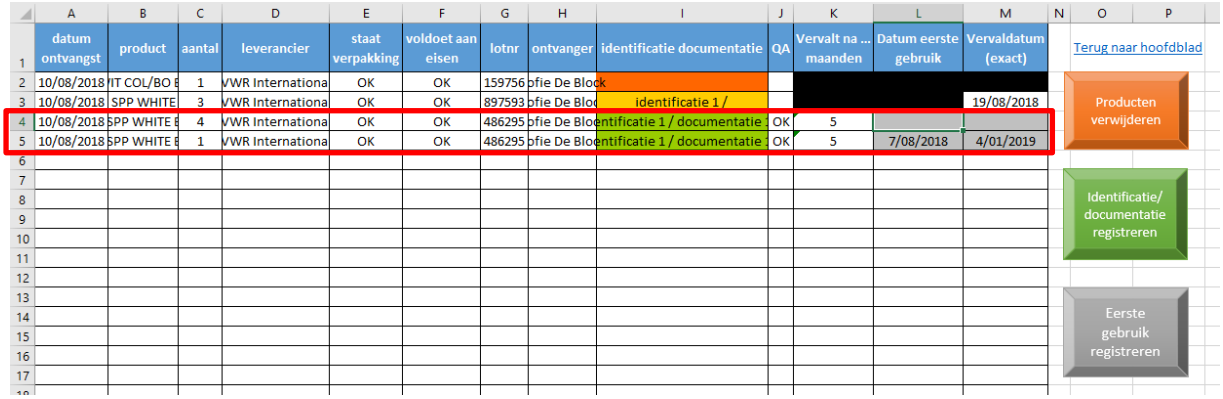

Figure 18: registration of first use of a product

In order to efficiently remove the expired products, the personnel members can simply go to sheet ‘Vervallen producten’ and click on the green button ‘Update’, which is shown in Figure 19. An overview will then be generated of all the expired products, and if desired, the overview can be printed by clicking the grey button ‘Print deze lijst’. Hence, the personnel members can start removing all the expired products using the checklist. This is way easier and faster than checking all the stickers separately hence time lost due to the lack of overview of expiring products, being the fifth issue from the questionnaire, will be drastically reduced. After finishing the physical removal, they can click the orange button ‘Vervallen producten verwijderd’ to delete all the expired products from this list as well as the separate registration lists. One should note that the list can only be printed if it was updated today. Therefore, the date of the last update is kept in cell L5 and checked when the user clicks ‘Print’. The same applies for the deleting of all expired products from this list and the registration lists. An extract

of this sheet with some fictive products is shown in Figure 19. Remark that the physical removal of products can still be affected by human errors.

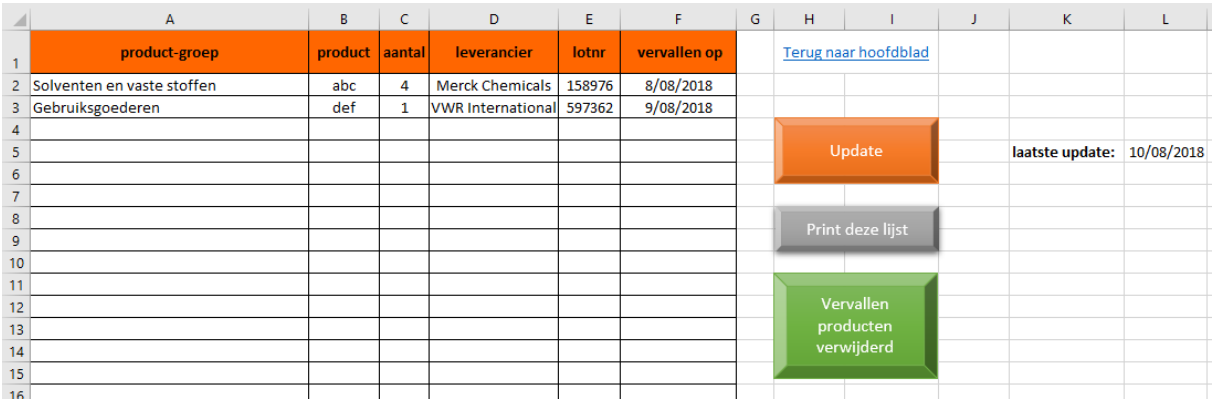

Figure 19: abstract sheet 'Vervallen producten' (=expired products)

Thanks to the use of the color in the field of documentation and identification as well as the prespecified expiry dates or registration of first uses of products, the sticker system that is currently used is exactly copied, except for the yellow. However, especially in the beginning, it is advisable to use both systems such that mistakes are limited.

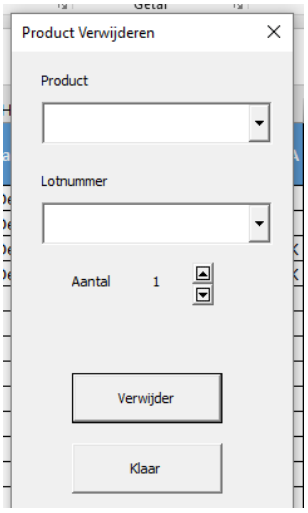

Figure 20: window for removal of products

Next to the removal of products due to expiration, the majority of products is simply used before they expire, or they never expire at all. Therefore, the button 'Product verwijderen' is visible in all the registration lists. For example, in Figure 17, one can see the orange button clearly. However, as the product can only be used and thus removed after it was approved for use by a green sticker and a QA signature, the program will first check whether the product line has a green field of 'identification and documentation'. If this condition holds, a window will pop up in which the user can select the product and its lot number. This window is depicted in Figure 20. Finally, the user indicates how many package units of these goods have been used and hence removed.

By clicking 'Verwijder', the user confirms the removal and then the window pops up again. In case the number of goods the user wants to remove exceeds the number of goods in the list, an error message appears, indicating the exact number of units that are in the list such that the user can adjust the number in the window. By clicking 'Klaar', the user indicates that he or she is ready with removing products. Note that the program will always look for the first line with

this product and lot number, meaning that the system uses a FIFO approach. For consistency purposes, a FIFO approach in the physical storage rooms should always be aimed for. By this last part of the to-be procedure, a better overview of what is in stock of a certain product is obtained, thereby improving issue 4 from the questionnaire.

Both in the case of removal because of exposure and removal because of usage, the removing of products is recorded in the 'Verwijderde producten' sheet, which is shown in Figure 21. Just like the sheet of 'Overzicht registraties', which contains an overview of all the registrations as is depicted in Figure 22, this sheet will prove its importance in the control of the procedure, which is discussed here below. Moreover, this sheet will play a crucial role in the approach to the seventh issue of overstocking and accordingly, products that expire before being used. As was indicated in the literature review, gathering data is essential to build a well-performing ordering model in the inventory system. It is exactly this that will be achieved thanks to these two sheets.

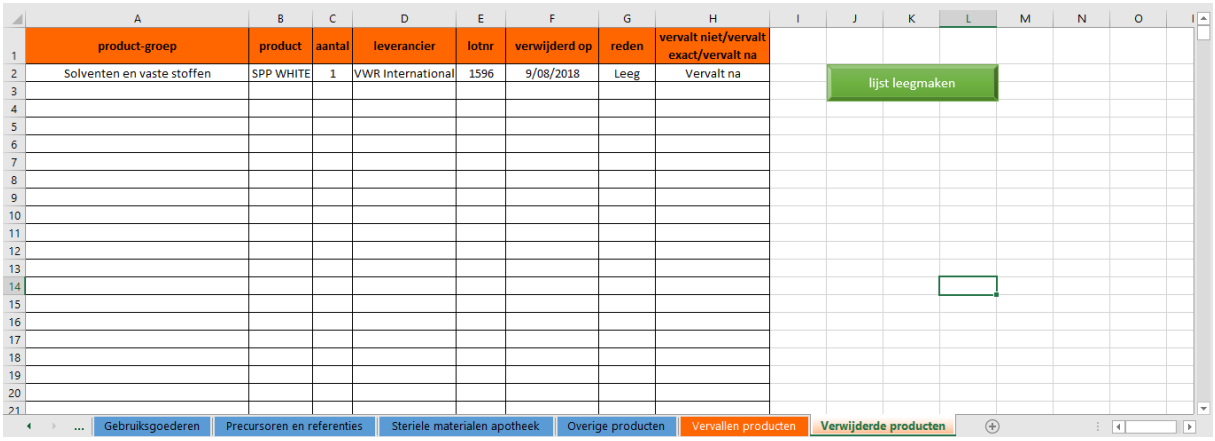

Figure 21: sheet 'Verwijderde producten' (Removed products)

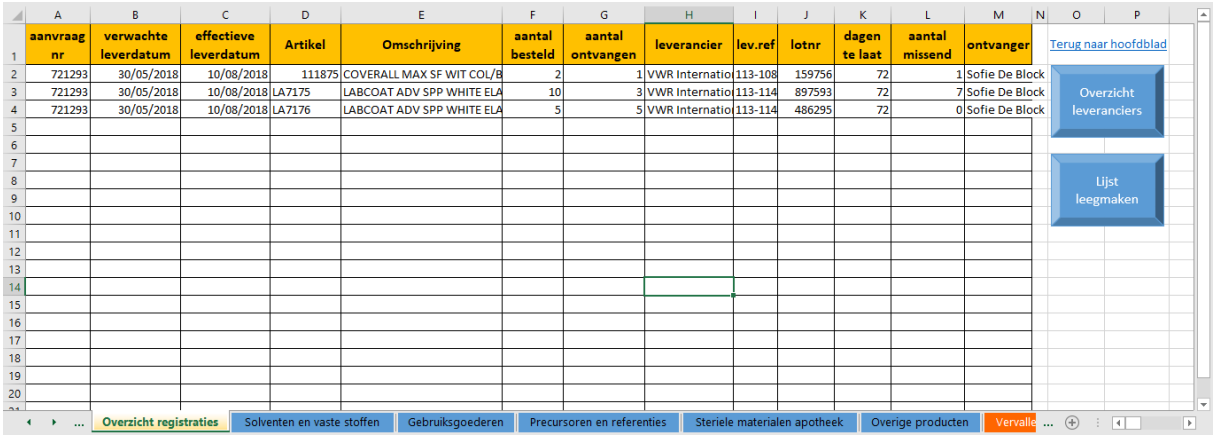

Figure 22: sheet 'Overzicht registraties' (overview registrations)

6.5 Control the procedure

The system that was developed is a first step towards a well-built inventory system. However, to increase the system towards the future, several figures need to be obtained. These figures will be referred to as KPI's and their importance for the future will be thoroughly discussed below.

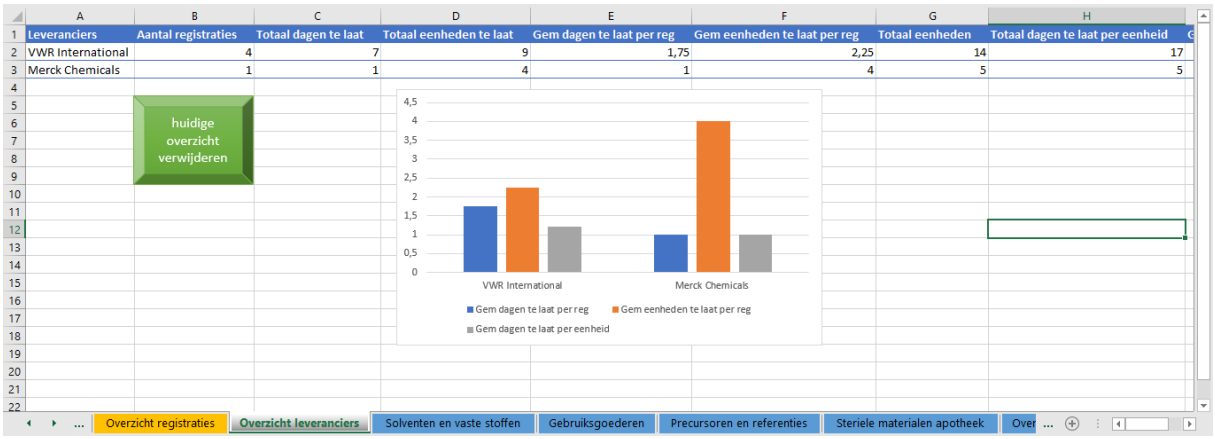

Figure 23: fictive supplier performance overview

First of all, as was clearly emphasized in the literature review, supplier lead times are a key factor in a model for ordering decisions. Even though the lead times themselves might be already known as they are indicated by the suppliers, one needs to have a clear idea about their variability. Therefore, a button 'Overzicht Leveranciers' is included in the sheet 'Overzicht registraties'. This is the upper blue button in Figure 22 and it generates an overview of the following figures for each supplier that is found in the list of registrations. The first number that is generated is the average number of days between promised delivery and effective delivery, in other words the average delay of deliveries. Secondly, the average number of missing units per delivery is calculated. An important remark to make here is that when a supplier delivers all missing units at a few later points in time, this will negatively affect the KPI compared to when the supplier delivers all the missing units at once at the same moment in time. This is explained by the fact that when units are missing, the program registers the delivery twice. To overcome this issue, the third KPI gives a clearer idea. In particular, the third number calculates the average days of delay per unit of goods. Hence, the missing days per unit are only taken into account once. For all the aforementioned figures, a graph is generated in order to visually compare the competitors. A supplier overview created with fictive products is illustrated in Figure 23.

Apart from these supplier related KPI's, and the lead time variability, the department can now also analyze the overstocking issue that was described in the definition part of DMAIC thanks to the registration of all incoming goods and their removal, being due to depletion or expiration. Ideally, they should further obtain information about the exact level of depletion when the product expires. However, registering this would cause time losses again, whereas the main goal of the procedure improvements as explained above focus on reducing these time losses for personnel members.

7. Conclusion

Throughout this text, a case study of the procedure of receipt, storage and removal of products in the radiopharmacy department of UZ Leuven was conducted by means of DMAIC. The general introduction of the company has emphasized the complexity and size of the organization and included a set out of the vision for the future, containing key points of focus that were further emphasized throughout the remainder of the text. From the literature review, it was clear that it is too soon to implement a complete inventory model due to the lack of data and the complexity of establishing such models. Moreover, from the analysis of the issues that were identified, it was clear that many of them could be solved by an IT system.

Therefore, the solution developed comprises a VBA excel tool that is user friendly and easy to adopt. From the current procedure description, the main issues were defined, measured and analyzed, followed by the development of the VBA tool. The solution should be regarded as an intermediate step towards the implementation of a full model and a first step towards inventory leanness, which was shown to have great potential in the healthcare industry. The KPI's implemented can serve as a basis for negotiations with main suppliers as well as the inputs of the model to be developed.

Limitations of this research include the lack of data provided by the department itself, due to insufficient data gathering currently being in place. Moreover, it should be emphasized that limited professional programming skills could have harmed the computation times needed for the excel tool. In addition, the link with the existing systems, in particular the People Soft system could not be built due to restricted access and confidentiality constraints. Ideally, the hospital could implement RFID technology to register every transaction in the inventory management process. However, costs associated with this technology are still substantial. Hence, government budget cuts might not allow the investments in these types of technologies.

In my view, this research project is part of a trend in healthcare institutions towards improved business practices as a result of increasing pressure from governments. Too often, we hear voices saying that governments should not cut budgets for healthcare as it automatically harms the quality. In Belgium, healthcare quality is the top of the world on many aspects and from the interviews conducted in this research, one immediately recognizes that quality is key priority for all employees. Personally, I feel that with tackling inefficiencies at inventory level as well as other aspects such as personnel planning etc. the industry will face the budget cuts successfully and will even be able to provide better quality with less resources.

Therefore, future research and business projects should focus on implementing practices in the healthcare industry that have been established in many other industries and have proven their effect on financial firm performance. In addition, it is advisable to train the workforce in hospitals from a business point of view on top of their medical background.

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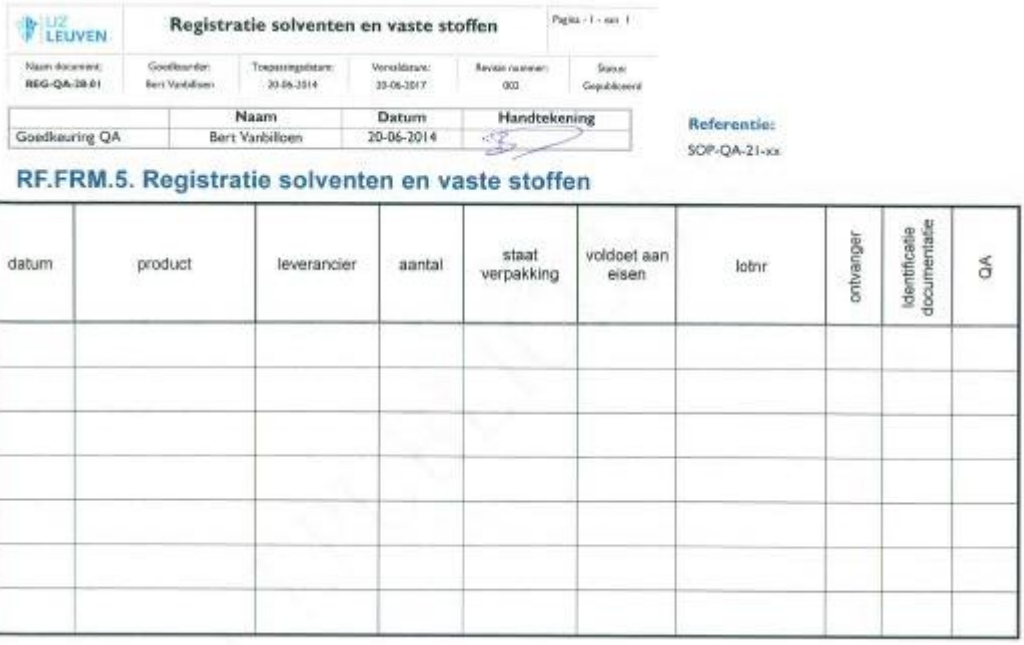
9. Appendices

Appendix 1: registration forms for four types of products.

(A) Registration form solvents and solids



UZ LEUVEN

Registratie solventen en vaste stoffen

Pagina - 1 - van 1

Naam document:	Goedkeurder:	Toepassingsdatum:	Vervaldatum:	Revisie nummer:	Status:
REG-QA-28-01	Bert Vanbilloen	20-06-2014	20-06-2017	002	Gepubliceerd

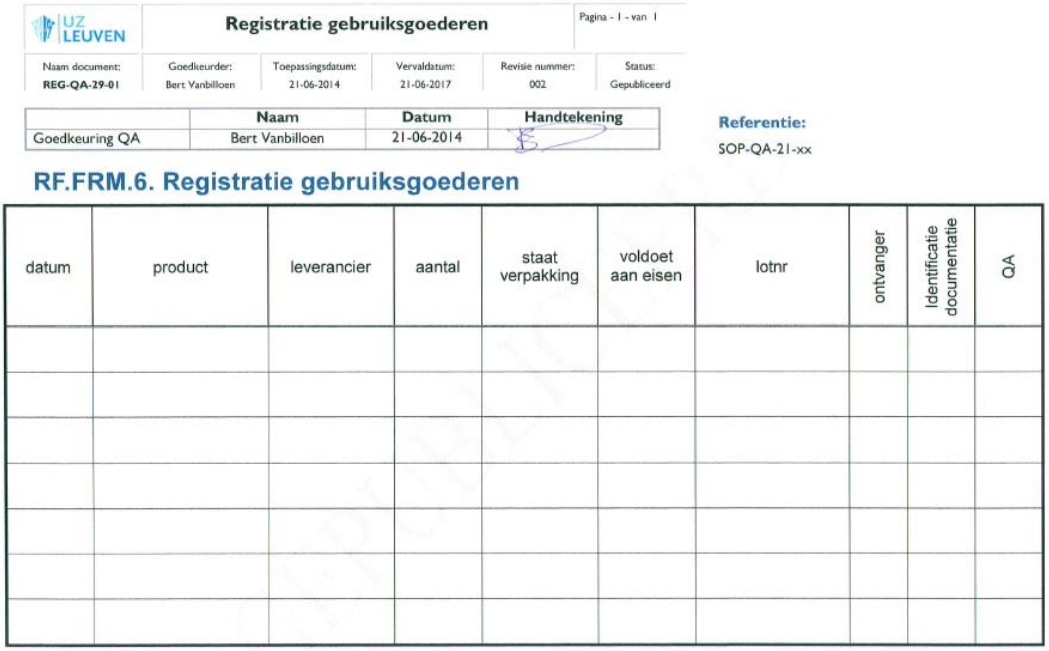
	Naam	Datum	Handtekening
Goedkeuring QA	Bert Vanbilloen	20-06-2014	

Referentie:
SOP-QA-21-xx

RF.FRM.5. Registratie solventen en vaste stoffen

datum	product	leverancier	aantal	staat verpakking	voldoet aan eisen	lotnr	ontvanger	Identificatie documentatie	QA

(B) Registration form frequently used goods



UZ LEUVEN

Registratie gebruiksgoederen

Pagina - 1 - van 1

Naam document:	Goedkeurder:	Toepassingsdatum:	Vervaldatum:	Revisie nummer:	Status:
REG-QA-29-01	Bert Vanbilloen	21-06-2014	21-06-2017	002	Gepubliceerd

	Naam	Datum	Handtekening
Goedkeuring QA	Bert Vanbilloen	21-06-2014	

Referentie:
SOP-QA-21-xx

RF.FRM.6. Registratie gebruiksgoederen

datum	product	leverancier	aantal	staat verpakking	voldoet aan eisen	lotnr	ontvanger	Identificatie documentatie	QA

(C) Registration form sterile materials from internal pharmacy

UZ LEUVEN

Registratie steriele materialen apotheek

Pagina - 1 - van 1

Naam document:	Goedkeurder:	Toepassingsdatum:	Vervaldatum:	Revisie nummer:	Status:
REG-QA-27-01	Bert Vanbilloen	20-06-2014	20-06-2017	002	Gepubliceerd

	Naam	Datum	Handtekening
Goedkeuring QA	Bert Vanbilloen	20-06-2014	

Referentie

SOP-QA-21-xx

RF.FRM.8. Registratie steriele materialen apotheek

product	
fabrikant	
referentie	

Datum	aantal	Staat verpakking	lotnr	vervaldatum	Paraaf ontvanger

Appendix 2: overview of products with limited shelf-life after opening

UZ LEUVEN

Formulier overzicht producten met beperkte houdbaarheid na opening

Pagina - 3 - van 3

Naam document:	Goedkeurder:	Toepassingsdatum:	Vervaldatum:	Revisie nummer:	Status:
FOR-QA-10-01	Kim Serdons	21-06-2016	21-06-2019	001	Gepubliceerd

Producten met een beperkte houdbaarheid na eerste opening van de verpakking	
	Houdbaarheid na opening
Oplossingen	
Methylmagnesiumbromide 3.0 M in diethylether 100 ml	3 maand
Solventen	
Dibromomethaan-D_2	1 jaar
Vaste stoffen	
Fosforpentoxide (P_2O_5)	1 jaar
Watervrije solventen	
Acetonitrile (ACN) watervrij 100 ml	1 maand
Dimethylsulfoxide (DMSO) watervrij 10 ml	1 maand
1,2-dichloorbenzeen (DCB) watervrij 100 ml	1 maand
N,N-dimethylformamide (DMF) watervrij 100 ml	1 maand
Tetrahydrofuran (THF) watervrij 100 ml	1 maand

EINDE DOCUMENT

Appendix 3 : categorization of products

HATS code	#in HATS	HATS name	ATS code	#in ATS	ATS name	SUBATS code	#in SUBATS	SUBATS name
100	13	Afdek en protectiemateriaal	20	13	Afdek en protectiemateriaal: staf	50	8	Schoenovertrekken & schoenen
100	13		20	13		60	5	Andere
130	8	basismateriaal verzorging en behandeling	50	7	STERILISATIE&MEDISCHE REINIGING	50	7	REINIGINGSMATERIAAL
160	1	onderzoeksmateriaal en toebehoren medische toestellen	60	1	toebehoren diverse medische toestellen	50	1	disposable toebehoren medische toestellen
320	153	LABO-, ANALYSEMATERIAAL & CHEMISCHE PRODUCTEN	10	41	SCHEIKUNDIGE PRODUCTEN	10	17	DROGE SCHEIKUNDIGE PRODUCTEN
320	153		10	41		126	23	SCHEIKUNDIGE VLOEISTOFFEN
320	153		20	2	SCHEIKUNDIGE PRODUCTEN	10	1	BEKERS, MAATCYLINDERS, MAATKOLVEN, TRECHTERS
320	153		20	2		70	1	OVERIGE LABOFLESSEN
320	153		30	25	KITS EN GEBRUIKSKLARE PRODUCTEN	118	16	DIVERSE KITS-EN GEBRUIKSKLARE PRODUCTEN
320	153		30	25		600	9	Bacteriologie
320	153		40	1	KLEINE LABO APPARATUUR	10	1	KLEINE LABO APPARATUUR
320	153		60	7	ONDERDELEN TOESTELLEN	10	7	ONDERDELEN TOESTELLEN
320	153		80	72	LABO KLEIN MATERIAAL	20	2	TIPS
320	153		80	72		30	15	STOPPEN
320	153		80	72		40	8	FILTERS EN FILTREERPAPIER
320	153		80	72		50	5	TUBES EN BUISJES
320	153		80	72		90	8	DIVERSE LABORECIPIENTEN
320	153		80	72		110	21	DIVERSE TOEBEHOREN LABO
320	153		80	72		120	12	HPLC TOEBEHOREN
360	3	Hygiëne	20	3	onderhoud	30	2	???
360	3		20	3		40	1	Schoonmaakmateriaal

390	14	Kantoorbenodigheden	10	1	KLASSEMENT	110	1	ARCHIEFDOZEN
450	1	Milieu en veiligheid	70	1	Veiligheid allerlei	10	1	overige veiligheid
500	1	TECHNISCHE VERBRUIKSMATERIALEN EN WISSELSTUKKEN	40	1	ELEKTRICITEIT & ELECTRONICA	20	1	ELEKTRICITEIT ALLERLEI

Appendix 4: number of products from product groups per supplier

HATS	ATS	SUB ATS	Achrom	Sigma-Aldrich	Waters	STAXS	Vandeputte Safety	Acros	RS Components	ABX	Contel Control Equipment/ NResearch Europe	Merck Millipore	Scintomics	Intermed	Fiers	VWR	GE
100	20	50	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
100	20	60	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
130	50	50	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
160	60	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
320	10	10	0	5	0	0	0	9	0	0	0	2	0	0	0	1	0
320	10	126	0	6	0	0	0	1	0	1	0	1	0	0	0	12	0
320	20	10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
320	20	70	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
320	30	118	0	0	0	0	0	0	0	9	0	0	1	0	0	0	1
320	30	600	0	0	0	0	0	0	0	0	0	1	0	5	0	0	0
320	40	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
320	60	10	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
320	80	20	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
320	80	30	0	4	0	0	0	0	0	0	0	0	0	0	0	1	0
320	80	40	0	0	3	0	0	0	0	0	0	1	0	0	0	4	0
320	80	50	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
320	80	90	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
320	80	110	0	0	0	0	0	0	0	0	0	0	0	0	1	17	0
320	80	120	3	0	4	0	0	0	0	0	0	0	0	0	0	1	0
360	20	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
360	20	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
390	10	110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
450	70	10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
500	40	20	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

HATS	ATS	SUB ATS	Starstedt	Beton Dickinson	Filter service	Alpheios	TCPS	Veru Chemie	TRAPOL	OASIS	Shimadzu benelux	CMI	TRASIS	Partool Gils & Vervaet	Thermo fischer scientific	Comecer Nederland	kaiser &kraft
100	20	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	20	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
130	50	50	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
160	60	50	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
320	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
320	10	126	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
320	20	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
320	20	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
320	30	118	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0
320	30	600	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0
320	40	10	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
320	60	10	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
320	80	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
320	80	30	0	0	2	0	0	0	0	0	0	0	3	0	0	0	0
320	80	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
320	80	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
320	80	90	0	0	5	0	0	0	0	0	0	0	1	0	0	0	0
320	80	110	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
320	80	120	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
360	20	30	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
360	20	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
390	10	110	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
450	70	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
500	40	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HATS	ATS	SUB ATS	Norhof	magazijn	BGB	Clippard Europe SA	Phenomenex	Greiner Bio One	Avery Zweckform
100	20	50	0	0	0	0	0	0	0
100	20	60	0	0	0	0	0	0	0
130	50	50	0	0	0	0	0	0	0
160	60	50	0	0	0	0	0	0	0
320	10	10	0	0	0	0	0	0	0
320	10	126	0	1	0	0	0	0	0
320	20	10	0	0	0	0	0	0	0
320	20	70	0	0	0	0	0	0	0
320	30	118	0	0	0	0	0	0	0
320	30	600	0	0	0	0	0	0	0
320	40	10	0	0	0	0	0	0	0
320	60	10	0	0	0	1	0	0	0
320	80	20	0	0	0	0	0	0	0
320	80	30	0	0	0	0	0	0	0
320	80	40	0	0	0	0	0	0	0
320	80	50	0	0	0	0	0	2	0
320	80	90	0	0	0	0	0	0	0
320	80	110	0	0	0	0	0	0	0
320	80	120	0	0	0	0	2	0	0
360	20	30	0	0	0	0	0	0	0
360	20	40	0	0	0	0	0	0	0
390	10	110	0	0	0	0	0	0	0
450	70	10	0	0	0	0	0	0	0
500	40	20	0	0	0	0	0	0	0

Appendix 5: Complete questionnaire

Belang van problemen in huidige procedure

Hieronder vindt u de 8 problemen die reeds zijn vastgesteld in de huidige procedure van ontvangst, vrijgave en opslag van de goederen. Helemaal onderaan is er de mogelijkheid om andere problemen, die nog niet geïdentificeerd zijn, aan te geven. De vragenlijst duurt ongeveer 15 minuten. Alvast bedankt voor uw medewerking!

*Required

1. Belang van problemen voor financieel resultaat van de afdeling

Gelieve te beoordelen hoe belangrijk volgende problemen volgens u zijn voor het financieel resultaat van de afdeling. Indien u vindt dat een bepaald probleem zich niet voordoet, duidt dan steeds 0 aan.

Probleem 1: wanneer goederen toekomen, worden deze eerst manueel gezocht in de map PeopleSoft, afgevinkt en dan opnieuw geregistreerd op een van de registratielijsten, dit is tijdsrovend. *

	0	1	2	3	4	5	
geen invloed op financieel resultaat	○	○	○	○	○	○	een zeer grote invloed op financieel resultaat

Probleem 2: wanneer een (deel van een) bestelling niet toekomt, wordt dit op geen enkele wijze geregistreerd, de personeelsleden onthouden dit zelf. *

	0	1	2	3	4	5	
geen invloed op financieel resultaat	○	○	○	○	○	○	een zeer grote invloed op financieel resultaat

Probleem 3: de reeds verzamelde identificatie en documenten alvorens de QA handtekening te plaatsen in de registratielijst moeten telkens opnieuw gecontroleerd worden. *

	0	1	2	3	4	5	
geen invloed op financieel resultaat	○	○	○	○	○	○	een zeer grote invloed op financieel resultaat

Probleem 4: er is weinig overzicht van de totale hoeveelheid van een bepaald product in voorraad doordat ze zowel in voorraadkamers als op de gebruiksplaats gestockeerd staan. *

	0	1	2	3	4	5	
geen invloed op financieel resultaat	○	○	○	○	○	○	een zeer grote invloed op financieel resultaat

Probleem 5: het controleren van goederen die vervallen zijn en die binnen de volgende periode zullen vervallen is tijdrovend en soms gebeuren er fouten bij tellingen van voorraad. *

	0	1	2	3	4	5	
geen invloed op financieel resultaat	○	○	○	○	○	○	een zeer grote invloed op financieel resultaat

Probleem 6: nadat de goederen goedgekeurd zijn voor gebruik, zijn er verschillende stickers voor verschillende producten, waardoor soms de foute sticker gebruikt wordt. *

	0	1	2	3	4	5	
geen invloed op financieel resultaat	○	○	○	○	○	○	een zeer grote invloed op financieel resultaat

Probleem 7: het gebeurt vaak dat goederen vervallen alvorens ze volledig opgebruikt werden. *

	0	1	2	3	4	5	
geen invloed op financieel resultaat	○	○	○	○	○	○	een zeer grote invloed op financieel resultaat

Probleem 8: het gebeurt vaak dat goederen uit voorraad zijn wanneer we ze nodig hebben. *

	0	1	2	3	4	5	
geen invloed op financieel resultaat	○	○	○	○	○	○	een zeer grote invloed op financieel resultaat

2. Belang van problemen voor tijdsbesteding en ongemak personeel

Gelieve te beoordelen in welke mate volgende problemen volgens u ongemak en tijdsverlies veroorzaken voor het personeel. Indien u vindt dat een bepaald probleem zich niet voordoet, duidt dan steeds 0 aan.

Probleem 1: wanneer goederen toekomen, worden deze eerst manueel gezocht in de map PeopleSoft, afgevinkt en dan opnieuw geregistreerd op een van de registratielijsten, dit is tijdsrovend. *

	0	1	2	3	4	5	
zorgt absoluut niet voor tijdsverlies en ongemak	○	○	○	○	○	○	zorgt voor enorm veel tijdsverlies en ongemak

Probleem 2: wanneer een (deel van een) bestelling niet toekomt, wordt dit op geen enkele wijze geregistreerd, de personeelsleden onthouden dit zelf. *

	0	1	2	3	4	5	
zorgt absoluut niet voor tijdsverlies en ongemak	○	○	○	○	○	○	zorgt voor enorm veel tijdsverlies en ongemak

Probleem 3: de reeds verzamelde identificatie en documenten alvorens de QA handtekening te plaatsen in de registratielijst moeten telkens opnieuw gecontroleerd worden. *

	0	1	2	3	4	5	
zorgt absoluut niet voor tijdsverlies en ongemak	○	○	○	○	○	○	zorgt voor enorm veel tijdsverlies en ongemak

Probleem 4: er is weinig overzicht van de totale hoeveelheid van een bepaald product in voorraad doordat ze zowel in voorraadkamers als op de gebruiksplaats gestockeerd staan. *

	0	1	2	3	4	5	
zorgt absoluut niet voor tijdsverlies en ongemak	○	○	○	○	○	○	zorgt voor enorm veel tijdsverlies en ongemak

Probleem 5: het controleren van goederen die vervallen zijn en die binnen de volgende periode zullen vervallen is tijdrovend en soms gebeuren er fouten bij tellingen van voorraad. *

	0	1	2	3	4	5	
zorgt absoluut niet voor tijdsverlies en ongemak	○	○	○	○	○	○	zorgt voor enorm veel tijdsverlies en ongemak

Probleem 6: nadat de goederen goedgekeurd zijn voor gebruik, zijn er verschillende stickers voor verschillende producten, waardoor soms de foute sticker gebruikt wordt. *

	0	1	2	3	4	5	
zorgt absoluut niet voor tijdsverlies en ongemak	○	○	○	○	○	○	zorgt voor enorm veel tijdsverlies en ongemak

Probleem 7: het gebeurt vaak dat goederen vervallen alvorens ze volledig opgebruikt werden. *

	0	1	2	3	4	5	
zorgt absoluut niet voor tijdsverlies en ongemak	○	○	○	○	○	○	zorgt voor enorm veel tijdsverlies en ongemak

Probleem 8: het gebeurt vaak dat goederen uit voorraad zijn wanneer we ze nodig hebben. *

	0	1	2	3	4	5	
zorgt absoluut niet voor tijdsverlies en ongemak	○	○	○	○	○	○	zorgt voor enorm veel tijdsverlies en ongemak

3. Belang van problemen voor kwaliteit van onderzoek en patiëntenzorg.

Gelieve te beoordelen in welke mate volgende problemen volgens u onderzoek en patiëntenzorg binnen de afdeling negatief beïnvloeden. Indien u vindt dat een bepaald probleem zich niet voordoet, duidt dan steeds 0 aan.

Probleem 1: wanneer goederen toekomen, worden deze eerst manueel gezocht in de map PeopleSoft, afgevinkt en dan opnieuw geregistreerd op een van de registratielijsten, dit is tijdsrovend. *

	0	1	2	3	4	5	
geen invloed op kwaliteit van onderzoek en patiëntenzorg	○	○	○	○	○	○	Een enorme invloed op kwaliteit van onderzoek en patiëntenzorg

Probleem 2: wanneer een (deel van een) bestelling niet toekomt, wordt dit op geen enkele wijze geregistreerd, de personeelsleden onthouden dit zelf. *

	0	1	2	3	4	5	
geen invloed op kwaliteit van onderzoek en patiëntenzorg	○	○	○	○	○	○	Een enorme invloed op kwaliteit van onderzoek en patiëntenzorg

Probleem 3: de reeds verzamelde identificatie en documenten alvorens de QA handtekening te plaatsen in de registratielijst moeten telkens opnieuw gecontroleerd worden. *

	0	1	2	3	4	5	
geen invloed op kwaliteit van onderzoek en patiëntenzorg	○	○	○	○	○	○	Een enorme invloed op kwaliteit van onderzoek en patiëntenzorg

Probleem 4: er is weinig overzicht van de totale hoeveelheid van een bepaald product in voorraad doordat ze zowel in voorraadkamers als op de gebruiksplaats gestockeerd staan. *

	0	1	2	3	4	5	
geen invloed op kwailteit van onderzoek en patiëntenzorg	○	○	○	○	○	○	Een enorme invloed op kwaliteit van onderzoek en patiëntenzorg

Probleem 5: het controleren van goederen die vervallen zijn en die binnen de volgende periode zullen vervallen is tijdrovend en soms gebeuren er fouten bij tellingen van voorraad. *

	0	1	2	3	4	5	
geen invloed op kwailteit van onderzoek en patiëntenzorg	○	○	○	○	○	○	Een enorme invloed op kwaliteit van onderzoek en patiëntenzorg

Probleem 6: nadat de goederen goedgekeurd zijn voor gebruik, zijn er verschillende stickers voor verschillende producten, waardoor soms de foute sticker gebruikt wordt. *

	0	1	2	3	4	5	
geen invloed op kwailteit van onderzoek en patiëntenzorg	○	○	○	○	○	○	Een enorme invloed op kwaliteit van onderzoek en patiëntenzorg

Probleem 7: het gebeurt vaak dat goederen vervallen alvorens ze volledig opgebruikt werden. *

	0	1	2	3	4	5	
geen invloed op kwailteit van onderzoek en patiëntenzorg	○	○	○	○	○	○	Een enorme invloed op kwaliteit van onderzoek en patiëntenzorg

Probleem 8: het gebeurt vaak dat goederen uit voorraad zijn wanneer we ze nodig hebben. *

	0	1	2	3	4	5	
geen invloed op kwailteit van onderzoek en patiëntenzorg	○	○	○	○	○	○	Een enorme invloed op kwaliteit van onderzoek en patiëntenzorg

Overige problemen

Indien u vindt dat hierboven nog een belangrijk probleem (of meerdere, max. 3) over het hoofd is gezien, gelieve dit (deze) dan kort te omschrijven. Gelieve eveneens aan te geven wat het belang is voor het financieel resultaat, de tijdsbesteding en het ongemak van het personeel, en de kwaliteit van onderzoek en patiëntenzorg.

(Indien u dus geen andere problemen kan bedenken, mag u de rest van het formulier gewoon openlaten.)

Ik denk dat dit nog een belangrijk probleem is:

Your answer

Invloed op financieel resultaat

	0	1	2	3	4	5	
geen invloed op financieel resultaat	○	○	○	○	○	○	een zeer grote invloed op financieel resultaat

Invloed op tijdsbesteding en ongemak personeel

	0	1	2	3	4	5	
zorgt absoluut niet voor tijdsverlies en ongemak	○	○	○	○	○	○	zorgt voor enorm veel tijdsverlies en ongemak

Invloed op kwaliteit van onderzoek en patiëntenzorg

	0	1	2	3	4	5	
geen invloed op kwailteit van onderzoek en patiëntenzorg	○	○	○	○	○	○	Een enorme invloed op kwaliteit van onderzoek en patiëntenzorg

Ik denk dat dit nog een belangrijk probleem is:

Your answer

Invloed op financieel resultaat

	0	1	2	3	4	5	
geen invloed op financieel resultaat	○	○	○	○	○	○	een zeer grote invloed op financieel resultaat

Invloed op tijdsbesteding en ongemak personeel

	0	1	2	3	4	5	
zorgt absoluut niet voor tijdsverlies en ongemak	○	○	○	○	○	○	zorgt voor enorm veel tijdsverlies en ongemak

Invloed op kwaliteit van onderzoek en patiëntenzorg

	0	1	2	3	4	5	
geen invloed op kwailteit van onderzoek en patiëntenzorg	○	○	○	○	○	○	Een enorme invloed op kwaliteit van onderzoek en patiëntenzorg

Ik denk dat dit nog een belangrijk probleem is:

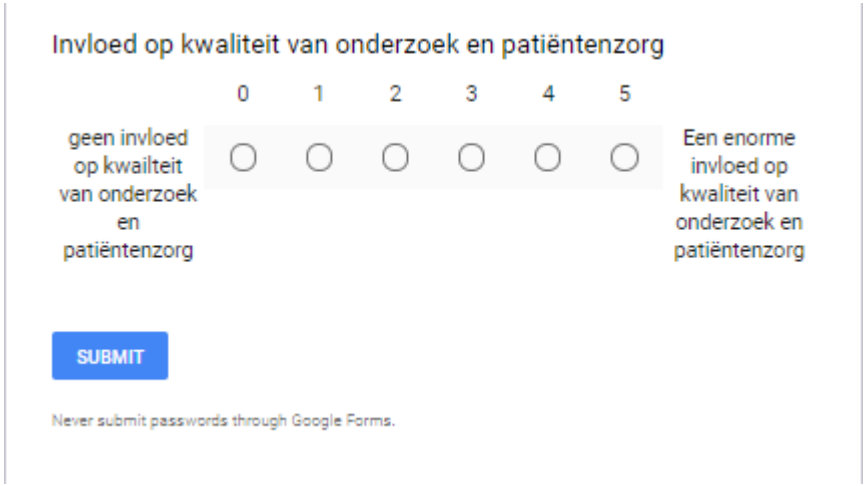
Your answer

Invloed op financieel resultaat

	0	1	2	3	4	5	
geen invloed op financieel resultaat	○	○	○	○	○	○	een zeer grote invloed op financieel resultaat

Invloed op tijdsbesteding en ongemak personeel

	0	1	2	3	4	5	
zorgt absoluut niet voor tijdsverlies en ongemak	○	○	○	○	○	○	zorgt voor enorm veel tijdsverlies en ongemak


Invloed op kwaliteit van onderzoek en patiëntenzorg

	0	1	2	3	4	5	
geen invloed op kwailteit van onderzoek en patiëntenzorg	◯	◯	◯	◯	◯	◯	Een enorme invloed op kwaliteit van onderzoek en patiëntenzorg

SUBMIT

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Appendix 6: separate rankings from questionnaire

respondent 1	problem 1	problem 2	problem 3	problem 4	problem 5	problem 6	problem 7	problem 8
cost	1	4	1	1	2	1	5	2
time	5	4	4	3	5	3	1	1
quality	1	2	1	1	3	1	1	3

respondent 2	problem 1	problem 2	problem 3	problem 4	problem 5	problem 6	problem 7	problem 8
cost	3	2	3	3	3	0	4	2
time	4	5	2	4	4	0	4	3
quality	2	2	3	3	3	0	1	4

respondent 3	problem 1	problem 2	problem 3	problem 4	problem 5	problem 6	problem 7	problem 8
cost	1	1	1	1	1	1	1	1
time	2	3	1	2	2	2	1	1
quality	1	1	1	1	1	1	1	1

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