Master's degree thesis

LOG945

SKU - classification at an intensive care unit

Espen Helset

Number of pages including this page: 61

Langevåg, 28. November 2022

Molde University College
Specialized University in Logistics

Mandatory statement

Each student is responsible for complying with rules and regulations that relate to examinations and to academic work in general. The purpose of the mandatory statement is to make students aware of their responsibility and the consequences of cheating. Failure to complete the statement does not excuse students from their responsibility.

*Please complete the mandatory statement by placing a mark **in each box** for statements 1-6 below.*		
1.	**I/we hereby declare that my/our paper/assignment is my/our own work, and that I/we have not used other sources or received other help than mentioned in the paper/assignment.**	☒
2.	**I/we hereby declare that this paper** 1. Has not been used in any other exam at another department/university/university college 2. Is not referring to the work of others without acknowledgement 3. Is not referring to my/our previous work without acknowledgement 4. Has acknowledged all sources of literature in the text and in the list of references 5. Is not a copy, duplicate or transcript of other work	Mark each box: 1. ☒ 2. ☒ 3. ☒ 4. ☒ 5. ☒
3.	I am/we are aware **that any breach of the above will be considered as cheating, and may result in annulment of the examination and exclusion from all universities and university colleges in Norway for up to one year, according to the Act relating to Norwegian Universities and University Colleges, section 4-7 and 4-8 and Examination regulations** section 14 and 15.	☒
4.	**I am/we are aware that all papers/assignments may be checked for plagiarism by a software assisted plagiarism check**	☒
5.	**I am/we are aware that Molde University College will handle all cases of suspected cheating according to prevailing guidelines.**	☒
6.	**I/we are aware of the University College's rules and regulation for using sources**	☒

Personal protection

Personal Data Act

Research projects that processes personal data according to Personal Data Act, should be notified to Data Protection Services (NSD) for consideration.

Have the research project been considered by NSD? ☐yes ☒no

- If yes:

Reference number:

- If no:

I/we hereby declare that the thesis does not contain personal data according to Personal Data Act.: ☒

Act on Medical and Health Research

If the research project is effected by the regulations decided in Act on Medical and Health Research (the Health Research Act), it must be approved in advance by the Regional Committee for Medical and Health Research Ethic (REK) in your region.

Has the research project been considered by REK? ☐yes ☒no

- If yes:

Reference number:

Publication agreement

ECTS credits: 30

Supervisor: Birgithe Eckermann Sandbæk

Agreement on electronic publication of master thesis

Author(s) have copyright to the thesis, including the exclusive right to publish the document (The Copyright Act §2).

All theses fulfilling the requirements will be registered and published in Brage HiM, with the approval of the author(s).

Theses with a confidentiality agreement will not be published.

I/we hereby give Molde University College the right to, free of charge, make the thesis available for electronic publication: ☒yes ☐no

Is there an agreement of confidentiality? ☐yes ☒no

(A supplementary confidentiality agreement must be filled in)

- If yes:

Can the thesis be online published when the period of confidentiality is expired? ☐yes ☐no

Date: 28.11.2022

Acknowledgments

This thesis marks the end of my experience-based Master degree at Molde University College. All the work with my degree has been done while I have been working full time at HMR.

First of all, I would like to thank HMR for allowing me leave when I needed this to follow my courses. HMR also deserve my gratitude along with HMN for allowing me to use the data necessary to write this thesis.

I would also like to thank my supervisor Birgithe Eckermann Sandbæk along with Arild Hoff for priceless guidance.

And of course, I would like to thank my family for being super patient with me these years I have been studying.

Langevåg, November 2022

Espen Helset

List of Abbreviations

- SKU - Stock keeping unit
- SS - Safety stock
- SL - Service level
- ROP - Reordering point
- CV - Coefficient of variation
- Q - Order quantity
- SC - Supply chain
- VED – Vital, Essential, Desirable
- VEN – Vital, Essential, Non-essential
- FSN – Fast moving, Slow moving, Non-moving
- FNS – Fast moving, Normal moving, Slow moving
- ICU - intensive care unit
- DMS - District medical centre
- HF – Health trust
- HMR – Helse Møre og Romsdal HF
- HNT – Helse Nord-Trøndelag HF
- STO – St. Olavs Hospital HF
- RHF – Regional health trust
- HMN – Helse Midt Norge RHF
- LS HMN – Logistikksenter HMN

List of figures

List of tables

Abstract

Purpose: The purpose of this thesis was to explore alternative stock keeping unit (SKU) classifications techniques with the aim of improving the inventory management at an intensive care unit. This need for inventory management at the intensive care unit is in this case study amplified through the commissioning of a new centralized warehouse for consumables. The choices of classification techniques assessed in the study and the following analysis are based upon literature on the subject and the techniques availability in the literature. Availability of data was also a factor influencing the choices regarding classifications techniques.

Method: The research was built up in the following order: Quantitative and qualitative data was gathered from the organisation in question and its ERP system. The collected data and literature on the subject found the base of performing single criteria classifications which again duo criteria classifications then are based upon. The two duo-criteria classifications performed in this study are ABC-VED and VED-FSN. Finally, a comparison of the performance of the two duo-criteria classification scenarios was conducted and assessed.

Results: Looking at the results of the SKU-classifications in this thesis we see that it is little difference between the number of SKUs that receive a high, medium, or low service level in the two scenarios. It can also be observed that 44% of SKUs given a low SL in the ABC-VED where either vital or fast moving in the VED-FSN classification. When comparing the performance of the two scenarios the VED-FSN performs closer to the set service level than the ABC-VED scenario.

Conclusion: The observations in this study implies that, compared to the ABC-VED classification, the VED-FSN classification seems to better secure the continuous supply of critical materials. It is also implied that this is achieved without increasing the need for storage space or disregarding the cost aspect.

Value: During the research for this study a VED-FSN analysis for SKU classification at hospital wards was not found. Also, the majority of healthcare SKU-classification studies seems to focus on pharmaceuticals. This study attempts to contribute to fill this gap.

Keywords: SKU classification, ABC, VED, FSN, service level, safety stock

Contents

1.0 INTRODUCTION

This study is based upon the case of a regional group of hospitals in the middle of Norway that in 2008 decided to establish a centralised warehouse for the whole region. The new regional warehouse will supply the regions hospitals with medical and non-medical consumables. This is done to save costs on purchasing, make inventory management more efficient and increase the general quality of the supply chain. This could be a gamechanger for the hospital wards in the region when the new warehouse is ready at the end of 2022.
At many of the local hospitals, healthcare personnel have been used to just take the elevator down to the basement where their local warehouse have been located if they ran out of necessary equipment. Now, for many of the hospital wards, this critical equipment will be stored at a warehouse in a different county.
With no longer having an inhouse warehouse at the hospitals, managing the inventory including the safety stock at the hospital wards will be crucial. The focus in the thesis is on an intensive care unit (ICU) within this group of hospitals, and its need for stock keeping unit classification with better inventory management as the aim. The study will keep a special focus on the need of safety stock after the commissioning of the centralised warehouse.
Keeping safety stock is a risk mitigating measure. "Risk is the potential for unwanted negative consequences that arise from an event or activity" according to Rowe (1975), and that is exactly what hospital wards wish to avoid by keeping extra stock. Some, like Tang (2007) argues that keeping strategic stock at some sort of hub is a better alternative than safety stock. This will be true for many companies and will also be possible for this group of hospitals through their new centralized warehouse, but very often at a hospital time is of the essence and sufficient safety stock will be essential.
This is very much the case at the ICU in question. As for ICUs in general the unit in question treats patients with life threatening or very serious conditions. This is often done using advanced medical equipment like respirators and equipment for monitoring critical bodily functions. Consumables that are needed to support the operation of this equipment is of course critical; very often for the life of the patient.
After talking to a nurse while visiting the intensive care unit in question I got the idea for this thesis. He wanted a more structured approach for deciding how much of their many

consumables they should have in stock. The new regional warehouse will replace the local warehouse in the basement of the hospital and amplifies this need. The storage space at the ward is limited and the inventory at the intensive care unit is very close to the final consumer, the patient. These two aspects affect how inventory management should be approached. The idea behind this study is that the described need at the ICU can be met through SKU classification and implantation of inventory management strategies based upon this analysis.

The need for SKU classification in healthcare has been a topic in literature for decades. In the 1980s Reid (1987) described the possible benefits of a volume value based ABC classification at hospital wards. Different inventory management policies for each of the three classes were specified. Regarding the level of safety stock, which is highly relevant for the ICU, three additional criteria were considered: criticality, availability of alternatives and lead time.

Bringing in criticality and availability of alternatives makes Reid's ABC analysis relatable to the criticality-based VED analysis (Kumar and Chakravarty 2015). These two SKU classification methods are frequently used in combination, as an ABC-VED analysis, for SKU classification within healthcare (Kumar and Chakravarty 2015, Vaz et al. 2008, Hussain, Siddharth, and Arya 2019, Nigah, Devnani, and Gupta 2010).

In other types of supply chains, such as maintenance, repair, and operations (MRO) supply chains the VED analysis has been combined with the SKU movement rate based FSN/FNS analysis in a VED-FSN/FNS analysis (Sople 2016, Cavalieri et al. 2008). The reasoning for using the FSN/FNS analysis with the VED analysis instead of the ABC analysis is that both criticality and movement rate is considered crucial because of unpredictability and emergencies (Sople 2016). This reasoning is relatable to the environment of the ICU.

The three mentioned methods of SKU classification are some of the better known, and thus most accessible in literature (Van Kampen, Akkerman, and van Donk 2012). They also seem to be relevant considering available data in the organisation and contextual factors linked to the intensive care unit. Thus, it is these three methods, and the mentioned combinations of these, that will be explored in this study.

1.1 RESEARCH OBJECTIVE AND QUESTION

The objective of this thesis is to explore alternative SKU-classifications techniques with the aim of improving the inventory management at an intensive care unit. There will be a special focus on service level and the need for safety stock. Considering the availability of data, literature on the subject and the techniques availability in the literature the research question of this theses is:

"How do the outputs of the ABC-VED analysis and the VED-FSN analysis compare regarding the ICU in question need for improved inventory management? "

This question will be assessed in this thesis through analysis based on data from HMN and the service level test model described later in this study. The research question will be attempted answered in chapter 7.

The conceptual framework of Van Kampen, Akkerman et al. (2012) specifies five general factors that influences the choice of SKU classification model: aim, context, characteristics, technique and classes. This model and its terminology will be used throughout the study to explain the choices made regarding the SKU classification techniques used, and to attempt to support the answer to the research question.

2 THEORETICAL FRAMEWORK

The theoretical framework is built up as follows: First there is a general description of SKU-classification. Secondly there is a description of the literature behind the SKU classifications performed later in the study, followed by a sub chapter regarding risk. Finally, the theory behind the conceptual framework for SKU-classification used through the thesis is presented.

2.1 SKU classification

SKU classification: a literature review and conceptual framework (Van Kampen, Akkerman, and van Donk 2012) attempts to give an overview over the academic work on the subject SKU classification up until 2010. SKU classification is described as systematic classification of materials in relation to various properties. The definition of SKU being used here is an item with a specific function, colour, size, style and most often location (Silver, Pyke, and Peterson 1998). In addition to the academic overview on SKU classification, Van Kampen, Akkerman et al. (2012) also addresses a subject they claim to be lacking in the literature, a general guidance for selecting the appropriate SKU classification technique. The different techniques are divided into two main groups:

1. Judgemental techniques like VED analyses, where the products criticality is assessed based on an expert opinion, are purely qualitative.
2. Statistical techniques like traditional ABC analysis or FSN/FNS analysis, based on volume value or how fast moving a product is, are quantitative techniques.

Two main questions must be addressed to generate a SKU classification according to Van Kampen, Akkerman et al. (2012):

1. What number of classes will be the output of the classification?
2. Where will the boarders between the different classes go?

2.2 ABC

Probably the most well-known SKU classification method is the ABC analysis (Silver, Pyke, and Peterson 1998). The traditional ABC analysis is a statistical technique usually based on volume value, and divides materials into three groups: A, B and C (Ravinder and Misra 2014, Van Kampen, Akkerman, and van Donk 2012). The volume value is found by multiplying the demand and the price for each item (Reid 1987). Sometimes demand volume alone is used as the characteristic in the ABC analysis (Teunter, Babai, and Syntetos 2010), but in this thesis ABC analysis will be considered to be based on the criteria volume value. The boarders between the classes in an ABC analysis are set according to the Pareto Principle (Ravinder and Misra 2014).

The origins of the Pareto Principle, also called the 80:20, rule come from the end of the nineteenth century, where it was observed that 80 % of a country’s wealth belonged to 20 % of the citizens, dividing them into two groups (Vaz et al. 2020):

A. 20 % of population owning 80 % of wealth
B. 80 % of population owning 20 % of wealth

Even though the principle has been applied to many different aspects, like costumer shopping pattern or how much we use our clothes, it is mostly used in SKU classification, and in the 1950s the C category was introduced (Vaz et al. 2020):

A. 20 % of SKU generate 80 % of volume value
B. 30 % of SKU generate 15 % of volume value
C. 50 % of SKU generate 5 % of volume value

These percentages in the ABC classification vary some in the literature. For incense in Inventory management and control system using ABC and VED analysis (Nirmala et al. 2021) the boarders between the classes are put so that A items represent 20 % of SKU and 70 % of volume value, B items 30 % of SKU and 25 % of volume value and finally C items represent 50 % of SKU and 5 % of volume value. The dataset used by Reid (1987) is frequently used for benchmarking ABC analyses (Van Kampen, Akkerman, and van Donk 2012).

Dividing SKU into classes allows managers to apply differentiated strategies regarding inventory, production or costumers for the different classes of SKU (Van Kampen, Akkerman, and van Donk 2012). When it comes to inventory management the SKU classification is typically used regarding strategies for safety stock (SS), service level (SL) and reorder point (ROP) (Vaz et al. 2008, Teunter, Babai, and Syntetos 2010, Vaz et al. 2020). The literature is however not clear on how different strategies should be applied to the different classes in a traditional ABC analysis based on volume value. For instance, while some argues that A items are the most important and thus should have the highest SL, other argues that C items should be given the highest SL so the A items can be prioritised (Teunter, Babai, and Syntetos 2010). Gourdin (2006) defines SL as "the probability that a stockout will NOT occur during a replenishment cycle".

Flores, Olson et al.(1992) addresses the value of including more than one criteria in the SKU classification. For instance, by including lead time and criticality to the analysis to achieve a multi criteria inventory classification. It is also argued that different criteria will be more important to an organisation depending on its nature.

2.3 VED

Criticality is the criteria used in the VED analyses which is conducted by dividing the SKU into vital (V), essential (E) and desirable (D) classes based on expert opinions (Kumar and Chakravarty 2015, Vaz et al. 2008). According to Kumar and Chakravarty (2015) a minimum of three expert opinions assessing the criticality of each SKU is necessary to achieve the appropriate level of concurrence. Sakthivelmurugan, Senthilkumar et al. (2021) demands at least 50 % of experts to concur to give a SKU a VED classification. For healthcare specific analyses Kumar and Chakravarty (2015) define vital, essential and desirable as follows:

V. “Critical for life and patient care.”
E. “Critical but alternatives acceptable.”
D. “Low critical value.”

Jobira et al. (2021) conduct a healthcare related SKU classification, and uses the class Non-essential (N) instead of the D-class, calling it a VEN analysis. The abbreviation VED will be used in this study. Shortage of items belonging in the N-class (equal to the D-class) is described by Jobira et al. (2021) as not threatening to patients health. Thus, the importance of avoiding overstock of these items is specified. Further, Jobira et al. (2021) stresses the importance of continuous availability of the V-items. Sufficient safety stock of these materials is also recommended. The E-items is recommended to have a lower stock level compared to the V-items.

2.4 ABC-VED

The ABC-VED analysis combines the output from the ABC analysis and the VED analysis in a matrix, cross tabulating the two analyses (Vaz et al. 2008). The output from the matrix is nine combinations of ABC and VED. Vaz et al. (2008), Nigah, Devnani, and Gupta (2010), Gizaw and Jemal (2021) and Kumar and Chakravarty (2015) divides these nine combinations, or subcategories, into three categories where I is either vital (V) or has a high volume value (A). II is the subcategories not belonging to I but is either essential (E) or has a medium volume value (B). III is desirable (D) and has a low volume value (C):

I. AV, AE, AD, BV and CV
II. BE, BD and CE
III. CD

Both Vaz et al. (2008) and Kumar and Chakravarty (2015) argues that items in category I should have a low level of SS and needs close monitoring. Jobira et al.(2021) however states that the AV-items are of such high criticality and importance that they need to always be available despite high holding cost. The two bin method is suggested to avoid stockouts of these vital materials (Nigah, Devnani, and Gupta 2010). Vaz et al. (2008) and Kumar and Chakravarty (2015) further argue that while category II items can have a little lower level of control than category I items, category III items have the lowest level of priority. According to Kumar and Chakravarty (2015) category III items could be ordered in big quanta to save ordering fees, while Vaz et al. (2008) argues they should have a high level of SS. A quite high volume of these materials can be stocked because of its low holding cost (Nigah, Devnani, and Gupta 2010).

Hussain, Siddharth, and Arya (2019) perform an ABC-VED SKU-classification of surgical consumables and also assess the lead time. They recommend the classification should lead to a prioritization of the category I items, to minimize lead times, and to use software to perform live monitoring of stock.

The ABC-VED analysis is used by Sakthivelmurugan et al. (2021) as part of quality improvement at a healthcare unit through the implementation of lean six sigma. Six sigma being a measuring tool for quality.

Hussain, Siddharth, and Arya (2019), Vaz et al. (2008), Kumar and Chakravarty (2015), Gizaw and Jemal (2021), Jobira et al.(2021), and Nigah, Devnani, and Gupta (2010) all use volume value as the characteristic of the ABC part of their ABC-VED analysis. An ABC-VED analysis that uses demand volume alone as the characteristic in the ABC analysis was not found for this study. Teunter, Babai, and Syntetos (2010) for instance uses demand volume alone as the characteristic in a single characteristic ABC analysis.

Vaz et al. (2008), Kumar and Chakravarty (2015), Gizaw and Jemal (2021), Jobira et al.(2021), Sakthivelmurugan et al. (2021), and Nigah, Devnani, and Gupta (2010) all focus on pharmaceuticals in their healthcare related ABC-classifications. Jobira et al.(2021) stresses the importance of efficient inventory management of pharmaceuticals. Reasons for this being that they need to be affordable, and they represent a high percent of healthcare budgets. In 2019 pharmaceuticals constituted about 10% of healthcare cost in the US. For developing countries this percentage could be as high as 40% (Jobira et al. 2021). Of the studies mentioned in this chapter only Hussain, Siddharth, and Arya (2019) focus on consumables. Their ABC-VED analysis classifies surgical consumables.

2.5 FSN

The FSN analysis is a SKU classification technique that divides SKU into classes based on if they are fast moving (F), slow moving or non-moving (N) (Jobira et al. 2021). Thus, FSN analysis focus on the movement rate of the SKU. Also the abbreviation FNS (fast, normal and slow moving) is used (Gizaw and Jemal 2021, Sople 2016), but in this thesis the abbreviation FSN will be used.

Different criteria/characteristics are used in the FSN analysis to assess the movement rate of SKU. Demand volume, as mentioned under ABC analysis, is frequently used (Van Kampen, Akkerman, and van Donk 2012, Hmida, Parekh, and Lee 2014, Cavalieri et al.

2008). Turnover rate is also used (Tambunan et al. 2018, Devarajan and Jayamohan 2016), as well as order frequency (Jobira et al. 2021).

The cut of points between the classes for the FSN analysis differ, also for the ones using the same criteria. While Gizaw and Jemal (2021) and Hmida, Parekh (2014) uses the first and third quartile in the demand, Cavalieri, Garetti et al. (2008) uses two pre-set points in the demand data as cut of points even though they use the same criteria in their analysis. Jobira, Abuye et al.(2021) and Jobira, Abuye et al. (2021) both uses two pre-set points in their turnover rate and order frequency data.

A central purpose with the FSN analysis is to achieve control over, and to avoid obsolete materials (Devarajan and Jayamohan 2016). Sople (2016) argues FSN is the correct approach for determining the appropriate level of safety stock in an unpredictable environment.

2.6 VED-FSN

Sople (2016) combines the VED analysis and the FSN analysis in matrix, similar to what is done in the ABC-VED analysis. In the VED-FSN matrix, the FSN score determines the safety stock level of a SKU. F items are given the highest level of SS. The VED score determines strategies regarding ROP, order quantity (Q) and continues vs. periodic review. The study is written regarding a Maintenance, Repair and Operation (MRO) supply chain (SC) where unpredictability and emergency assignments makes criticality and speed crucial. Cavalieri et al. (2008) also addresses the VED-FSN in regard to the MRO SC. Gizaw and Jemal (2021) and Hmida, Parekh et al. (2014) also conducts VED FSN analysis, but combines them with the ABC analysis with 27 different combinations of the three different criteria.

A study with a duo criteria VED-FSN analysis for SKU classification in healthcare was not found doing this research. However, Hussain, Siddharth, and Arya (2019) mention FSN as an alternative for their SKU-classification of surgical consumables at a hospital in Dehli. In the article an ABC-VED analysis is performed. The argument used for choosing the ABC-VED analysis is that it has both the cost and the criticality aspect. Both being important aspects in healthcare.

2.7 Risk

Rowe (1975) define risk as “the potential for realization of unwanted , negative consequences of an event or combination of events to individual groups of people or to physical and biological systems”. When talking about risk we usually mean the consequence of an event occurring and the potential for it to occur (Rowe 1975). An unwanted stockout can for instance be such an event.

Keeping safety stock is a risk reducing measure to avoid stockouts, but keeping stock comes with a cost. Tang (2007) argues that keeping strategic stock at some sort of hub is a better alternative than safety stock. This hub should serve several costumers or locations and would reduce both holding cost and cost regarding obsolescence. Other costs could increase as a consequence of implementing strategic stock or other robust strategies. It is however argued that the implementation of these strategies should be seen as an insurance in case of major disruptions. The ability to handle disruptions is highly relevant for healthcare supply chains.

Keeping strategic stock is referred to as one of nine robust supply chain strategies presented by Tang (2007). These robust strategies are meant to make the supply chain better equipped to handle supply and demand in normal circumstances as well as being more capable to manage major disruptions.

2.8 SKU classification conceptual model

Van Kampen, Akkerman et al.(2012) also suggests a framework for SKU classification, and identify two factors that influences the SKU classification method: aim and context. They further describe that the SKU classification model consist of three factors: characteristics, technique, and classes. These five factors and the relationship between them are visualized in figure 1, Conceptual framework for SKU classification below.

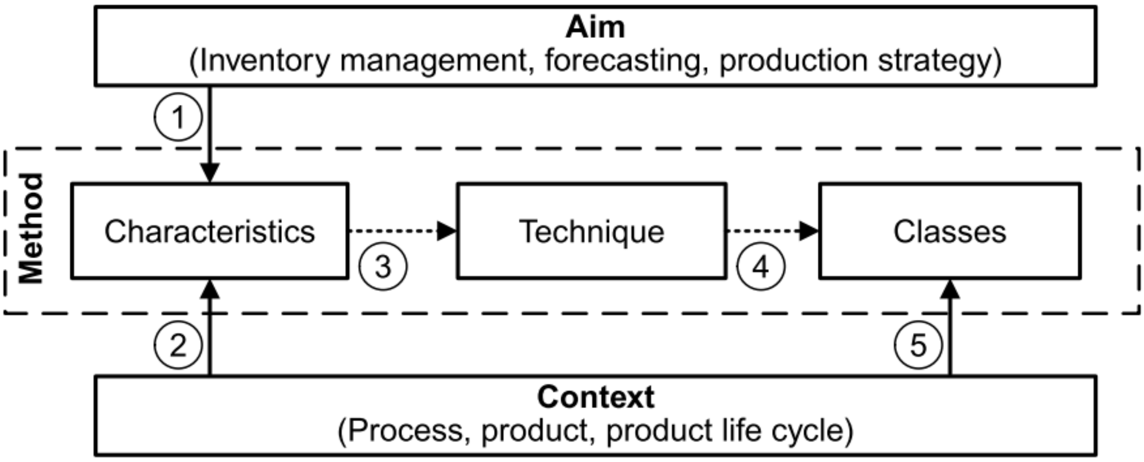

Figure 1 Conceptual framework for SKU classification (Van Kampen, Akkerman, and van Donk 2012)

The five factors are described as follows:

1. The aim is the reason for conducting the SKU classification, for instance inventory management or forecasting.
2. The context is typically the industry or sector related to the SKU classification, for instance the healthcare sector, or it could be more specific, like product life cycle.

The aim and the context will both affect the characteristics of the SKU classification model, and the context will also affect what Van Kampen, Akkerman et al. describes as operationalisation of the classes. Operationalisation of the classes is described as the process of selecting the number of classes and deciding the boarders between them.

3. The characteristics of the model could for instance be criticality, influenced by the aim and the context. This factor will again affect the technique. The term criteria is used as the equivalent to characteristic in this study.
4. The technique is either judgemental or statistical and is affected by the characteristics of the model. If the chosen characteristic is qualitative, like criticality, the judgemental technique VED analysis could, for instance, be chosen. If the characteristics is quantitative a statistical technique like ABC or FSN would be relevant,
5. The operationalisation of the classes is influenced by the technique and the context. If the chosen technique is VED analyses, as above, three classes would be natural. There could however be conceptual factors affecting both the number of classes and the cut of points between them.

To be aware of these factors and the relationship between them could make it easier for organisations to make a conscious choice of SKU classification model.

3 CASE DESCRIPTION

3.1 Helse Midt Norge RHF

Helse Midt Norge (HMN) is a regional health trust (RHF) located in the middle of Norway. A RHF has the responsibility to implement the Norwegian national health care politic in its region. The counties Møre og Romsdal and Trøndelag constitute the region under HMN.
HMN consists of three local health trusts (HF) providing patient treatment: Helse Nord Trøndelag HF (HNT), St. Olavs Hospital HF (STO) and Helse Møre and Romsdal HF (HMR). HMN is the owner of HNT, STO and HMR. These three HF consists of two till four hospitals in addition to several locations outside its hospitals for rehabilitation, mental health care and substance abuse treatment.
HMN has a principal that logistic operations should be handled by logistic personnel not by healthcare workers. An important aspect of this is the principal of active supply. Active supply implies that logistic personnel first make the orders for the hospital wards, and then physically place the ordered SKU at its predefined place at the ward. Orders are placed in the ERP system by scanning barcodes on the shelf of the SKUs predefined place. This way the healthcare personnel is not involved in the order process, they just find the material they need at its predefined location at the ward.
There is a total of four RHF like HMN in Norway, all owning several HF. The other three RHF are Helse Nord in the north, Helse Sør Øst in the southeast and Helse Vest in the west of Norway. Not all HF provides patient treatment, some have a pharmaceutical or other supportive functions.

3.1.1 HNT HF

HNT is the HF furthest to the north in HMN, bordering to Helse Nord. It consists of the hospitals in Levanger and Namsos who serves as local hospitals for the citizens of its associated municipalities. Levanger is the biggest of two hospitals serving as a local hospital for about 100 000 people while Namsos is serving about 40 000.

HNT has, as of September 2022, a central warehouse at the hospital in Levanger. This warehouse is serving both hospitals in the HF as well as locations outside the hospitals with medical and non-medical consumables.

3.1.2 STO HF

STO is geographically located in the middle of the region belonging to HMN. The health trust consists of the regional hospital St. Olavs Hospital in Trondheim which have the same name as the health trust and the two smaller hospitals in Røros and Orkdal. St. Olavs Hospital in Trondheim is the biggest and most specialised hospital in HMN and is the university hospital of the region working closely with the university in Trondheim.
As of September 2022, STO has a centralized warehouse outside the hospitals, located in Heimdal about 10 km from the hospital St. Olavs Hospital. This warehouse in Heimdal is serving the whole HF with medical and non-medical consumables,

3.1.3 HMR HF

HMR is the health trust furthest to the south in HMN, serving the county of Møre og Romsdal. It consists of the hospitals in Kristiansund, Molde, Ålesund and Volda, presented in order from north to south. Ålesund is the biggest and most specialised hospital in HMR. HMR has in 2022 started the construction of a new hospital called Sjukehuset Nordmøre og Romsdal (SNR) which will replace the hospitals in Kristiansund and Molde. The hospital in Kristiansund will be transformed into a district medical centre (DMS) providing outpatient treatment, while the hospital in Molde will be closed entirely. The construction of SNR is planned to be finished in 2025.
As of September 2022, all the four current hospitals in HMR have warehouses inside the hospitals. These warehouses serve the hospitals and other geographically close locations belonging to HMR with medical and non-medical consumables. SNR is planned without a warehouse for consumables inside the hospital.

3.2 LS HMN

In 2008 HMN agreed upon establishing a new warehouse for supplying the hospitals in the whole region with medical and non-medical consumables. Some essential preconditions for establishing such a warehouse were however not in place back then. The most relevant requirements missing was a standard logistic and economy system, a common registry of materials and general master data in the region.

Through the implementation of a standard ERP system, with common registry of materials and master data in 2016 these requirements were fulfilled, and the decision from 2008 was brought back up. The project Fremtidig Forsyningsstruktur (FFS) HMN was established to assess the decision to establish a regional warehouse for HMN. In 2018 it was decided that the decision from 10 years before still stands, and the planning of the regional warehouse, named Logistikk Senter (LS) HMN could start. FFS was prolonged to conduct the planning of LS HMN.

Early in the project internal or external operation of LS HMN was assessed. It was decided that STO should be given the responsibility to run LS on behalf of all HMN at inauguration. External operation will be assessed again in the future. STO was given this responsibility based on that they are geographically located in the middle of the HMN region, and that they have the experience with running a centralized warehouse for STO HF.

LS will supply the hospitals in HMN with trolleys packed with consumables in boxes for each hospital wards. There will be a sterile area at LS, allowing breakbulk of even sterile consumables. One truck will arrive at each of the hospitals in HMN mentioned in chapter 3.1 from LS every day. This will allow urgent deliveries outside the planned deliveries.

The assortment stored at LS will be purchased of LS through either regional or national agreements negotiated by the central purchasing unit Sykehusinnkjøp HF. The central purchasing unit is owned together by all the four mentioned RHF. A central task for FFS has been to standardize the assortment today stored at the six warehouses mentioned in chapter 3.1 into one joint assortment for all the hospitals in HMN to be stored at LS. To be included in the LS assortment a material must fulfil one or more of several criteria like for example degree of criticality and level of consumption.

If a material has a real demand at one of the mentioned hospitals in HMN but hasn't fulfilled any of the criteria to be included in the LS assortment it can be purchased directly from the supplier. These materials will be delivered directly to the hospitals.

There will be a regional delivery schedule plan describing when all hospital wards and units within the three HF described in chapter 3.1.1 to 3.1.3 will be getting deliveries from LS. This plan will further in this thesis be referred to as the delivery schedule. In the delivery schedule it will be defined which weekdays a specific ward is getting supplies from LS. Orders outside the delivery schedule must be defined as extra deliveries in the ERP system to get deliveries outside the units predefined delivery days. Extra deliveries will be sent on the next truck going from LS to the hospital in question. The delivery schedule will be adapted to the hospital wards delivery days pre-LS.

LS HMN will replace the six internal warehouses in HMR, HNT and STO, described in chapter 3.1, suppling the daily demand of consumables at the hospitals. It will only be one level of inventory locally to serve daily operation at the hospitals, the stock at the hospital wards. Hence, the importance of inventory management at the hospital wards will increase. Sufficient stock at the hospital wards, close to the patient, will be important after the commissioning of LS to reduce risk of stockouts. However, the implementation of LS could also be seen as a risk reducing measure described by Tang (2007) as strategic stock. Strategic stock is referred to as a robust strategy and explained in chapter 2.7.

3.3 The ICU

I will in my thesis focus on the four hospitals of my employer HMR. All these four hospitals have today as mentioned in chapter 3.1.3 local in-house warehouses supplying the hospital wards with medical and non-medical equipment. When LS HMN is commissioned the hospital wards of the four hospitals in HMR will go from being supplied from local storage inside the hospital to being supplied from LS as illustrated in figure 2 below.

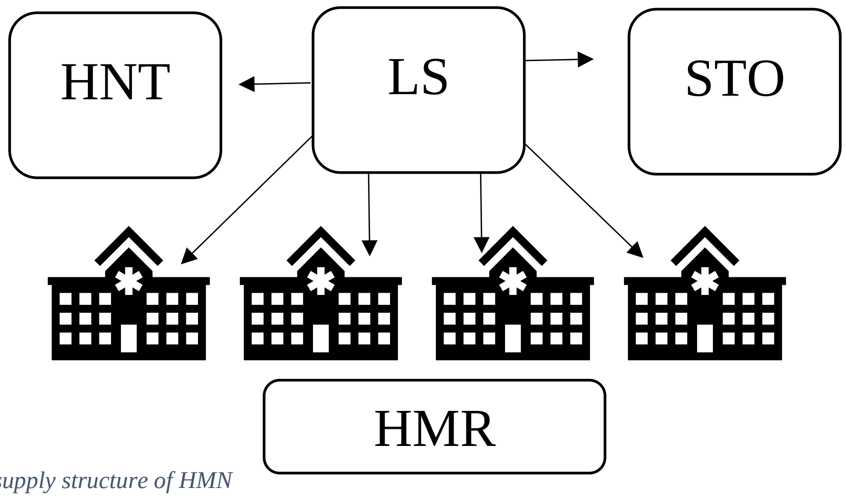

Figure 2 Future supply structure of HMN

The hospital wards in HMR are represented by one of its intensive care units in this study. The ICU is located at the hospital in Ålesund. This is one of the hospitals in the region located furthest away from LS. Only the hospital in Volda will be further away from LS. Deliveries to the hospital in Ålesund from LS will be initiated autumn 2023.The ICU in question will further just be addressed as the ICU.

Typically for hospital wards in the region the space for inventory is limited, which makes keeping the right amount of the right SKU essential. The patients at the ICU often have life threatening or very serious conditions. The treatment is often done using advanced medical equipment like respirators and equipment for monitoring critical bodily functions. Consumables that are needed to support the operation of this equipment is often crucial for the life of the patient making criticality an important characteristic for a SKU classification of the ICUs inventory.

The inventory at the hospital wards is as of October 2022 managed by selected healthcare workers at the ICU. There is no classification of the SKU, and the inventory management is largely depending on the knowledge and experience of the selected ICU personnel in partnership with the logistic personnel at the hospital. This includes determining SS, ROP, and Q. The inventory level at the ICU is not managed in the ERP system. When an order is delivered from the local warehouse the materials are regarded as consumed in the system, meaning that it is only manual inventory management at the ward.

Before the initiation of LS in HMR, it is planned that logistic personnel should take over this responsibility. The supply at the ICU will then be handled according to the principle of active supply, as described in chapter 3.1. The logistic personnel performing the active supply will also serve several other units where they make the orders and put the deliveries in place.

The ICU has as of October 2022 deliveries from the local warehouse on Monday, Wednesday, and Friday. If urgent demand, some deliveries is done outside the set delivery days. Also, some delivery days will lapse due to holidays. In these cases, orders will be higher on the previous delivery day to secure inventory through the holydays. This sums up to approximately 150 delivery days pr year The different SKUs at the local warehouse is purchased through the same agreements as described in chapter 3.2.

It is planned that the ICU will have deliveries from LS on the same days as before LS, so it will be defined in the delivery schedule described in chapter 3.2 that the ICU will have deliveries on Monday, Wednesday, and Friday. The orders must be placed within a time limit the day before the delivery day (order stop Friday for Monday deliveries). Thus, the lead time (LT) is one day for the deliveries on Wednesday and Friday and three days for the delivery on Monday. The delivery is transported to HMR by night and waiting for the logistic personnel in the morning. The logistic personnel will then distribute the deliveries out in the hospital.

SKU classification will allow differentiated inventory strategies for materials in the different classes, such as level of safety stock, and reordering point. There are some classification features available in the ERP system (ABC), but these are not actively in use.

4 DATA AND METHODS

All the data handling, the descriptive statistics, the t-test, the analysis and finally the test model (4.3 SL Scenario model) described in chapter 4 including sub chapters are conducted using Microsoft Excel.

The research is built up in the following order: The quantitative 2018 data from chapter 4.1.1 and the qualitative data presented in chapter 4.1.2 founds the base of the SKU classification analysis presented in chapter 4.2.1 – 4.2.3. The duo-characteristic SKU classifications presented in chapter 4.2.4 and 4.2.5 are combinations of the single-characteristic classifications from chapter 4.2.1 – 4.2.3. Finally, the quantitative 2019 data from chapter 4.1.1 is used to assess the performance of the two duo-characteristic SKU classification techniques, and their corresponding SL policies, in chapter 4.3 SL Scenario model.

The definitions of SKU and SKU classification in this thesis, are those describes by (Van Kampen, Akkerman et al. (2012) and Silver, Pyke et al. (1998) in chapter 2.1.

- SKU being an item with a specific function, colour, size, style and most often location. The terms SKU, material, and item is being used in the same meaning in this thesis.
- SKU classification being a systematic classification of materials in relation to various properties.

4.1 Data

All the materials in the analysis are intensive care specific materials from the HMN criticality evaluation data set, described in chapter 4.1.1. This means that there are materials in stock at the ICU that are excluded from the study because they were not defined as intensive care specific, and thus not part of the HMN criticality evaluation data set. It also means that all the materials described in chapters 4.1.2 ICU daily consumption data 2018 and 4.1.3 ICU daily consumption data 2019 also is part of the HMN criticality evaluation data set.

4.1.1 HMN criticality evaluation

During the Covid-19 pandemic that advanced through the world from late 2019 a group of intensive care healthcare personnel from the hospitals in all the three regional groups within HMN, together with mercantile recourses from logistics, agreed on a critical or desirable classification for all material that was labelled as intensive care specific. The materials were further given a priority as unique in assortment, first choice in assortment, equal alternatives in assortment, second choice in assortment or third choice in assortment. The HMN classification agrees with Kumar and Chakravartys (2015) definition of vital (V), essential (E) and desirable (D) in a health care specific VED analyses where V, E, and D is defined as follows:

V. "Critical for life and patient care."
E. "Critical but alternatives acceptable."
D. "Low critical value."

V (Critical for life and patient care) corresponds with materials defined as critical and unique in assortment in the HMN criticality evaluation. E (Critical but alternatives acceptable) corresponds with the materials defined as critical and first, second, or third choice in assortment or equal alternatives in assortment. D (Low critical value) corresponds with all the materials defined as desirable in the HMN criticality evaluation regardless of alternatives in assortment.

The HMN criticality evaluation also complies with Kumar and Chakravartys (2015) demand of minimum three expert opinions assessing the criticality of each SKU to achieve the appropriate level of concurrence. Since the expert group discussed each SKU until agreeing on a classification it also fulfil the demand of Sakthivelmurugan, Senthilkumar et al. (2021) that at least 50 % of experts involved must concur to give a SKU a VED classification.

The data set was divided in three groups: general intensive care items, equipment specific items and children's specific items. Only the two first groups were relevant to the ICU in question, so the children's specific items were excluded from the data. The general intensive care items, equipment specific items were joined in one list. This data was used in the VED analysis and will from now be referred to as the HMN criticality evaluation data set.

Five of the items in the HMN criticality evaluation data set was either missing criticality assessment or priority, not making it possible to give them a VED score. These were excluded from the study, leaving 162 items in the HMN criticality evaluation data set. Each of these 162 items had a material number that is identifiable in the ERP system used by HMN. The HMN material numbers are not used in this thesis, but each of the 162 items in the HMN criticality evaluation was given a number between 1 and 162 to identify the SKUs. These identifiers will further be referred to as SKU ID.

4.1.2 ICU daily consumption data

Consumption data with prices for 2018 and 2019 were gathered from the ERP system for materials from the HMN criticality evaluation data set that were ordered by the ICU in both 2018 and 2019. This constituted a total of 65 individual SKU.
The consumption data extracted from the ERP system contained 30 columns with a total of 5203 observations. 2727 observations where from 2018 and 2476 where from 2019. One observation is one order of one material registered on the day of delivery. Data from the two years in question were extracted and handled separately. Below follows a description of each of the 4 columns from the ERP data used in the analysis in this thesis and what it is used for:

1. Material number is the SKU identifier in the ERP data. This was matched to the SKU ID described in chapter 4.1.1 which again was used to identify each of the 65 SKU used in the analysis. This was used to identify the number of observations (or orders) for each SKU per year. Theis is referred to as order frequency.
2. Posting date is the date the order was registered as delivered to the ICU in the ERP data. This was used to identify the date, the weekday, and the week number the order was delivered.
3. Quantum in the ERP data is the number of units delivered of the specific SKU in one order. The summed quantum each year is referred to as order volume.
4. The column amount in the ERP data is the amount the ICU was charged for each order. The summed amount each year is referred to as volume value. This will be the same as multiplying the demand and the price for each item to find the volume value as described in chapter 2.2.

The orders in the ERP data were, as described in chapter 3.3, delivered to the ICU from the local warehouse. The ordering was done by personnel at the ICU. The deliveries were mainly executed on the planned delivery days Monday, Wednesday, and Friday. This is described more thoroughly in chapter 3.3.

The 2018 ERP data set is used in the SKU classifications described in chapter 4.2.1 to 4.2.5. This data will further be referred to as the ICU daily consumption data 2018. The 2019 ERP data set is used to test the output from the classifications in the SL scenario model described in chapter 4.2.6. This data will further be referred to as the ICU daily consumption data 2019.

Descriptive statistic for ICU consumption data 2018 is presented in table 1 Descriptive statistic, Order quantity 2018 below.

Table 1 Descriptive statistic, Order quantity 2018

Order quantity 2018							Total number of orders	Total number of units
Mean	Median	Mode	Std dev	Skewness	Minimum	Maximum		
40	15	50	66	3,8	1	600	2727	109090

As table 1 shows, the ICU daily consumption data 2018 consists of 2727 orders and a total of 109 090 ordered units. As the skewness of 3,8 shows, the data is right/positive skewed. This is confirmed by the median being lower than the mean and indicates that the ICU daily consumption data 2018 contains a predominance of small orders. The minimum order quantum is 1 unit. A total of 229 orders, or 8 % of total orders, were 1-unit orders. The standard deviation of 66 confirms a widely spread order quantity through 2018, ranging from 1 to 600 units with a mean of 40 units.

Descriptive statistic for ICU consumption data 2019 is presented in table 2 Descriptive statistic, Order quantity 2019 below.

Table 2 Descriptive statistic, Order quantity 2019

Order quantity 2019							Total number of orders	Total number of units
Mean	Median	Mode	Std dev	Skewness	Minimum	Maximum		
41	14,5	100	67	3,7	1	800	2476	102088

As can be seen in table 1 and 2 the ICU consumption data 2018 and 2019 are both positive skewed with almost the same standard deviation (66 and 67) and mean (40 and 41). The most common order quantity, the mode, has risen from 50 in 2018 to 100 in 2019. This indicates that the order quantity has been adjusted up for some of the materials in 2019.

This is supported by a reduced number of incoming orders from 2727 to 2476 units. The reduction in orders can also be explained by a reduction in total number of units by 7002. Just looking at table 1 and 2 the ICU consumption data 2018 and 2019 seems similar enough for using the 2019 data to test the classification based on the 2018 data. In addition, a two-tailed t-test is used to test if the observed differences between mean order quantity (40 and 41) is significant. Since we have a large N in both samples (2727 and 2476) the t-test is used even though none of the samples are normally distributed. We have the following two hypothesises: $H_0: \mu 1 - \mu 2 = 0$ and $H_0: \mu 1 - \mu 2 \neq 0$. With a t-stat of -0,67 and a critical value of 1,96 we get that -1,96<-0,067<1,96 and thus do not reject H_0. The t-test do not show significant difference between mean order quantity at the ICU in 2018 and 2019. A p- value as high as 0,5 also indicates that the null hypothesis should not be rejected.

Table 3, ICU daily consumption data 2018, grouped descriptive statistic below shows how the order volume, the volume value, and the order frequency at the ICU in 2018 are divided among 14 product categories defined in the ERP system for the 65 SKU in this study. The categories are based upon the categorization used by the central purchasing unit described in chapter 3.2. Seven material groups which contained just one material is gathered in the bottom group called Other. Mean, standard deviation, minimum and maximum for order quantity per category in 2018 is also presented in the table. As mentioned, the 2018 daily consumption data is the dataset that will be used in the SKU classifications.

The categories where not part of the consumption data extracted from the ERP system and had to be gathered from a different report in the ERP system. The product categories were then matched with the consumption data using the material numbers.

Table 3 ICU daily consumption data 2018, grouped descriptive statistic

Material group	Nr of SKU	Order volume (%)	Volume value (%)	Order frequency (%)	Order quantity 2018			
					Me-an	Sd	Min	Max
Suction, tubes, and bags	2	502 (0,5)	12892 (1,2)	84 (3,1)	6	6,4	2	60
Respiratory products, tubes, and accessories	8	782 (0,7)	60087 (0,7)	193 (7,1)	4	4,1	1	20
Patient monitoring and examination, anaesthesia	4	707 (0,6)	110839 (10,2)	181 (6,6)	4	2,5	1	15
Stool control product	2	62 (0,1)	40287 (3,7)	27 (1,0)	2	3,9	1	20
Suction catheter and suction kit	7	1672 (1,5)	45834 (4,2)	90 (3,3)	19	37	1	100
Syringes and needles	7	35095 (32,2)	137780 (12,7)	509 (18,7)	69	40	10	300
Central and peripheral venous catheters, vein	7	2580 (2,4)	56325 (5,2)	115 (4,2)	22	24	1	50
Fixation products	2	4093 (3,8)	9236 (0,9)	54 (2,0)	76	65	8	400
Infusion and transfusion products	9	55279 (50,7)	159749 (14,7)	640 (23,5)	86	106	1	600
Blood substitutes and infusion solution	3	3698 (3,4)	61475 (5,7)	308 (11,3)	12	9	1	90
Nutrition systems	3	600 (0,6)	5595 (0,5)	45 (1,7)	13	20	1	100
Equipment and concentrates for peritoneal	2	758 (0,7)	153173 (14,1)	45 (1,7)	17	11	2	52
Oxygen therapy	2	403 (0,4)	72905 (6,7)	39 (1,4)	10	2	5	20
Other	7	2859 (2,6)	158834 (14,6)	397 (14,6)	7	8	1	50
Sum	**65**	**109090**	**1085012**	**2727**				

One category that stands out is infusion and transfusion products which stands for 50,6 % of order volume but only 14,5 % of volume value. This is also material that are typical high volume (in cm^3) so keeping the right amount in stock is important. Together with syringes and needles this category stands for 83,1 % of order volume, but only 27,4 of volume value.

As described earlier in this chapter the ICU daily consumption data 2018 contains many small orders. This can also be seen in table 3 where 9 out of 14 groups has a minimum order quantity of 1. 1042 of 2727 orders had quantity less than 10. The reason for this is, according to logistic personnel at the hospital, that the implementation of the ERP system was fresh. The ERP system was implemented in 2016. Also, the order process was not yet fully incorporated at the ICU leading to more single unit orders when whole boxes perhaps should have been ordered.

The seven material groups which contained just one material only had an order volume of 2859. These groups constitute just 2,6 % of order volume but 14,6 % of both volume value and order frequency.

4.2 Research model

According to the conceptual model of Van Kampen, Akkerman et al. (2012) the aim of a SKU-classification is the reason for doing the classification and the context is related factors like availability of data or the industry in question. This conceptual model is visualized in figure 1. The characteristic of a SKU classification is given by the aim of the classification and the context related to the classification. The characteristics of SKU classification is typically connected to volume in one way or the other but can also for instance have a customer focus like criticality. The characteristic of the classification will further decide if a judgemental or statistical technique is preferable. This conceptual framework is used below in an attempt to explain why the chosen SKU classification techniques presented in the following sub chapters are selected for this study.

The aim of the classifications in this study is to improve the inventory management at the ICU through a systematic method of deciding the SL in a try to find the correct level of SS. The correct SS at the ICU will help secure constant access to the most necessary equipment, take into account the available storage area, minimize waste of materials, and reduced cost.

One important contextual factor for the classifications in this study is the related industry, healthcare. Being in healthcare and treating as sick patients as an ICU does, together with the need for equipment specific consumables, implies how urgent the need of the SKU in the classifications can be. Limited storage space, the removal of local central warehouses at the hospitals, and a pressure on leaders to reduce costs are other related factors.

The need for important lifesaving equipment at the ICU strongly point to the characteristic criticality. Being a qualitative characteristic criticality implies a judgmental technique such as the VED analysis. Just having a high SL of critical materials would probably ensure access to the most important items but would most likely not be so good with regards to waste and cost reduction and efficient use of the limited storage space. Thus, combining the VED analysis with a statistical technique such as the volume-value based ABC analysis or the movement based FSN analysis would take into account these other mentioned factors as well. With regard to availability of data the ABC and FSN analysis are highly relevant. The three specified SKU-classification techniques and the two combinations of the judgmental and the statistical techniques are presented in the five following sub chapters. The operationalisation of classes as defined in the conceptual model of Van Kampen, Akkerman et al. (2012) is also addressed these chapters.

4.2.1 ABC

With the choice of ABC analyses the operationalisation of the classes is quite set at three classes and boarders according to the Pareto principle as described in chapter 2.2. The Volume value, also described in chapter 2.2, is the most common characteristic used in ABC analysis and will also be used for this purpose in this thesis. Volume value pr SKU 2018 is extracted from the dataset ICU daily consumption data described in chapter 4.1.2. Descriptive statistic for volume value pr SKU 2018 is presented in table 4 below.

Table 4 Descriptive statistic, Volume value pr SKU 2018

Volume value pr SKU 2018							Total number of SKU	Total volume value
Mean	Median	Mode	Std dev	Skewness	Minimum	Maximum		
16692	8157	-	22320	2	127	100327	65	1085011

The volume value data is, as shown by the minimum and maximum as well as the standard deviation in table 4, quite spread. Compared to the order quantity from the same data presented in table 1 the volume value is however less skewed.

The boarders between the classes set with regards to the demand pattern of the respective ward and the prices of the items, which must be considered as contextual factors. The high volume of especially three items, contributing to 49 % of order volume, would suggest traditional A = 80%, B = 15% and C = 5% (of volume value) boarders, as described by Vaz, Tedjamulja et al. (2020), not to get too few A items. The low price of these items however points to A = 70%, B = 25% and C = 5% (of volume value) boarders, as described by Nirmala, Kannan et al. (2021). The last described boarders are used for the ABC analysis in this study.

After selecting the SKUs to be part of the analysis, standard procedure for ABC calculations begins with calculating the volume value for each SKU (Reid 1987). This was already done for each order line in the consumption data from the ERP system, so the sum of the volume value for all order lines for each SKU had to be calculated. Then, the items were sorted in descending order of volume value and the cumulative volume value was calculated. Next, the percentage of volume value and the cumulative percentage of volume value was computed. Based on the cumulative volume value in percent the materials was divided into A, B and C categories according to the set boarders (Vaz et al. 2008). Finally, the number of SKU in each category was summed, and the percentage of total SKU in each category calculated.

A benchmarking using the results from Reid (1987) will be conducted on the output of the ABC analysis. This dataset is frequently used for benchmarking ABC analyses (Van Kampen, Akkerman, and van Donk 2012)

4.2.2 VED

In compliance with the definitions of Kumar and Chakravarty (2015) for vital, essential and desirable materials in a healthcare specific VED analyses as described in chapter 2.3 and 4.1.1, the HMN criticality evaluation could be transformed to V,E and D classes. How this transformation complies with Kumar and Chakravarty (2015) and Sakthivelmurugan, Senthilkumar et al. (2021) is explained in chapter 4.1.1. The relationship between the HMN criticality evaluation and the VED classes is described in table 5 below.

Table 5 The relationship between the HMN criticality evaluation and the VED classes.

HMN criticality evaluation	Criticality	Priority	Criticality with priority	VED
Critical, unique in assortment	C	U	CU	V
Critical, first choice in assortment	C	A1	CA1	E
Critical, equal alternatives in assortment	C	A0	CA0	E
Critical, second choice in assortment	C	A2	CA2	E
Critical, third choice in assortment	C	A3	CA3	E
Desirable, unique in assortment	D	U	DU	D
Desirable, first choice in assortment	D	A1	DA1	D
Desirable, equal alternatives in assortment	D	A0	DA0	D
Desirable, second choice in assortment	D	A2	DA2	D
Desirable, third choice in assortment	D	A3	DA3	D

The HMN criticality evaluation data set has a criticality code and a priority code. In the second column in table 5 the criticality code is defined, C for critical and D for desirable. The priority code is given in the third column, U for unique, A1 – A3 for first - third choice in assortment, and A0 for equal alternatives in assortment. A combined criticality with priority code was given in this study for easier data handling this is defined in the fourth column. The VED class corresponding to the HMN criticality evaluation can be seen in the fifth column of table 5 and are explained below.

The CU items are critical and unique in assortment which complies with V:" Critical for life and patient care". The rest of the C material are either first, second or third choice in assortment, or they have equal alternatives in assortment. Thus, they comply with E:" Critical but alternatives acceptable". All the D materials are labelled desirable in the evaluation and complies with D:" Low critical value" (Kumar and Chakravarty 2015). The 65 SKU in the ICU daily consumption data 2018, described in chapter 4.1.2, was matched with the HMN criticality evaluation data set, described in chapter 4.1.1, and given a combined criticality with priority code. Using this code, the 65 SKU from chapter 4.1.2 was matched with table 5, and each material was given a V, E, or D classification. Finally, the number of SKU in each category was summed, and the percentage of total SKU in each category calculated.

4.2.3 FSN

As mentioned in chapter 4.2.1 ABC the demand of three specific items was particularly high in 2018. Thus F = 80%, S = 15% and N = 5% (of demand volume) boarders would be relevant to use in a demand based FSN analysis where demand volume/order volume is the characteristic as done by Hmida, Parekh, and Lee (2014) and Cavalieri et al. (2008). In an FSN analyses based on order volume from the ICU consumption data 2018, and the borders mentioned above, the maximum within the F class would contribute to 30 % of order volume while the lowest to only 3 %. Instead order frequency, as used by Jobira et al. (2021) and described in table 6 Descriptive statistic, Order frequency pr SKU 2018 below will be used in the FSN analysis. Order frequency pr SKU 2018 is extracted from the dataset ICU daily consumption data described in chapter 4.1.2.

Table 6 Descriptive statistic, Order frequency pr SKU 2018

Order frequency pr SKU 2018							Total number of SKU	Total number of orders
Mean	Median	Mode	Std dev	Skewness	Minimum	Maximum		
42	25	9	40	1,2	1	162	65	2727

With a mean of 42, a standard deviation of 40, and skewness of 1,2 order frequency is much less spread and more evenly distributed than the order volume data, but the data still varies from just one order in 2018 to 162 orders.

The calculations done in the FSN analysis are quite like those described for the ABC analysis in chapter 4.2.1, but instead of starting with sorting the SKU in descending order by volume value order frequency is used. Then cumulative order frequency, order frequency in percent and cumulative order frequency in percent is computed.

As described in chapter 2.9 it can be conceptual factors, in addition to the chosen technique (FSN), affecting both the number of classes and the cut of points between them in a SKU classification. With three predefined classes (F, S, and N) we will leave the number of classes at three as in the ABC and VED analyses but assess the cut of points between them. Also mentioned in chapter 2.9 is that different cut of points, such as two set points in the data (Cavalieri et al. 2008) (Jobira et al. 2021) or the first and third quartile (Gizaw and Jemal 2021, Hmida, Parekh, and Lee 2014), are used in the FSN analysis. Cut of point at first and third quartile will give a low number of F-units (5). Using cut of point at 45 % of top order frequency (F), 35 % of middle (S), and 20 % of bottom order frequency (N) gives a F-class with order frequency above 100 and a N class with order frequency in percent below 1 % (except one SKU at 1,06 %). 45%, 35% and 20% of order frequency are the boarders used in the analysis. When the boarders are set the SKU are given a F, S, or N classification accordingly based on the cumulative order frequency in percent. Finally, the number of SKU in each category was summed, and the percentage of total SKU in each category calculated.

4.2.4 ABC-VED

By combining the classifications from the ABC analysis described in chapter 4.2.1 and the VED analysis described in chapter 4.2.2 the 65 SKU is, as described in chapter 2.6, given an ABC-VED classification from nine possible combinations (Vaz et al. 2008). With respect to the ABC-VED classification the SKU is divided into three categories (I, II, and III):

I. Either high volume value (A) or vital (V): AV, AE, AD, BV, and CV
II. Not I, but either medium volume value (B) or essential (E): BE, BD, and CE
III. Both low volume value (C) and desirable (D): CD

Using the inventory policies for the three categories (I, II, and III) in an ABC-VED analysis based on Vaz et al. (2008), Ferreira et al. (2008) and Kumar and Chakravarty (2015) SKU belonging to category I are given a lower service level than II, while category III is given the highest SL of the SKU in the analyses. The SL is set in such a manner to be able to prioritise and keep focus on the I-items, while the III-items will demand a very low level of monitoring.

4.2.5 VED FSN

Much like the ABC-VED analysis in chapter 4.2.4 the classifications from the VED analysis described in chapter 4.2.2 and the FSN analysis in chapter 4.2.3 are combined into nine possible combinations of VED and FSN. Sople (2016) defines a matrix for inventory policies in a VED-FSN analysis where the level of SS is defined by the FSN classification and the policies on periodic review, ROP and purchasing is given by the VED classification. This decision matrix is suggested with respect to an MRO supply chain where criticality and speed is decisive.

This thesis argues that criticality in the case of the ICU in question is so crucial that the VED classification also should affect the SL (and then the level of SS). The consequences of stock out on the V-items could be a matter of life and death. Thus, the following categories for inventory policies in the VED-FSN analysis is suggested:

I. Either vital (V) or Fast (F): VF, EF, DF, VS, and VN
II. Not I, but either essential (E) or slow (S): ES, EN, and DS
III. Both desirable (D) and non-moving (N): DN

It is suggested that service level is put high for the I-items, lower for the II-items and lowest for the III-items to avoid stock outs and obsolete SKU and at the same time secure availability of the V-items. This way the items with a high risk of stock outs and/or a severe consequence if a stock out receives a high SL.

4.3 SL scenario model

The SL scenario model presented in this sub chapter was built on the data presented in chapter 4.1 and the analysis presented in chapter 4.2 using Microsoft Excel. The model considers two scenarios: one where the described SL-policies of the ABC-VED analyses is applied and one where the VED-FSN SL-policies are applied.
Based on the results of the 2018 ABC-VED and VED-FSN analyses the ICU daily consumption data 2019 is used to assess the performance of the SL policies connected to the two SKU classification techniques. The SL policies of the ABC-VED and VED-FSN analyses are described in chapter 4.2.4 and 4.2.5. The t-test described in chapter 4.1.2 show no significant difference between the 2018 and 2019 ICU daily consumption data. The SL scenario model used to assess the mentioned SL policies is explained in the sub chapters below. SL being defined as “the probability that a stockout will NOT occur during a replenishment cycle” (Gourdin 2006).

4.3.1 SKU selection

First, the SKUs with the most stable demand was selected for the SL scenario model using the coefficient of variation (CV) to get a more reliable result. Since it is analyses based on 2018 data being tested, the CV was also calculated using 2018 data. The CV for all the 65 SKU in the daily consumption data 2018 was calculated using the formula [1] below. The weekly demand in 2018 computed from the order volume in the ICU daily consumption data 2018 is used to compute the CV. Weekly demand is used instead of daily demand to compute the CV since the ICU daily consumption data do not contain actual daily demand, but order volume (mainly on the order days described in chapter 3.3).

$$[1]\ CV = \frac{\sigma}{\mu}$$

Where σ is the standard deviation and μ is the mean.

The 14 SKU with CV<1 and different SL in the ABC-VED and VED-FSN was selected for the test model (if equal SL, the result would be equal for both techniques and the SKU would have no comparative value). 2 of the 14 SKU had too low demand to work in the test model (mean order quantity 2018 below 1 per day). This meant that finally 12 SKU was selected to be assessed in the SL scenario model. The calculated CV together with summed values for order volume, volume value and order frequency for the 12 selected SKU is presented in table 7 below.

Table 7 CV and summed values of the 12 SKU selected for the SL test

SKU ID	Order volume	Volume value	Order frequency	CV
79	8090	24873	105	0,57
45	9390	21084	127	0,60
63	32000	9401	120	0,61
99	11250	47813	124	0,62
38	529	28354	102	0,63
40	5625	14676	114	0,68
124	616	83072	100	0,70
65	5690	45643	112	0,72
82	1966	14562	162	0,75
130	2140	32100	82	0,76
81	1504	10285	129	0,77
44	6460	31160	59	0,98
Sum	**85260**	**363022**	**1336**	

As we can see in table 7, CV and summed values of the 12 SKU selected for the SL test, the order volume and volume value vary quite a lot between the 12 SKU with the most stable demand in 2018. The SKU with the highest order volume had 32000 ordered units through 2018, while the lowest only 529. Volume value vary from 9401 to 83072. The order frequency however is more stable and only varies from 59 to 162.

4.3.2 SL and SS

Based on the SL policies for ABC-VED analyses and VED-FSN analysis described in chapter 4.2.4 and 4.2.5 the different categories (I, II, or III) were given either a low, medium, or high degree of SS for both classification techniques. The three degrees of SS was then given a corresponding SL that would apply for both the ABC-VED analyses and VED-FSN analysis. The SL is set quite high because stockouts of critical equipment at the ICU could have life threatening consequences, The degree of SS and the selected corresponding SL is given in table 8 Service level in the SL test below.

Table 8 Service level in the SL test

Safety stock	Service Level	Z
High	**99,98**	3,49
Medium	**97,06**	1,89
Low	**95,05**	1,65

All the 12 selected SKU had an ABC-VED classification and a VED-FSN classification from the analysis in chapter 4.2.4 and 4.2.5 that corresponded with a category (I, II, or III) in both classifications. Based on its classification each SKU was given a degree of SS and a SL according to table 8 for both scenarios.

To calculate the units of SS for each of the 12 SKU in question the following formula [2] is used:

$$[2]\ SS = \sigma_L * Z$$

Where Z is the statistical z-score from the normal distribution corresponding to the SL applied to the different categories in the ABC-VED and VED-FSN analysis. The statistical z-score is presented in table 8 along with its corresponding SL and degree of SS. σ_L is the standard deviation of demand in LT. The LT is addressed in chapter 3.3. LT from LS on the ICU`s delivery days and the standard deviation of weekly average daily demand 2018 (σ_D) is used in the calculation of σ_L [3] below:

$$[3]\ \sigma_L = \sigma_D * \sqrt{LT}$$

4.3.3 Test

To test the described SL policies the outgoing inventory for each day in 2019 was estimated for each of the 12 SKU using the following inventory equation [4] for both classification techniques:

[4] $I_{m,t} = I_{m,t-1} + X_{m,t} - D_{m,t}^{R,M}$

Where:

$I_{m,t}$ is outgoing inventory of material m on day t and $I_{m,t-1}$ is ingoing inventory on day t which equals outgoing inventory on day t-1.

$D_{m,t}^{R,M}$ is randomised daily demand of material m on day t in month M between $\overline{D}_m - \sigma_D$ and $\overline{D}_m + \sigma_D$, where $\overline{D}_m$ is average daily demand calculated from order volume 2018 for material m. The summed monthly randomised demand is adapted so it is equal to the summed monthly average demand/order volume per month in 2019 for all materials in all months. Every time the Excel model is updated $D_{m,t}^{R,M}$ generates a new randomized value between $\overline{D}_m \pm \sigma_D$.

$X_{m,t}$ is ingoing order volume of material m on day t and is given by the ROP [5] and the order quantity (Q). There are only incoming orders on the ICU`s defined delivery days (Monday, Wednesday, and Friday) in the model. If $I_{m,t-1}$ reaches ROP on Monday, Wednesday, or Friday $X_{m,t}$ equals Q for the given SKU on this day. Average order quantity in the ICU daily consumption data 2019 is used as Q for all materials.

[5] $ROP = \overline{D}_m * LT + SS$

Since the inventory level at the ICU is not available in the ERP system (as described in chapter 3.3) an assumption had to be made to have a starting point of the test. Ingoing inventory on day one (01.01.2019), $I_{m,0}$, was assumed to be equal to the ROP [5] for all 12 materials in the test in both scenarios. Backorders in the model is fulfilled on the upcoming delivery day.

4.3.4 Output

The SL scenario model is run by updating/refreshing the Excel model so that $D_{m,t}^{R,M}$ generates a randomized demand for the 12 SKU in question on each day in 2019. Based on this the outgoing inventory $I_{m,t}$ for each day in 2019 is estimated using the inventory equation [4].

For each of the 12 SKU the output from each run of the SL scenario model is the following estimates for both the scenario where the ABC-VED SL-policy is applied, and in the scenario where the VED-FSN SL-policy is applied:

- The amount of stockouts
- The number of units not supplied on time
- The average inventory levels
- The estimated SL 2019 (using total demand and units not supplied on time)

5 Results

The results of the three single classification techniques, ABC, VED, and FSN, are presented in the three first sub chapters of chapter 5. Results of the two combined techniques, ABC-VED and VED-FSN, are explained and compared in chapter 5.4. and tested in chapter 5.5.

5.1 ABC

The boarders between the A, B and C classes were set at 70 %, 25 % and 5 % of volume value, as described in chapter 4.2.1. The result of the classification based on these boarders is described below, and the distribution of SKUs between the ABC classes is visualised in figure 3, Distribution of SKU between the ABC classes.

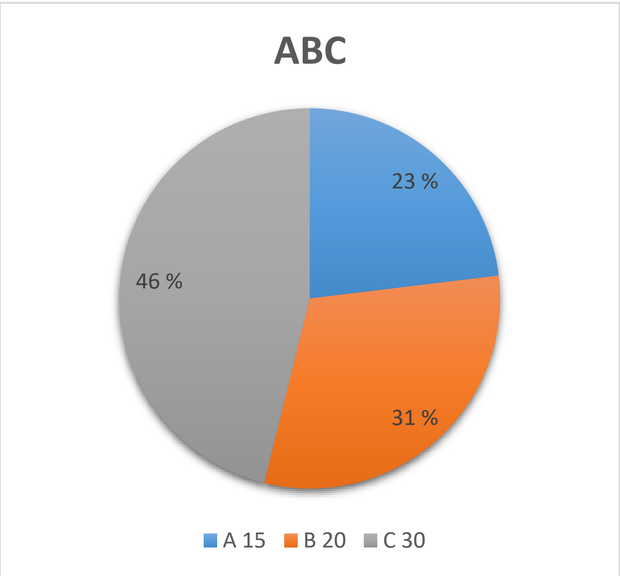

Figure 3 Distribution of SKU between the ABC classes

A. 15 SKU, constituting 23,08 % of SKU and 69,66 % of volume value
B. 20 SKU, constituting 30,77 % of SKU and 25,12 % of volume value
C. 30 SKUs, constituting 46,15 % of SKUs and 5,22 % of volume value

The 15 SKUs in the A-class had a volume value between 26858 (2,52 %) and 97833 (9,18 %). B-items ranged from 5820 (0,55 %) to 24985 (2,34 %) and C-items from 127 (0,01%) to 4771 (0,45 %).

5.2 VED

In the qualitative VED analysis, the distribution of SKU between the VED classes (illustrated in figure 4, Distribution of SKU between the VED classes) are based on an expert evaluation and process described in chapter 4.1.1. The result from the described process is presented below.

V. 5 SKU, constituting 7,69 % of SKU
E. 32 SKU, constituting 49,23 % of SKU
D. 28 SKU, constituting 43,08 % of SKU

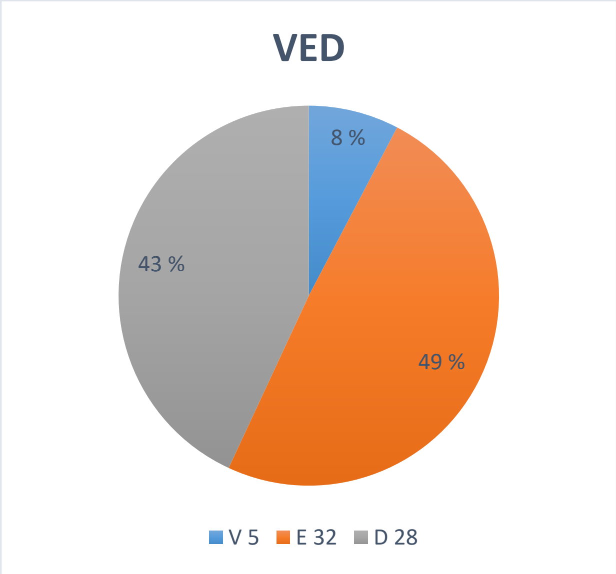

Figure 4 Distribution of SKU between the VED classes

Only 5 SKU in the ICU assortment was considered both critical and unique in assortment in the HMN criticality evaluation and thus given the V-classification. The rest of the 32 critical SKU received an E classification because they had alternatives in the assortment. All the 28 SKU considered desirable in the HMN criticality evaluation is given a D classification regardless of if they had alternatives in assortment or not. The transformation from the HMN criticality evaluation data to the VED-classes is explained in chapter 4.1.1 and table 5.

5.3 FSN

Cut of points in the FSN analyses is, as described in chapter 4.2.3 set at 45 %, 35 %, and 20 % of order frequency. This resulted in the distribution of SKU between the three classes visualised in figure 5, Distribution of SKU between the FSN classes and described below.

F. 10 SKU, constituting 15,38 % of SKU and 43,82 % of orders

S. 18 SKU, constituting 27,69 % of SKU and 35,72 % of orders

N. 37 SKU, constituting 56,92 % of SKU and 20,46 % of orders

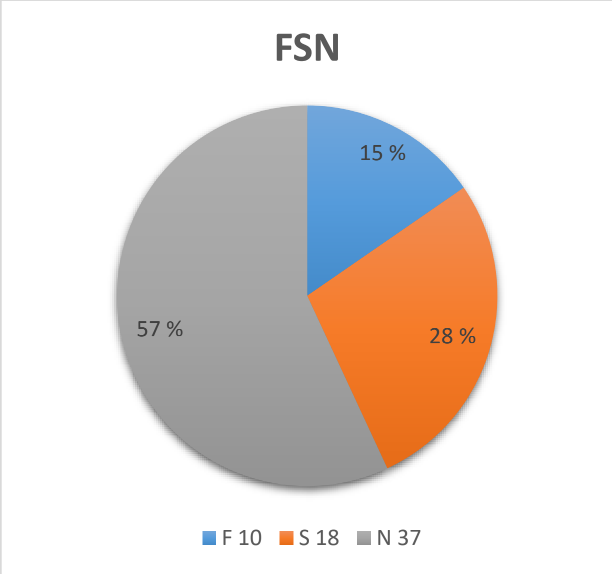

Figure 5 Distribution of SKU between the FSN classes

The 10 SKU in the F-class had a minimum order frequency of 100 (3,67 %) and a maximum of 162 (5,94 %), among the total of 65 SKU and 2727 orders. The 18 S-items had between 29 (1,06 %) and 82 (3,01) orders in 2018, while the N-items had between 1 (0,04 %) and 29 (1,06 %) orders.

In the description above we see that the S-class ends, and the N-class begins at 29 orders. This means that two SKU with the same order frequency has ended up in different classes. In situations like this the classification should be assessed and one of the SKU should be moved either up or down a class depending on an overall assessment.

5.4 ABC-VED/VED-FSN

Based on the results from the three sub chapters above the 65 SKU are, as described in chapter 4.2.4 and 4.2.5, given an ABC-VED and VED-FSN classification from nine possible combinations. The SKUs are then divided into categories (I, II, and III) as can be seen in Appendix 1. Based on its categories the SKUs are given either SL high (H), medium (M) or low (L) in compliance with the description in the mentioned chapters. The results of the classifications are presented pr material group in table 9, Distribution of SKU between categories in ABC-VED and VED-FSN analyses pr material group below. The material groups are the same 14 as in table 3, ICU daily consumption data 2018, grouped descriptive statistic and as described in chapter 4.1.2.

Table 9 Distribution of SKU between categories in ABC-VED and VED-FSN analyses pr material group

Material group	**Total nr of SKU**	**ABC – VED (Nr pr category)**			**VED - FSN (Nr pr category)**		
		I	**II**	**III**	**I**	**II**	**III**
Service level		**L**	**M**	**H**	**H**	**M**	**L**
Suction, tubes, and bags	2	0	1	1	0	1	1
Respiratory products, tubes, and accessories	8	2	5	1	1	6	1
Patient monitoring and examination, anaesthesia	4	1	2	1	1	2	1
Stool control product	2	1	0	1	0	0	2
Suction catheter and suction kit	7	0	5	2	0	3	4
Syringes and needles	7	2	3	2	3	3	1
Central and peripheral venous catheters, vein	7	1	3	3	0	2	5
Fixation products	2	0	1	1	0	1	1
Infusion and transfusion products	9	2	5	2	3	4	2
Blood substitutes and infusion solution	3	1	2	0	2	1	0
Nutrition systems	3	1	2	0	1	2	0
Equipment and concentrates for peritoneal	2	2	0	0	0	2	0
Oxygen therapy	2	1	0	1	0	0	2
Other	7	4	2	1	3	3	1
Sum	**65**	**18**	**31**	**16**	**14**	**30**	**21**

The aggregated results in the bottom of table 7 shows that almost the same amount of SKU (31 and 30) end up in the II categories and thus are given a medium service level in both classifications. Looking behind table 7 at the individual SKUs presented in Appendix 1, we see that 22 SKU are category II items in both the ABC-VED and the VED-FSN analyses. Of the 31 II-category SKU from the ABC-VED analyses 6 are category I, and 3 are category III in the VED-FSN analysis. Of the 30 II-category SKU in the VED-FSN 7 are category I and 1 is category III in the ABC-VED analysis. We also observe in table 7 that in the two biggest groups, Respiratory products, tubes, and accessories and Infusion and transfusion prod the majority of SKU are category II items with a medium SL in both classifications. These are product groups with typical high volume (in m^3) articles. Looking at the I and III categories we observe in table 7 that almost the same amount of SKU is given the same SL in both the ABC-VED and the VED-FSN analysis. 18 SKU belongs to a category with low SL in the ABC-VED analysis, while the equivalent number is 21 for the VED-FSN analysis. 14 SKU has a high SL in the VED-FSN and 16 SKU the same in the ABC-VED analysis.

8 SKU are category I in both classifications and 15 are category III in both classifications. Of the 18 category I items given a low SL in the ABC-VED analysis, 5 SKU are vital (V) and 4 are fast moving (F), one is both, and thus 8 of these SKU also belong to category I in the VED-FSN analysis where they are given a high SL. Only 3 out of the 18 category I items with low SL in the ABC-VED analysis are DN classified and given a low SL in the FSN-VED III-category. This can be seen in appendix 1. In table 7 we observe that in the group Other, 4 items have a low SL in the ABC-VED analysis while only 1 has a high SL. For the same group 3 items has a high SL and 1 has a low SL in the VED-FSN analysis.

5.5 SL scenario model

In accordance with table 8, Service level in the SL test the 12 SKU had a corresponding average SL of 96,06 % given an ABC-VED classification and 99,49 % given a VED-FSN classification.

After running the SL scenario model on the 12 selected SKU 30 times, with the SL described in table 8, the average results from a total demand of 80474 in 2019 was 85 stock outs and 1455 materials not delivered on time for the ABC-VED SS-policy and 32 stockouts and 473 materials not delivered on time for the VED-FSN SS-policy. These results correspond with a SL of 98,24 % for the ABC-VED SS-policy and 99,33 % for the VED-FSN SS-policy. The SL results from the test is visualised in figure 6 SL test results below. Figure 6 shows the average SL in percent for the 12 selected SKU per run of the SL scenario model for each scenario.

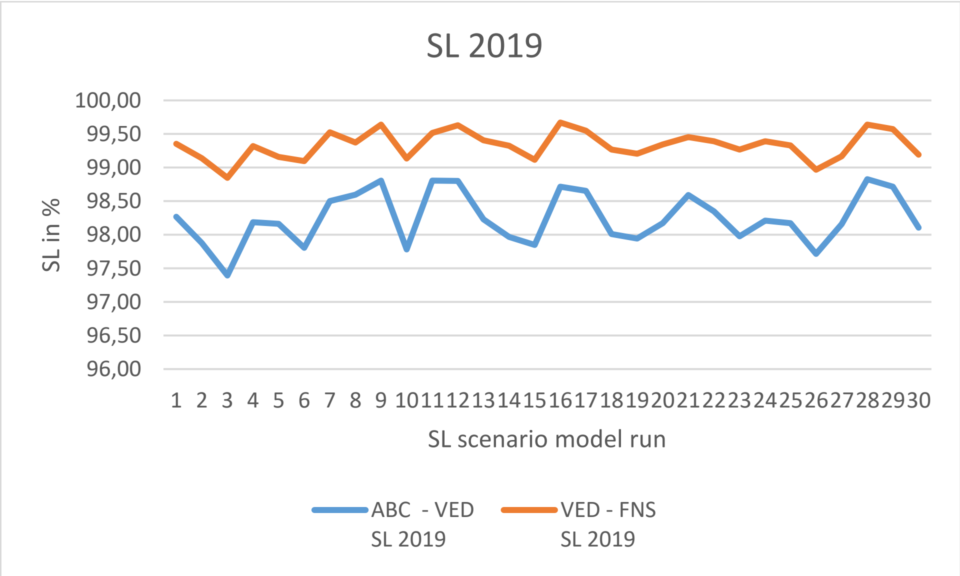

Figure 6 SL test results

Compared to the set SL the ABC-VED SS-policy differed 2,18 percentage points in its performance in the model. For the same 12 SKU the VED-FSN SS-policy only differed 0,16 percentage points from the set SL. It can also be observed in figure 4 that the SL of the ABC-VED SS-policy is more fluctuating. The same fluctuation in the ABC-VED results can be observed for stock outs in figure 7 Stock outs test results below. Figure 7 shows the aggregated number of stockouts for the 12 selected SKU per run of the SL scenario model for each scenario.

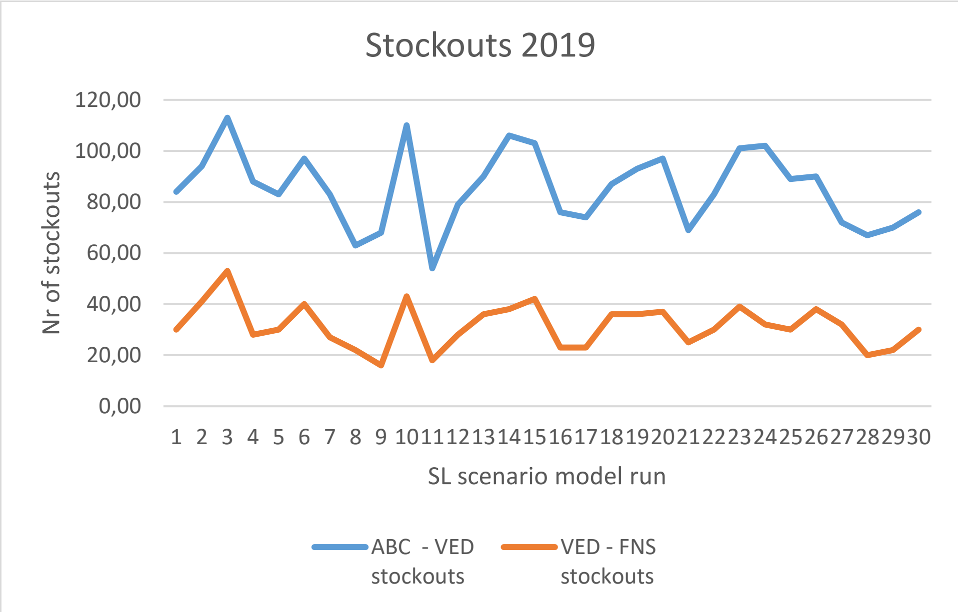

Figure 7 Stockouts test results

As figure 7 shows the amount of stock outs is lower for the VED-FSN test results, as they should be with a SL set 3,43 percentage points higher than for the ABC-VED SS-policy, but it can also be observed that the curve is more stable for the ABC-VED SS-policy. Another aspect of the results is that of the average amount of inventory. The average total inventory level for the 12 SKU were 665 units for the ABC-VED SS-policy and 844 units for the VED-FSN SS-policy.

To sum up the results from the SL scenario model the cost of the 3,43 percent point higher SL set for the VED-FSN scenario was a higher average inventory level of 179 units spread across the 12 selected SKUs. The effect of storing these 179 units was:

- 53 fewer stockouts
- 982 more materials delivered on time

Other detected results from the SL scenario model were:

- The actual SL for the VED-FSN scenario differed 0,16 percent points from the set SL. For the ABC-VED scenario the difference between the set SL and the actual

SL was 2,18 percent points. This resulted in an actual difference in SL of 1,09 compared to the set difference of 3,43 percent points.

- It can, in figure 4 SL test results and 5 Stockouts test results, be observed more fluctuations in both the SL results and the stockout results for the ABC-VED scenario than in the VED-FSN scenario.

The results of the 30 runs of the SL Scenario model can be observed in appendix 2.

6 Discussion

The purpose of this thesis was to explore alternative stock keeping unit (SKU) classifications techniques with the aim of improving the inventory management at an intensive care unit. This need for inventory management at the intensive care unit is in this case study amplified through the commissioning of a new centralized warehouse. The choices of classification techniques assessed in the study and the following analysis are based upon literature on the subject and the techniques availability in the literature. Availability of data was also a factor influencing the choices regarding classifications techniques. A comparison of the chosen techniques was performed based on the performed analysis.
Looking at the results of the performed ABC-VED and VED-FSN classifications in chapter 5.4 we observe in table 9 that it is little difference between the number of SKUs receiving a high, medium or low SL in the two scenarios. Also taking into regard that typical high volume (in m^3) product groups like Respiratory products, tubes, and accessories and Infusion and transfusion products almost have equal distribution between high, medium, and low SL it can be assumed that there is not much storage space to save choosing one classification technique over the other.
In chapter 5.4 it can also be observed that 8 out of 18 SKUs given a low SL in the ABC-VED where either vital or fast moving in the VED-FSN classification. The consequence of a stock out could be severe and the risk of a stock out is increased for these materials caused by the low SL. In accordance with the ABC-VED results in this study (chapter 5.4) and the corresponding SL policy all the 5 V-items get a low SL and of the 16 category III items given a high SL all but one are N-items. The literature presented in chapter 2.4 seems to be quite unison on the ABC-VED SL policy, but if the argument is that the ABC-VED SL policy is wrong and the category I items should have a high SL (for mono criteria ABC analyses the literature differs on this subject (Teunter, Babai, and Syntetos 2010)) all

the 5 V-items would get a high SL, but also half of the SKU in the category would be N-items given a high SL. This could be a source of obsolescence when using the ABC-classification.

Looking at the results from the SL scenario model we see that the VED-FSN results are closer to the set SL than for the ABC-VED classification. We also observe more fluctuation in both SL and stockouts in the ABC-VED scenario than the VED-FSN scenario. This might imply a higher degree of reliability for the order-frequency based VED-FSN analyses. We can also observe that the average amount of inventory was lower, the number of stockouts higher and the number of materials not delivered on time higher for the ABC-VED scenario because of a lover SL. The difference in average inventory is related to the 12 selected SKUs in the SL scenario model. As we already have seen it is about the same amount of total SKU receiving either high, medium, or low SL regardless of classification technique. Thus, the average inventory at the ICU would probably be quite similar regardless of the chosen SKU classification technique was ABC-VED or VED-FSN.

A central objective of the healthcare supply chain is to secure continuous supply of critical material (Vaz et al. 2008). We can call this the superior aim, as described by Van Kampen, Akkerman et al. (2012), of the SKU classifications performed in this thesis. Since we have established that the superior aim of doing the SKU classification is to secure continuous supply of critical material, the criticality-based VED-analysis seems like a good fit. This applies for both for the analysis in this study and for SKU classification in healthcare in general. The VED analysis is thorough described for use in healthcare, and often in combination with the volume-value based ABC-analysis (Vaz et al. 2008, Jobira et al. 2021, Kumar and Chakravarty 2015, Hussain, Siddharth, and Arya 2019).

The VED-analysis seems like the obvious choice for the SKU classification in this study. Combining it with the volume-value based ABC-analysis also seem like an obvious choice, but mostly because of the frequent use of this combination. The price is decisive for the volume-value based characteristic. For the ICUs case however, the price of the item is not decisive regarding inventory management. The price is important when deciding which material to use in cases where there are alternatives in the assortment. However, when a material is chosen the price of a potential lifesaving material is subordinate with regards to how much to keep in stock.

We then come to the more specific aim of the classifications in this study: improving the inventory management through setting the correct SL to achieve a sufficient degree of SS.

A third SKU classification technique is needed to combine with the VED-analysis to have an alternative duo-criteria classification to compare the ABC-VED to. The movement rate based FSN-analysis is chosen for a VED-FSN classification. With the FSN technique we get a classification that disregard the price aspect but keeps the cost aspect through reduction of obsolete SKUs. Healthcare leaders have a pressure from management to keep costs down, so keeping the cost element is essential, but not at the expense of the classifications superior aim: to secure continuous supply of critical material.
As a benchmarking of the ICU ABC analysis a comparison to that of Reid (1987), as mentioned in chapter 2.2 and 4.2.1, is carried out:

A. Reid has an A-class consisting of 21,3 % of the SKUs and 73,6 % of volume value. Compared to the ICU ABC analysis the share of SKUs differs 1,78 percentage points and the volume value 3,94 percentage points.
B. The B-class in Reids results consists of 27,6 % of the SKU and 18,1 % of volume value. Compared to the ICU classification the share of SKUs differs 3,17 percentage points and the volume value 7,02 percentage points.
C. Reids C-items constitute 51,1 % of SKU and 8,3% of volume value. Compared to the ICU classification the share of SKUs differs 4,95 percentage points and the volume value 3,08 percentage points.

We see that except of volume value in the B-class all the reference points in the benchmarking differ less than five percentage points. In what Van Kampen, Akkerman et al.(2012) refers to as the operationalisation of the classes the boarders that divide the classes in the classification is set. For the ABC-analyses this is generally accepted to be according to the Pareto principle, while for the FSN-analysis in this thesis the boarders are set according to an assessment of the data described in chapter 4.2.3.
The ABC benchmarking is quite close to the reference and the distribution between degree of SL for both duo-characteristic techniques is highly comparable. The latter can be observed in table 9. Based on this the boarders set for the FSN-analysis might be generalisable for SKU classifications with the same characteristic at similar healthcare units. The generalisation of SKU-classification approaches for classifications with similar contextual factors like connected industry is also addressed by Van Kampen, Akkerman et al.(2012).
The focus on cost reduction is an essential part of healthcare logistics. So, using the VED-FSN approach instead of ABC-VED might seem off since the price element is removed.

Also looking at the literature, ABC-VED is frequently used in healthcare SKU classification.

A study with a duo criteria VED-FSN analysis for SKU classification in healthcare was not found doing this research. However, Hussain, Siddharth, and Arya (2019) mention FSN as an alternative for their SKU-classification of surgical consumables at a hospital in Dehli. In the article an ABC-VED analysis is performed. The studies used in chapter 2.6 to describe the literature behind the VED-FSN analyses performed in this thesis are all based on MRO supply chains. An important aspect that Sople (2016) points out is that in MRO supply chains unpredictability and emergency assignments makes criticality and speed crucial. This is the argument used to choose VED-FSN over ABC-VED, and it is so relatable to the ICU that it seems surprising that VED-FSN is not addressed more thoroughly regarding healthcare SKU-classification.

Of the studies used in chapter 2.4 to describe the literature behind the ABC-VED analyses performed in this thesis six out of seven focus on pharmaceuticals. Only Hussain, Siddharth, and Arya (2019) focus on consumables. There are other studies on SKU-classification in healthcare that focus on consumables like in this thesis. However, the overall impression from doing this research is that the majority focus on pharmaceuticals. The reasons why pharmaceuticals seem to be so highly prioritised when it comes to healthcare SKU-classification in literature may be several. Two possible reasons are pointed at by Jobira et al (2021):

1. Pharmaceuticals needs to be affordable and thus require efficient inventory management.
2. Pharmaceuticals represent a high percent of healthcare budgets. In 2019 pharmaceuticals constituted about 10% of healthcare cost in the US. For developing countries this percentage could be as high as 40%

Both these reasons are good arguments for conducting a SKU-classification on pharmaceuticals. Regulations that demand strict inventory control on pharmaceuticals may be another reason and may also be a contextual factor that contributes to the availability of data.

Availability of data may be a reason for what seem to be a lack of literature regarding consumables in healthcare, and then especially the patient near materials like the ones at the ICU in this thesis. Based on the situation at the ICU described in chapter 3.3 the inventory levels for these materials are not managed in the ERP system. This will affect the availability of data and might make it harder to implement inventory management

strategies based on SKU-classifications. Implementation of inventory management strategies is still highly possible but will be a more manual process.
An important aspect of the ABC-VED analysis is to avoid piling up with the most expensive items, and instead have high SL on the less expensive C-items (Vaz et al. 2008, Kumar and Chakravarty 2015). This will tie up less capital and thus be cost reducing. One of the main aspects of the FSN analysis is to avoid obsolescence which can, as implied earlier in this thesis, be a risk with the ABC classification. The point is that the cost element is taken into account in both the ABC-VED and the VED-FSN, but in different manners.
The contextual factors from Van Kampen, Akkerman, and van Donks framework (2012) affecting the characteristics of the classification together with the aim is that this is healthcare and the responsibility for the patient must be weighted heavily together with the limited space at the ICU and the available data. Criticality as characteristic and VED analyses as technique seem to be a viable choice to identify the critical materials but should be combined with the ABC or FSN analysis to get a statistical aspect of the classification. The available data points to both techniques, but the presented results seem to imply a VED-FSN approach would be favourable for the ICU.

7 Conclusion

In an attempt to answer the research question, "How do the outputs of the ABC-VED analysis and the VED-FSN analysis compare regarding the ICU in question need for improved inventory management? ", we first look at the output from the SKU-classifications. Output from both the ABC-VED analysis and the VED-FSN analysis points to the same amount of SKU at the same SL. This implies that there is not much to gain regarding the space saving for inventory at the ICU if selecting one of the classification techniques over the other.
With the inventory policy for VED-FSN proposed in chapter 4.2.5 all vital SKU`s will be given a high SL to ensure availability of critical SKUs at the ICU. This is in compliance with the aim of the classification. The aim being to secure continuous supply of critical material thorough improved inventory management. It also as described in the paragraph above, does not seem to affect the space of inventory at the ICU compared to the SL policy of an ABC-VED classification.

With the inventory policy for ABC-VED described in chapter 4.2.4 the expensive A-items will be given a low SL to keep costs down. Logistic personnel will need to keep a close eye on these items as they often have a high turnover rate in addition to being high priced. A central question is if the logistic personnel have the capacity to follow these items as closely as needed. To turn the ABC-VED SL policy around and have a high SL for the A-items, as could be augmented for through the literature, would as we have seen in chapter 6 not necessarily been beneficial and could be a source of obsolescence. In the VED-FSN analysis the cost focus is through avoiding obsolescence.
The final point in the conclusion is the output in the SL scenario model implying a more predictable outcome using the VED-FSN classification. The ABC-VED results clearly show more fluctuation, and the VED-FSN classification performed much closer to its pre-set SL than the ABC classification.
Summing up the observations presented the overall rating is that the VED-FSN classification seems to better secure the continuous supply of critical materials at the ICU without increasing the need for storage space or disregarding the cost aspect. Supported by the output of the SL scenario model it is implied that a VED-FSN classification might be preferable to an ABC-VED classification for the ICU when it comes to the need for inventory control and a clear safety stock policy.

8 RESEARCH SUMMARY

The purpose of this thesis was to explore alternative inventory classifications techniques with the aim of improving the inventory management at an intensive care unit. This need for inventory management at the intensive care unit is in this case study amplified through the commissioning of a new centralized warehouse. The idea behind this study is that the described need at the ICU can be met through SKU classification and implantation of inventory management strategies based upon this analysis.
The need for SKU classification in healthcare has been a topic in literature for decades. In the 1980s Reid (1987) described the possible benefits of a volume value based ABC classification at hospital wards. The criticality-based VED analysis (Kumar and Chakravarty 2015) is frequently used in combination with the ABC analysis as an ABC-VED analysis, for SKU classification within healthcare (Kumar and Chakravarty 2015, Vaz et al. 2008, Hussain, Siddharth, and Arya 2019)

The FSN analysis is a SKU classification technique that divides SKU into classes based on the movement rate of the SKU (Jobira et al. 2021). In other types of supply chains, such as maintenance, repair, and operations supply chains the VED analysis has been combined with the FSN analysis in a VED-FSN analysis (Sople 2016, Cavalieri et al. 2008).

The three mentioned methods of SKU classification are some of the better known, and thus most accessible in literature (Van Kampen, Akkerman, and van Donk 2012). They also seem to be relevant considering available data in the organisation and contextual factors linked to the intensive care unit. Thus, it is these three methods, and the mentioned combinations of these, that was explored in this study.

The research was built up in the following order: Quantitative and qualitative data was gathered from the organisation in question and its ERP system. The collected data and literature on the subject found the base of performing single criteria classifications which again duo criteria classifications then are based upon. The two duo-criteria classifications performed in this study are ABC-VED and VED-FSN. Finally, a comparison of the performance of the two duo-criteria classification scenarios was conducted and assessed.

Looking at the results of the performed SKU-classifications in this thesis we see that it is little difference between the number of SKUs that receive a high, medium, or low SL in the two scenarios. It can also be observed that 8 out of 18 SKUs given a low SL in the ABC-VED where either vital or fast moving in the VED-FSN classification. When comparing the performance of the two scenarios the VED-FSN performs closer to the set SL than the ABC-VED scenario.

Based on the observations in the study the overall rating is that the VED-FSN classification seems to better secure the continuous supply of critical materials at the ICU without increasing the need for storage space or disregarding the cost aspect. Supported by the assessment of the performance of the two techniques it is implied that a VED-FSN classification might be preferable to an ABC-VED classification for the ICU when it comes to the need for inventory control.

8.1 MANAGERIAL IMPLICATIONS

The inventory management at the ICU in question is largely depending on the knowledge and experience of hospital personnel. The results presented in this study implies that there is both available statistical data and available knowledge in the organization to conduct combined statistical and judgmental SKU classifications. This would be a less vulnerable approach to inventory management.

8.2 LIMITATIONS OF THE STUDY

- The study is limited to the materials defined as intensive care specific during the HMN criticality evaluation.
- The available data for this study was limited to 2018 and 2019. The ERP system was implemented in 2016, so 2017 data was considered too close to the implementation. Data from 2020 and 2021 was considered too unreliable because of the Covid-19 pandemic,
- It is in the study focused on the process of setting the correct SL through SKU classification. Other factors, such as available m^2 is addressed, but not part of the research model.

Limitations of the SL scenario model:

- Q used in the SL scenario model might not always be in accordance with the different order quantity delivered in 2018/2019. Meaning that a SKU that is always delivered in a certain amount of unts (probably because this constitutes a full pack/box) might be delivered in breakbulk in the SL scenario model. However, an important prerequisite for LS is that the hospitals should get breakbulk on items, including sterile ones. This increases the flexibility of Q on deliveries from LS.
- The LT for deliveries is set accordingly to the situation at the ICU pre-LS. Meaning the orders are delivered later the same day as they are registered in the ERP system. After LS the Wednesday and Friday deliveries will have LT of one day, while the Monday deliveries will have a LT of three days.

8.3 SUGGESTIONS FOR FURTHER RESEARCH

The SL scenario model was in this thesis used for comparing the ABC-VED analysis with the VED-FSN analysis. It could be interesting to further develop the model to also consider available m^2 at the ICU (or at an alternative ward) and setting a value for Q that is accordingly to the limitation described in chapter 8.2.
As described in chapter 2.5 the FSN analysis is often conducted with different characteristics and cut of points between the classes than used in this thesis. It could be interesting to see how the FSN with a different set up would perform in a similar healthcare case,

9 Bibliography

Cavalieri, Sergio, Marco Garetti, Marco Macchi, and Roberto Pinto. 2008. "A decision-making framework for managing maintenance spare parts." *Production planning & control* 19 (4):379-396.

Devarajan, Divya, and MS Jayamohan. 2016. "Stock control in a chemical firm: combined FSN and XYZ analysis." *Procedia Technology* 24:562-567.

Flores, Benito E, David L Olson, and VK Dorai. 1992. "Management of multicriteria inventory classification." *Mathematical and Computer modelling* 16 (12):71-82.

Gizaw, Tafesse, and Awol Jemal. 2021. "How is Information from ABC–VED–FNS Matrix Analysis Used to Improve Operational Efficiency of Pharmaceuticals Inventory Management? A Cross-Sectional Case Analysis." *Integrated Pharmacy Research & Practice* 10:65.

Gourdin, Kent. 2006. *Global logistics management: a competitive advantage for the 21st century*. 2nd ed: Wiley-Blackwell.

Hmida, Jalel Ben, Siddharth Parekh, and Jim Lee. 2014. "Integrated inventory ranking system for oilfield equipment industry." *Journal of Industrial Engineering and Management* 7 (1):115-136.

Hussain, Mansoor, Vijaydeep Siddharth, and Sanjay Arya. 2019. "ABC, VED and lead time analysis in the surgical store of a public sector tertiary care hospital in Delhi." *Indian journal of public health* 63 (3):194.

Jobira, Tadesse, Habtamu Abuye, Awol Jemal, and Tadesse Gudeta. 2021. "Evaluation of Pharmaceuticals Inventory Management in Selected Health Facilities of West Arsi Zone, Oromia, Ethiopia." *Integrated pharmacy research & practice* 10:1.

Kumar, Sushil, and A Chakravarty. 2015. "ABC–VED analysis of expendable medical stores at a tertiary care hospital." *Medical journal armed forces india* 71 (1):24-27.

Nigah, R, M Devnani, and AK Gupta. 2010. "ABC and VED analysis of the pharmacy store of a tertiary care teaching, research and referral healthcare institute of India." *Journal of young pharmacists* 2 (2):201-205.

Nirmala, D Annie Rose, Vijila Kannan, M Thanalakshmi, S Joe Patrick Gnanaraj, and M Appadurai. 2021. "Inventory management and control system using ABC and VED analysis." *Materials Today: Proceedings*.

Ravinder, Handanhal, and Ram B Misra. 2014. "ABC analysis for inventory management: Bridging the gap between research and classroom." *American journal of business education*.

Reid, Richard A. 1987. "The ABC method in hospital inventory management a practical." *Production and Inventory Management Journal* 28 (4):67.

Rowe, W. D. . 1975. *An "anatomy" of Risk*. Washington, D. C.: Environmental Protection Agency.

Sakthivelmurugan, E, G Senthilkumar, A Tajdeen, and S Manojkumar. 2021. "Application of lean six sigma in reducing the material consumption at wards in a selected healthcare unit." *Materials Today: Proceedings* 45:8011-8016.

Silver, Edward Allen, David F Pyke, and Rein Peterson. 1998. *Inventory management and production planning and scheduling*. 3 ed. Vol. 3: Wiley New York.

Sople, Vinod. 2016. "MRO Supply Chain Striving for Operational Efficiency." *International Journal of Business Insights and Transformation* 10 (1):40-45.

Tambunan, Mangara M, Khalida Syahputri, Indah Rizkya, Rahmi M Sari, and Muhammad D Cahyo. 2018. "Storage design using Fast moving, Slow moving and Non moving (FSN) analysis." MATEC Web of Conferences.

Tang, Christopher S. 2007. "Robust strategies for mitigating supply chain disruptions." *International Journal of Logistics Research and Applications* 9 (1):33-45. doi: 10.1080/13675560500405584.

Teunter, Ruud H, M Zied Babai, and Aris A Syntetos. 2010. "ABC classification: service levels and inventory costs." *Production and Operations Management* 19 (3):343-352.

Van Kampen, Tim J, Renzo Akkerman, and Dirk Pieter van Donk. 2012. "SKU classification: a literature review and conceptual framework." *International Journal of Operations & Production Management*.

Vaz, Anthony, Anwar Tedjamulja, Akalpita Tendulkar, and Premkumar Rajagopal. 2020. "Order Frequency as a Variable to Determine Slow Moving D Items in ABC Inventory Categorization." *Int. J Sup. Chain. Mgt Vol* 9 (2):36.

Vaz, Federick S, AM Ferreira, MS Kulkarni, DD Motghare, and I Pereira-Antao. 2008. "A study of drug expenditure at a tertiary care hospital: An ABC-VED analysis." *Journal of Health Management* 10 (1):119-127.

Appendix 1

The table in this section shows the order volume, order value, order frequency and the criticality with priority along with the results of the SKU classifications for each of the 65 SKU. The ABC-VED and VED-FSN categories (cat) is also presented for each SKU as well as the CV.

SKU ID	Order volume	Volume value	Order frequency	Criticality with prority	VED	ABC	FSN	ABC-VED	ABC-VED cat	VED-FSN	VED-FSN cat	CV
79	8090	24873	105	CL0	E	B	F	BE	II	EF	I	0,57
45	9390	21084	127	DL0	D	B	F	BD	II	DF	I	0,60
63	32000	9401	120	CL1	E	B	F	BE	II	EF	I	0,61
99	11250	47813	124	DL0	D	A	F	AD	I	DF	I	0,62
38	529	28354	102	CL1	E	A	F	AE	I	EF	I	0,63
40	5625	14676	114	CL1	E	B	F	BE	II	EF	I	0,68
124	616	83072	100	CU	V	A	F	AV	I	VF	I	0,70
121	417	9367	81	CL2	E	B	S	BE	II	ES	II	0,71
65	5690	45643	112	CL1	E	A	F	AE	I	EF	I	0,72
82	1966	14562	162	CL1	E	B	F	BE	II	EF	I	0,75
130	2140	32100	82	CL2	E	A	S	AE	I	ES	II	0,76
81	1504	10285	129	CL1	E	B	F	BE	II	EF	I	0,77
84	307	16462	71	CL0	E	B	S	BE	II	ES	II	0,81
93	204	34469	67	CL0	E	A	S	AE	I	ES	II	0,95
66	670	4220	51	CL1	E	C	S	CE	II	ES	II	0,98
44	6460	31160	59	DL0	D	A	S	AD	I	DS	II	0,98
7	118	43372	57	CL1	E	A	S	AE	I	ES	II	0,99
19	975	3900	79	CL0	E	C	S	CE	II	ES	II	1,05
43	900	20952	36	CL1	E	B	S	BE	II	ES	II	1,06
61	4450	13037	75	CL1	E	B	S	BE	II	ES	II	1,06
20	376	4771	37	CL1	E	C	S	CE	II	ES	II	1,13
137	303	82416	58	CU	V	A	S	AV	I	VS	I	1,26
75	58	15911	32	DL0	D	B	S	BD	II	DS	II	1,29
131	1274	28228	64	CL0	E	B	S	BE	II	ES	II	1,35
150	40	10002	29	CU	V	B	N	BV	I	VN	I	1,42
48	1200	6179	24	DL0	D	B	N	BD	II	DN	III	1,45
64	690	1787	25	DL0	D	C	N	CD	III	DN	III	1,49
3	64	1059	31	CL1	E	C	S	CE	II	ES	II	1,53
36	46	11918	22	CL1	E	B	N	BE	II	EN	II	1,59
10	21	197	18	CL0	E	C	N	CE	II	EN	II	1,60
41	520	1341	29	DL1	D	C	S	CD	III	DS	II	1,61
127	65	8157	33	DL2	D	B	S	BD	II	DS	II	1,61
148	215	70734	21	DU	D	A	N	AD	I	DN	III	1,62
110	393	2901	22	DL0	D	C	N	CD	III	DN	III	1,66
78	52	26858	26	DL0	D	A	N	AD	I	DN	III	1,67

39	950	754	20	DL0	D	C	N	CD	III	DN	III	1,70
56	3700	6334	32	DL1	D	B	S	BD	II	DS	II	1,70
128	32	39204	25	DU	D	A	N	AD	I	DN	III	1,71
147	188	2171	18	DU	D	C	N	CD	III	DN	III	1,71
105	484	100327	24	CL1	E	A	N	AE	I	EN	II	1,74
102	75	2258	26	CL0	E	C	N	CE	II	EN	II	1,77
107	274	52846	21	CL1	E	A	N	AE	I	EN	II	1,80
12	91	209	16	DL0	D	C	N	CD	III	DN	III	1,80
47	650	3350	13	CL0	E	C	N	CE	II	EN	II	1,85
37	42	10897	19	DL0	D	B	N	BD	II	DN	III	1,90
34	43	11126	18	CL1	E	B	N	BE	II	EN	II	2,00
126	32	3804	19	DL1	D	C	N	CD	III	DN	III	2,10
100	228	36628	17	CL2	E	A	N	AE	I	EN	II	2,10
11	21	198	16	CL0	E	C	N	CE	II	EN	II	2,13
49	550	2835	11	DL0	D	C	N	CD	III	DN	III	2,21
30	1104	1462	12	DL1	D	C	N	CD	III	DN	III	2,22
155	21	3648	9	CU	V	C	N	CV	I	VN	I	2,35
104	450	4333	9	DL0	D	C	N	CD	III	DN	III	2,37
35	37	9622	15	DL0	D	B	N	BD	II	DN	III	2,38
13	55	127	9	CL0	E	C	N	CE	II	EN	II	2,41
16	60	1212	11	CL0	E	C	N	CE	II	EN	II	2,48
144	145	2318	10	CU	V	C	N	CV	I	VN	I	2,62
72	10	543	5	DL0	D	C	N	CD	III	DN	III	2,96
143	380	1019	9	CL0	E	C	N	CE	II	EN	II	3,06
46	60	650	4	DL0	D	C	N	CD	III	DN	III	3,56
31	300	498	3	CL1	E	C	N	CE	II	EN	II	4,08
21	85	3525	3	DL1	D	C	N	CD	III	DN	III	5,14
60	275	460	6	DL0	D	C	N	CD	III	DN	III	5,25
129	30	1083	2	DU	D	C	N	CD	III	DN	III	6,62
32	100	309	1	DL0	D	C	N	CD	III	DN	III	7,07

Appendix 2

The table in this section shows the results of the 30 runs of the SL Scenario model that is the base of the results in chapter 5.5.

Simulation round	ABC - VED stockouts	ABC - VED not suplied	ABC - VED Avg stock	ABC - VED SL 2019	VED - FNS stockouts	VED - FNS not suplied	VED - FNS Avg stock	VED - FNS SL 2019
1	84,00	1316,06	666,64	98,27	30,00	437,57	845,64	99,36
2	94,00	1687,65	656,50	97,88	41,00	590,25	835,50	99,14
3	113,00	2348,87	652,97	97,39	53,00	943,75	831,97	98,85
4	88,00	1442,84	667,90	98,19	28,00	422,11	846,90	99,32
5	83,00	1438,87	662,59	98,16	30,00	562,29	841,59	99,16
6	97,00	1801,18	671,53	97,81	40,00	693,73	850,53	99,10
7	83,00	1210,96	674,59	98,50	27,00	325,06	853,59	99,52
8	63,00	1061,91	676,98	98,60	22,00	378,30	855,98	99,37
9	68,00	1146,23	670,14	98,80	16,00	292,25	849,14	99,64
10	110,00	2199,57	654,25	97,78	43,00	744,43	833,25	99,13
11	54,00	871,05	686,89	98,80	18,00	308,92	865,89	99,52
12	79,00	1068,69	663,93	98,80	28,00	296,33	842,93	99,63
13	90,00	1294,04	667,53	98,23	36,00	395,47	846,53	99,41
14	106,00	1614,55	659,10	97,97	38,00	471,07	838,10	99,33
15	103,00	1826,28	676,15	97,85	42,00	700,25	855,15	99,12
16	76,00	1093,26	659,59	98,72	23,00	244,92	838,59	99,67
17	74,00	1032,88	672,09	98,65	23,00	296,73	851,09	99,55
18	87,00	1517,29	664,98	98,01	36,00	466,96	843,98	99,27
19	93,00	1680,42	669,98	97,95	36,00	558,91	848,98	99,21
20	97,00	1839,90	653,43	98,17	37,00	584,49	832,43	99,34
21	69,00	1195,46	671,26	98,59	25,00	396,78	850,26	99,45
22	83,00	1472,20	647,60	98,35	30,00	414,88	826,60	99,39
23	101,00	1815,57	656,94	97,98	39,00	564,88	835,94	99,27
24	102,00	1320,94	668,66	98,21	32,00	367,30	847,66	99,39
25	89,00	1692,82	654,81	98,17	30,00	491,65	833,81	99,33
26	90,00	1792,65	655,11	97,72	38,00	669,65	834,11	98,97
27	72,00	1330,63	671,95	98,16	32,00	505,40	850,95	99,17
28	67,00	972,94	676,74	98,83	20,00	232,72	855,74	99,64
29	70,00	1103,61	661,33	98,72	22,00	301,35	840,33	99,57
30	76,00	1465,88	669,56	98,10	30,00	518,83	848,56	99,19
	85	**1455**	**665**	**98,24**	**32**	**473**	**844**	**99,33**