Master of Science in Supply Chain Engineering

Improvement of Medical Supplies Inventory Management

Sponsor Company: Pacifica Salud Hospital via Georgia Tech Panama Logistics Innovation & Research Center.

Capstone Project Proposal

ISyE 6341 & 6342

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Summer 2023

August 2nd, 2023

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I. Disclaimer

This capstone project report was written by students from the Georgia Institute of Technology as part of the requirement to complete the degree of Master of Science in Supply Chain Engineering. This report represents the exploration by the students of supply chain challenges typically in a quantitative manner that hasn't necessarily been tried before, rather than a professional consulting report. This document may be of benefit to the community with its interesting ideas. Any mention of a specific commercial item, method, or service in this report – by trade name, trademark, manufacturer, or otherwise, does not imply support from the Georgia Institute of Technology. The views and opinions of the author(s) expressed herein do not state or reflect those of the Institute nor the GT Panama Center and shall not be used for advertising or product endorsement purposes. This student project is presented in accordance with a non-disclosure agreement (NDA) signed with the sponsor company and therefore only includes the necessary results for explanatory purposes.

II. Acknowledgements

The valuable feedback of our advisor, Dr. John Vande Vate, is appreciated. Without his insightful advice and assistance, this capstone project would not have been a success. The team also wants to express our gratitude to the Panama Georgia Tech Logistics Innovation & Research Center's for always helping give us the resources we needed to complete the project. Most importantly, we highly value the support of the sponsor company employees, especially the Logistics Manager who gave us timely assistance with the project, suggestions, and the information we needed to compute our calculations and projections. Finally, our sincere appreciation goes out to SENCYT and the Georgia Institute of Technology for believing in our abilities and providing us with the chance to learn more and participate in a project that may influence Panamanian logistics.

III. Executive Summary

Healthcare facilities account for different varieties of inventory, from high rotation to low, very expensive, and not so, they are all necessary for the unexpected and uncertain demand of the incoming patients. Effective inventory management is a key component for healthcare institutions to ensure the availability of medical supplies while providing high-quality patient care. Although there is a ton of studies on supply chain, the suggested approaches have seldom been put into practice in real healthcare settings in Panama. This project is looking for opportunities to improve the inventory management system of the sponsor medical institution that has two locations in Panama City while assessing what they have now by analyzing their processes and performance. Also implementing a model that could be replicated in other medical facilities. The sponsor is expected to benefit from better data-driven decision-making and cost reduction measured in dollars in inventory and space.

The measurable improvement that the project is going to target is the improvement of the days of inventory which is the average number of days it takes to sell an item. To accomplish this, the team was challenged to find accurate data that could represent the true demand. To get a better focus, the team limits the type of medical supplies to surgical medical supplies which represent almost half of the medical supply's investment by family. Now that the team narrow the number of products, the next opportunity was to find cycle count inventory, rather this information was not readily available. Then we compare the days in inventory in the system based on sales and purchases and we assumed that within these two metrics ranges was the true demand enclosed.

Following up, since the scope of the items used was still too broad and the team wanted to be more specific, an ABC-VED analysis of the surgical medical supplies was done, after identifying the rotation and importance of the materials, five supplies were chosen and at the end, the team used one item to make an Inventory Replenishment Analysis. Working on investigating one item allowed us to go deeper into the opportunity that we can take advantage of. This surgical medical supply is the fastest moving, vital with short lead time but days in inventory were not optimal. Once analyzing the historical replenishment trend, the sponsor has a clearer view of the improvement in training their personnel on accomplishing reorder points. The team also compares the true demand computed with this item ending inventory with the sales and purchases. We noted that purchases have a better estimate of the true demand.

The second part of the project is to focus on the inventory deployment to the care unit storage rooms which are growing much faster than the system inventory. The team made some recommendations, based on the results of this analysis, and proposed a 2-equal-bin Kanban System which allows the inventory management to have visual control when replenishing which could help to improve the flow and efficiency of usage of the medical supplies. The results for the simulation for Kanban show that using two-bin Kanban, the storage room will only need 20% of the space needed in the original system that this could be a tradeoff to be used efficiently for other products.

The project is estimated to be completed within 10 weeks working aside with the Medical Institution Logistics Manager and interviewing the relevant responsible processes people in charge. By leveraging this project model, it is expected to be easier to adapt and implement among other medical facilities.

IV.Introduction

1. Sponsor Overview

Figure 1 Punta Pacifica Hospital - 2005

Figure 2 Costa Del Este Hospital - 2022

Pacifica Salud Hospital Punta Pacifica [1] is a renowned hospital that began operation in 2005 in the strategic location of Panama City, first in the Punta Pacifica neighborhood, now with its second location in the Costa del Este neighborhood established in 2022. This is the first hospital in Latin America and the Caribbean to be affiliated with Johns Hopkins Medicine International. Johns Hopkins Medicine International is the global division of Johns Hopkins Medicine, one of the leading academic healthcare systems in the United States. Currently, Pacifica Salud Hospital is ranked #1 among the hospitals in Panama and #11 in Central America Region. They are also prestigious because of obtaining the Joint Commission Hospital accreditation and certification in their processes and Quality Standard ISO 9001 certification in their radiology and laboratory department.

Obtaining their certification with Johns Hopkins Medicine allowed them to design the organization's medical protocols and procedures, and improve the architecture of the facility, technological infrastructure, and quality control programs. Patient safety is one of their major focuses on indicators such as frequent air changes, positive and negative pressure depending on the patient therapy requirements, ensuring the application of intravenous medication, laminar flow hoods, and others. The control of these indicators highly preserves the patient's safety.

The personnel in this medical facility, doctors, administrative and other collaborators are leaders in their area; the facility is equipped with world-class medical solutions. Pacifica Salud Hospital's goal is to achieve the greatest level of well-being for everyone through the combination of clinical and human excellence with their equipped cutting-edge technology and information-driven health research and education. Their vision is to become a medical facility in which the population looks for high-quality medical care, contributions to knowledge, and ongoing talent development throughout Latin America.

Pacifica Salud Hospital has two branches, one in Punta Pacifica and one in Costa del Este. Their main amenity in Punta Pacifica accounts for one presidential suite, eleven suites, and fifty-one private rooms, all designed to promote relaxation to provide a quick and complete recovery. Besides the rooms, they account for eight private rooms for intensive care and three private rooms for semi-intensive care for patients who need to be observed 24 hours a day. Besides they also account for a variety of services such as maternity, neonatology, operating room, intensive and semi-intensive care unit, radiology, cardiovascular center, perioperative clinic, clinical laboratory, and blood bank.

2. *About the Project*

a. *Main Objectives*

- Managing Space and Investment in the system inventory.
- Better manage inventory deploy to Care Units Storage.

b. *Specific Tasks*

- Identify and analyze the key factors impacting inventory management to determine the most critical points for improvement.
- Implement measures to reduce the number of days that medical supplies spend in inventory by improving inventory turnover.

3. *Scope of the Study*

The scope of this project as mentioned before is based on the inventory from January to October of 2022, accounting for medical supplies only, this doesn't include any drugs or medication since medical supplies and medicines inventories are controlled in a different matter.

The medical supplies inventory is sectioned into more specific categories called families, to make the project more manageable and to work on the most significant supplies in the hospital, our team as well as the hospital team has decided to scope the project down into analyzing and evaluating only the Surgical Medical Material family, this decision was made based on that the surgical medical material family shows a great percentage of the total investment in inventory in the hospital, accounting for almost half of it as it is showed on figure 3.

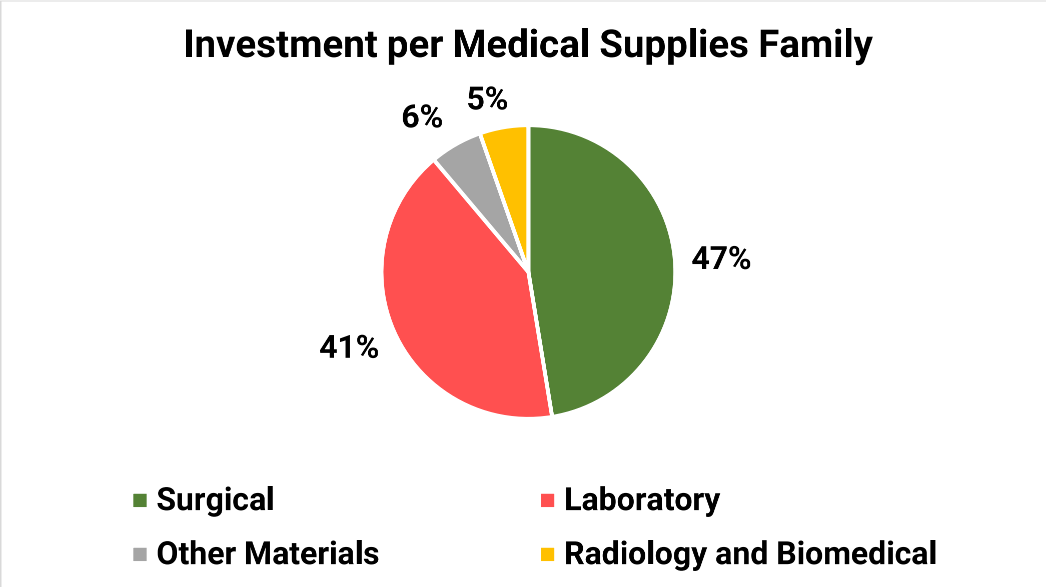

Figure 3 Investment per Medical Supply Family

4. *General Description of the Area of Study*

a. Hospital Operation

We can define inventory management as a controlled system where the target is to decrease the investment of the supplies by planning and organizing while also putting into balance the supply and the demand of these. To make sure that the inventory will be enough without being overstocked the management must consider the supervision of the supply, storage, and accessibility of the commodities.

In this section, we will learn about Pacifica Salud operation. Figure 4 illustrates the part of the supply chain that we are more concerned about in this project. Physical medical supplies are delivered from external suppliers to each hospital location's Central Warehouse which is located inside the hospital, and these materials are replenished when they reach the reorder point normally set by worders by looking at historical data. Then Materials Flow from Central Warehouse to Care Units Storage Locations, each hospital location has approximately the same quantity of care unit storage rooms as follows: Emergency room, Intensive Care Unit, Obstetrics and Gynecology, 7th floor, Radiology, and Endoscopy. In the Care Unit Storage rooms, materials are replenished in an Ad Hoc way, without a formal Reorder point. And these materials are sent to the patient service room as they are required based on surgery schedules.

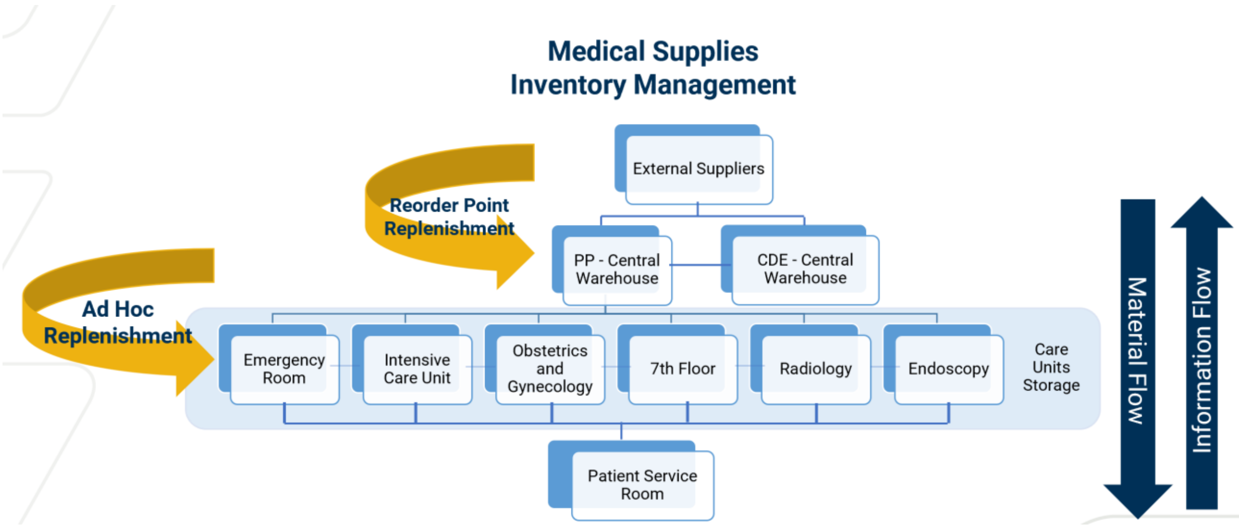

Figure 4 Pacifica Salud Operation

This specific hospital applies periodic inventory, in which supplies are ordered and delivered in batches from the central inventory. There is no real-time inventory status record. Contrary to perpetual inventory, which is tracked in real-time with biometric readers and bar code readers are used. The periodic replenishment mode used is the Ad Hoc Replenishment and Reorder point Replenishment.

- Ad Hoc Replenishment: In this mode, the hospital worker counts inventory and estimates consumption. Products that reach low inventory are requested from each care unit through electronic or manual requisition. Workers perform all operations from request to put away products in storage units.
- Reorder point Replenishment: Each product has a fixed estimated reorder point determined by the inventory worker. Each week the inventory worker verifies the medical supplies that reach the expected reorder point. Then based on the difference between a product picked up in a period before, he makes a requisition for the supplies to the central warehouse.

Points that we want to point out in this section are doing the reorder point replenishment in the central warehouses do not know what is in the Care Units storage room and probably the Ad Hoc Replenishment in Care Units is not doing the best job of managing the space and dollars. We can see that these systems are not doing well and there is a huge opportunity for improvement.

In the Central Warehouse, some medical supplies remain in their inbound boxes and are stored in standard racks and others are unboxed and stored in plastic bins as shown in Figure 5. The aisles, racks, and rack storage space are labeled by number and letter for easier picking and put-away operation. Care Unit Storage Rooms consist of smaller rooms and medical supplies are stored in closets and smaller plastic drawers as shown in Figure 6.

Figure 5 Punta Pacifica Central Warehouse

Figure 6 Care Unit Storage Room

V. Methodology and Results

In this section, the team will describe the set of activities for the analysis of the inventory process that will be followed to address the problem statement incorporating the analytical approach.

1. Inventory Process Overview Documentation

It is important to know the process of how the data is collected since it will be relevant to analyze if there are parts of the process in which there can be some opportunities for improvement leading to better management of the inventory. To gather this information, the team made several visits to the hospital's main location. Then by observing and interviewing the different people in charge of the processes, the team could collect the information. This step is relevant to make future modifications and compare with the productivity they have right now.

The following is the overall process when it is determined if the supply needs to be restocked or not. The same process is used for the main branch in Punta Pacifica and its second location in Costa del Este. With the process overview of Figure 7, we can analyze the flow of physical inventory and information through the system. As we can notice, not all purchases are charged to the patients, rather are lost in the system.

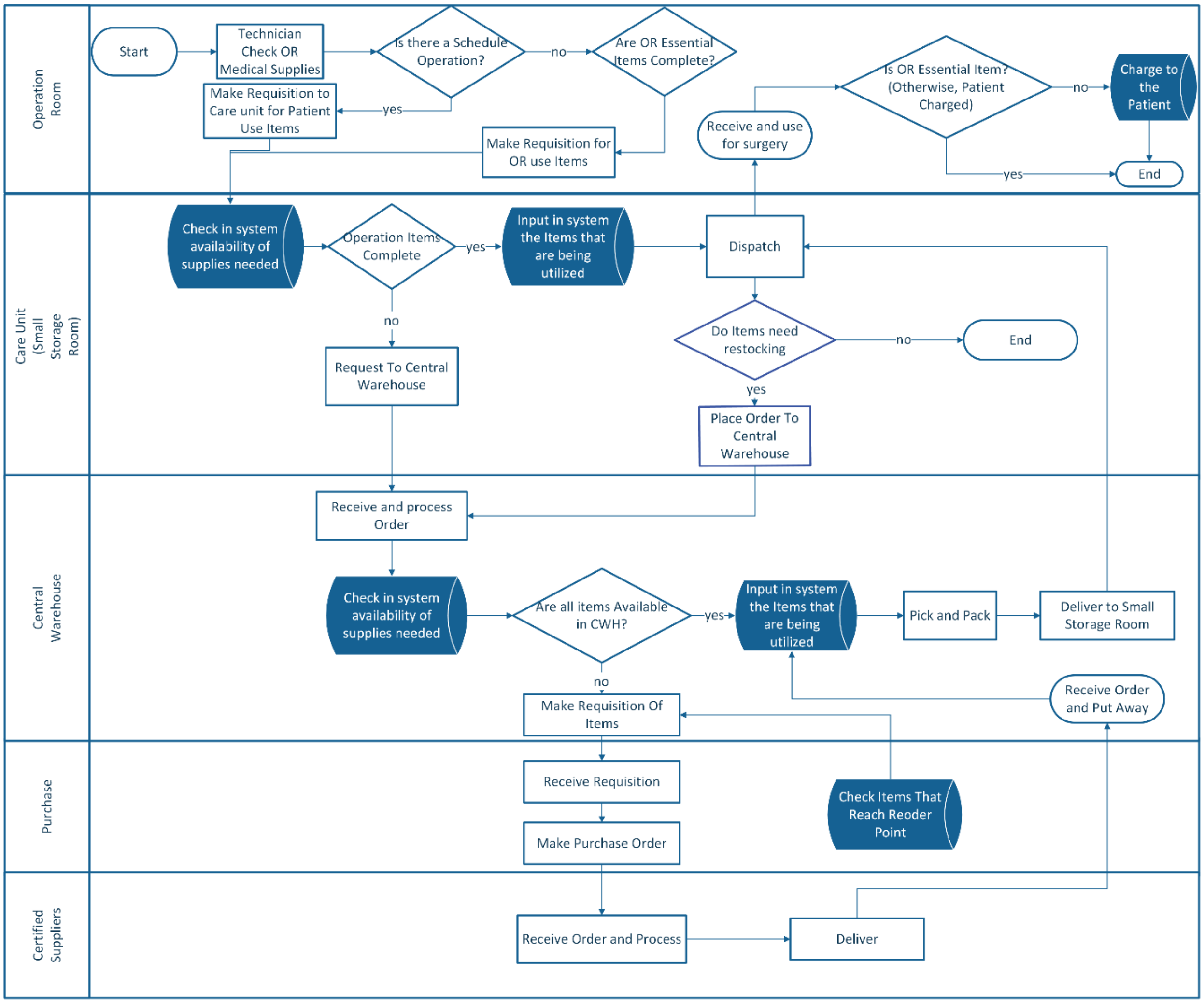

Figure 7 Inventory Capturing Process

- Additional to Items charged to patients, those that are "used" in service and expenses must be registered as charged to the hospital.
- Centralized purchasing is required for CWH.
- Supply Purchases are charged to the care unit at the time of delivery and no longer appear as an asset. Unofficial inventory may be tracked in some way.

2. *Data Collection and Depuration*

The initial phase of data collection began with visits to the main branch of the hospital, located in Punta Pacifica. Before having data sets to work with it, is necessary for the team to understand the way the inventory of medical supplies works throughout the different warehouses located across the hospital. After this, the team received two data sets, one containing information about the receiving in the central warehouse and the other one being the medical supplies charged to the patients from all of 2022 and expected another dataset of Inventory on hand or cycle inventory.

The latter was not readily available, so with our project, we want to prove the value of this requested data so that the sponsor can see the value of getting it and let the workers that are related to the replenishment have it available.

The first data set, medical supplies received in the central warehouse contain the branch (Punta Pacifica or Costa del Este), Date of reception, user creation, number of document, supplier code, supplier name, article code, article name, family code, family name, class code, name of the class, subclass code, name of subclass, cost, quantity, price, billed amount, article Tax, variation, total, available, type of document.

In the second data set, medical supplies charged to the patients has the following fields: Patient account number, date, branch (Punta Pacifica or Costa del Este), Service Center, Description, Charged Description, Article Number, family, class, quantity, price, admission state, and procedure name.

The team assumes that the two types of datasets are one for the reception of inventory and another for outbound from the inventory used by the patients. The team eliminated the columns that are not relevant to our computations. Then because inventory is assigned to patients as expected to be used, but in some cases, they are not wholly consumed then they reduce it from the system as not been used as in the table "Cargos Paciente" from the Data Pacifica Salud, column "Cantidad" (Quantity). To clean the data, the team subtracts the article not used from the assigned ones to have the real number.

The team also got the movement from central warehouse to Care Units Storage rooms of one specific product which is the Bbraun infusion set in a more detailed table.

The datasets mentioned before are the primary data, then the secondary data is obtained through observation in the visits to the facility and other research papers, and files published.

3. Formulas for Days in Inventory and Dollars in Inventory

To understand future results, we will first go through the formulas of important parameters that we will use to evaluate the inventory to find out the opportunity.

a. **Average dollars in Inventory** are the value of the average physical inventory held during a specific period**.**

$$Avrg.\ Dollars\ in\ Inventory\ = Average\ Inventory\ qty * Cost\ purchased\ per\ unit$$

$$Average\ Inventory = \frac{Beginning\ inventory + Ending\ Inventory}{2}$$

b. **Days in inventory** measure how long in days on average a product is in storage before being sold.

$$Days\ in\ Inventory\ (DII) = \frac{Average\ dollars\ in\ Inventory}{Cost\ of\ Goods\ Sold} * days\ in\ time\ period$$

c. **Current Days in inventory** measure how many future days of inventory are on hand at that moment**.**

$$Current\ Days\ in\ Inventory\ = \frac{Ending\ dollars\ in\ inventory}{Cost\ of\ Goods\ Sold} * days\ in\ time\ period$$

To compute the calculations of days in inventory and dollars in inventory, we consider both branches of the medical institution. We only consider the item codes that are purchased and sale in 2022, supposing these items were purchased before that year. Also, we deleted the items that were purchased but not sold, because these are for general use in the hospital and are not charged to the patients.

With the data that we got from the sponsor institution. For the inventory calculation, we consider the first day in the year that they purchased each item so that the beginning inventory will be available on that date in the central warehouse. The sponsor institution may implement live information of their inventory on the patient floor´s small storage room in the future, but right now the person in charge of each storage room checks the available items in the room and reorder from the central warehouse. Since this information is manually tracked, we only took into consideration inventory from the CDE and PP Central warehouses. Because the sponsor could only provide data until October of 2022, the ending inventory is the inventory on the 31st of October of 2022.

$$Ending\ Inventory = \ beginning\ inventory + quantity\ purchased - quantity\ sold$$

Some Ending Inventory is negative because these items may have been distributed from the central warehouse to small storage rooms before the period evaluated.

Cost of Goods Sold (COGS) [2] is the carrying value of goods sold during a particular period, medical supplies are typically considered as cost of goods sold because these materials are related to providing the service of treating the patients. Other than the cost of the purchased medical supplies, we have the constraint on not getting the cost of direct labor or other direct expenses to consider in the cost of goods sold. The formula for COGS is the following for our study:

$$Cost\ of\ Goods\ Sold(COGS) = \sum Price\ purchased * number\ of\ items$$

Now diving into the results of the analysis with the formulas used, it is in fact as mentioned before that the data is not actually readily available since the data contains discrepancies. The team made the computation based on purchases and sales trying to find where the actual and real demand really lies, since the purchases may be an overestimation of the real demand since there is the possibility of the item being bought in excess and sales being underestimating the real demand as there are items that are not charge directly into the patient and consequently not being reflected into the quantities of inventory.

First, as we can see in the Figure 8, the computation was made for dollars inventory and there are two lines, orange line being based on sales and blue line being based on purchases.

There are a few conclusions that we can take from this chart in Figure 8, first, that average inventory in the system lies between the two lines meaning the real demand may be between \$1.5M and \$4.1M.Second,that even though these numbers are showing the underestimation and overestimation of the actual demand, both suggests that the demand is actually growing over time which is logical as the hospital is also growing over time.

But dollars may not actually represent how well we are managing the inventory as the hospital needs these dollars to continue managing the real demand.

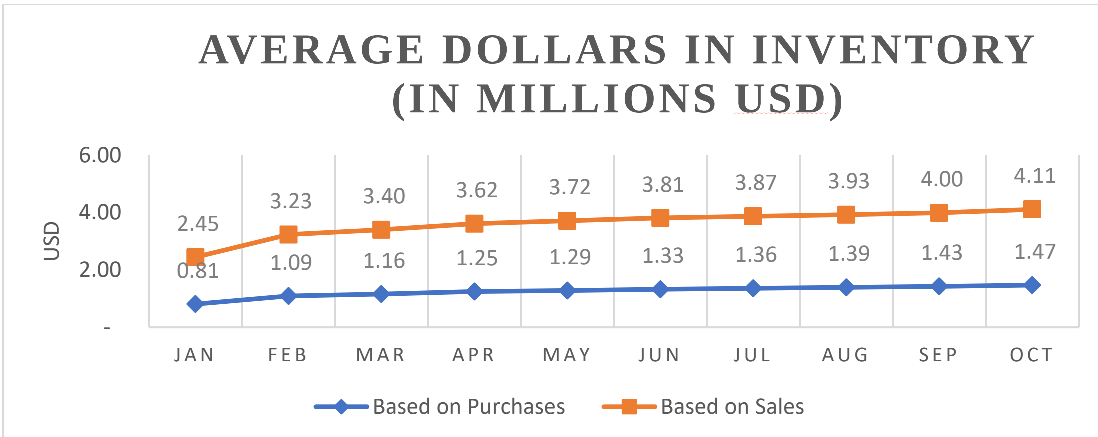

Figure 8 Average Dollars in Inventory

Now, since dollars in inventory do not really represent how good or bad the hospital is at managing their inventory. There is the need to look and analyze another metric which is the days in inventory.

As we can see in the Figure 9 ,one main issue that these numbers suggest is that across the system the average days in inventory will be somewhere 132-350,making it more than half of a year, also there is an alarming quantity of items that have way too much days in inventory, between 70-80% of the surgical supplies have more than 90 days of inventory meaning that these items stay in the warehouse/unit care without being used for around 3 months which can lead to a wasted opportunity to use the space for other supplies that have a faster rotation.

When days of inventory are going higher, it means that the hospital is keeping extra inventory on hand or sales have started slowing. DII drifting too high for the sponsor can result in monetary losses because almost all medical supplies are perishable. Lower is desirable meaning less cash is tied up in inventory. But below zero means that the company might not be able to fulfill the orders, which would be dangerous in a hospital. The lower number of days indicates faster inventory turnover, while the higher number of days suggests lower turnover.

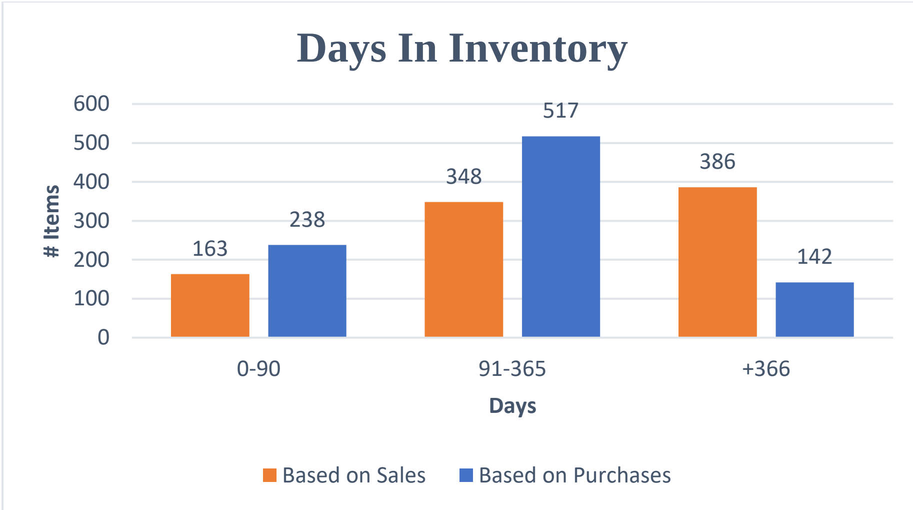

Figure 9 Days in inventory

After looking into these metrics, both dollars and days in inventory, we now know how difficult it is to have a better sense of where the real demand lies. It opens up the opportunity to tackle the challenge of how difficult it is for the people in charge of the reorder point procurement, also since the hospital has a great number of surgical supplies and the time of the project was limited, we needed to put our attention into more specific items ,where then in the future our recommendations about the system can be replicated into all the other supplies.

4. System Inventory Opportunity Assessment

Inventory takes a significant role in the total cost of any hospital. It is stated that at least one-third of any hospital annual budget is used on buying medical materials, supplies, and medicines [3]. Because of this, hospitals need to have efficient ways to control their inventory. Even if this control only saves around 1% or 2% of the previous costs means that there could be a change in the hospital to increase its productivity and profitability.

Since the sponsor faces challenges with their slow inventory turnover that can hinder overall efficiency, it opens the opportunity to proactively identify and address the factors that contribute to the accumulation of days in inventory. Because of inflation, the hospital days dollar in inventory is increasing, one of the most critical opportunities for improvement is the hospital reducing the value of inventory in the central warehouse and storage room by improving overstock inventory.

Not only we should put our attention to the turnover of the inventory but after looking into the data given, the team realized how difficult it is to have a better sense of where the real demand lies, opening up the opportunity to tackle the challenge of how tough it is for the people in charge of the reorder point procurement which can also lead to the issue of the accumulation of days in inventory since there can be data discrepancies.

5. ABC-VED Analysis

To make the ABC-VED analysis the team used the dataset provided by the sponsor, which included the items that were sold in 2022, is important to mention that the numbers shown are those which the items were charged directly to the patients, not including the number of items that were used by medical professionals.

With this method, the team wants to categorize medical supplies based on their usage frequency. An analysis of the ABC and VED classifications (Vital, Essential, Desirable) of a Pacifica Salud Hospital is carried out to identify the medical supplies that need greater administrative control.

For the ABC classification, the sales were taken by the cost of the medical supplies and sorted in descending order. Then, the cumulative cost of all items will be calculated, as well as the cumulative percentage of these expenses and the percentage of the number of items. Finally, the list is divided into three categories: Based on the percentage of cumulative costs, A accounts for 70%, B 20%, and C 10%.

The Surgical Medical Supplies were used in the reference hospital with an expenditure of 10 months in 2022, from January to October of $2,527,181.84. Of these medical supplies, 94 (11%) consume 70%,146(17%) consume 20%, and 605 (72%) consume 10%.

ABC	Number of Items	% of Items	Value of Total Consumption ($)	% Total Consumption
A	94	11%	$ 1,770,416.14	70%
B	146	17%	$ 505,720.17	20%
C	605	72%	$ 251,045.53	10%
Total	846	100%	$ 2,527,181.84	100%

Table 1 ABC Analysis Results

VED classification divides into V for vital, E for essential, and D for desirable. Medical Supplies that are critical for patients and must always be available were included in the vital (V) category. On the other hand, those that are less critical but should always be available in the hospital, as far as possible, were classified as essential (E). Finally, the remaining medical supplies that have the lowest criticality and whose shortage does not affect the patient's health were included in the desirable category (D).

With the help of medical professionals who are working in the field, we got to classify the different surgical medical supplies. It resulted that 431 (51%) of the items take about 62% of the consumption,363 (43%) consume 32% and 52 (6%) consume 5%.

VED	Number of Items	% of Items	Value of Total Consumption ($)	% Total Consumption
Vital	431	51%	$ 1,603,994.55	63%
Essential	363	43%	$ 799,283.92	32%
Desirable	52	6%	$ 123,902.57	5%
Total	846	100%	$ 2,527,181.04	100%

Table 2 VED Analysis Results

For the ABC-VED matrix, the results of the ABC and VED classification were combined. In the matrix, each of the elements is shown by two letters. The first letter shows the ABC analysis, and the second one represents the VED analysis. Three different results can be determined and are categories I, II, and III. If the medical supply goes into Category I then those will fall into these corresponding subcategories: AV, AE, AD, BV, and CV.

Category II supplies are included in the BE, CE, and BD subcategories and the remaining will fall into the CD subcategory which is part of the last category III.

In our case Category I (AV,BV,CV,AE,AD) consists of 467 expensive and high critical surgical supplies which consist 55% of total items and 85% of the total expenditure. Category II (BE, CE, BD) are essential and have an average cost. Category III (CD) consists of 36 supplies that are desirable and inexpensive. The results obtained are presented in Table 3.

Category	Combined Category	Number of Items	% of Items	Value of Total Consumption ($)	% Total Consumption
I	AV, BV, CV, AE, AD	467	55%	$ 2,150,374.50	85.09%
II	BE,CE,BD	343	41%	$ 361,785.72	14.32%
III	CD	36	4%	$ 15,021.61	0.59%
Total		846	100%	$ 2,527,181.84	100%

Table 3 ABC-VED Analysis Results

This analysis also can help the sponsor to set frequency of doing cycle count of the inventory. Normally the hospital does one cycle count every quarter. For high rotation A, it will be necessary to increase this frequency bimonthly and C low rotation can also be lower twice a year.

Additionally, as a result of this analysis made with all the surgical medical supplies, some of the supplies that were in category I, meaning they are critical to the items to the hospital happened to be PPE (personal protective equipment) which also had higher days in inventory compared to other supplies as we can see in Figure 10. The team decided not to use these items because, as a consequence of the pandemic, we are assuming the hospital needed a lot of stock of these PPE which led to the high count of days in inventory, instead, the team decided to go with the item that showed to be one of most critical and important in terms of dollars which is the Bbraun infusion set as it is shown in Figure 11.

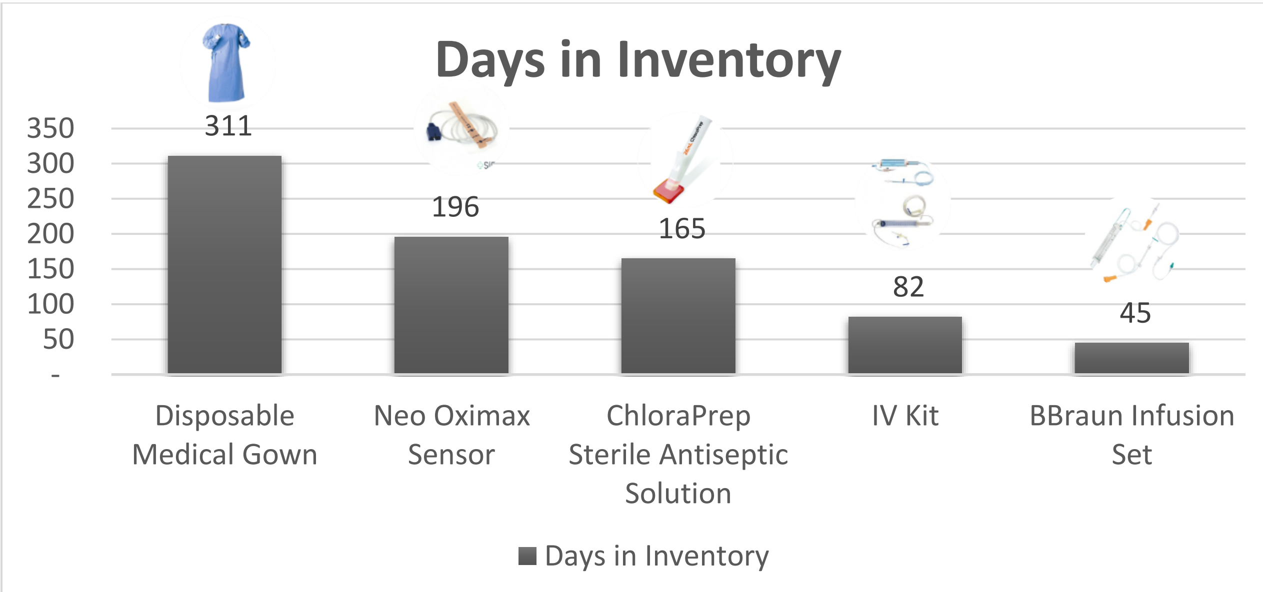

Figure 10 Days in inventory for influential items

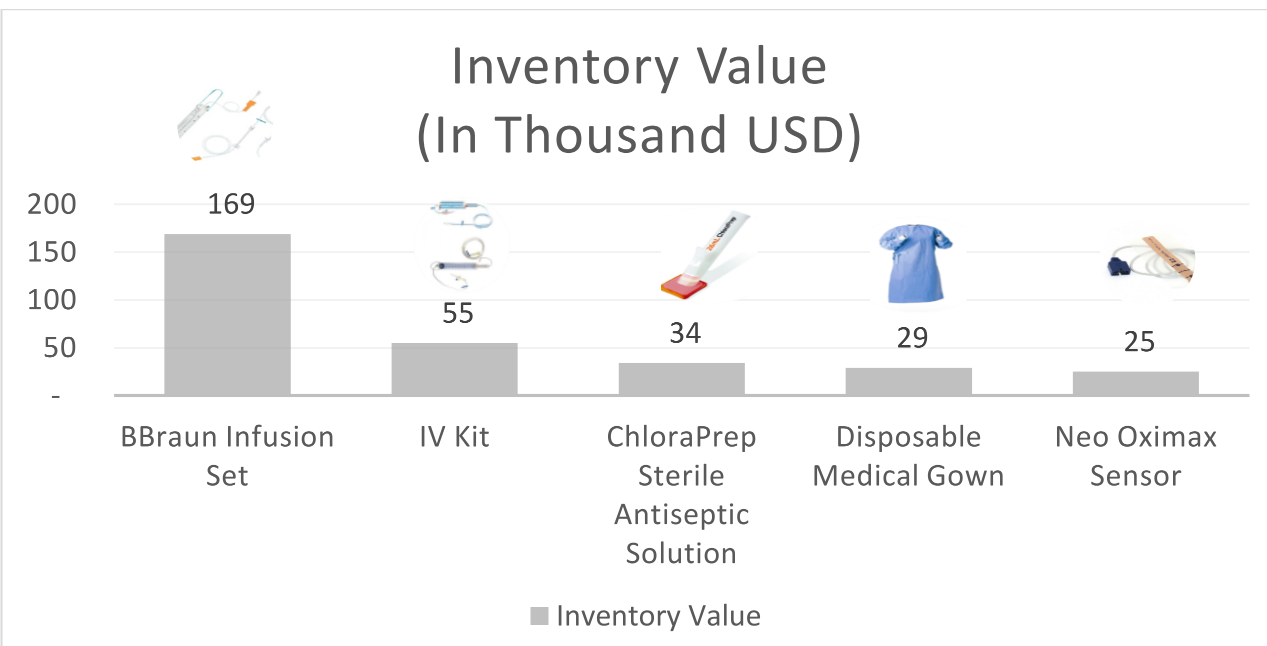

Figure 11 Inventory Value for influential items

6. *System Inventory Replenishment Analysis for one specific Item*

As a result, from the previous ABC-VED analysis, the team chose the Bbraun infusion set as our guiding item. This is a medical device used for delivering medications directly into a patient's bloodstream through an intravenous (IV) fluid source.

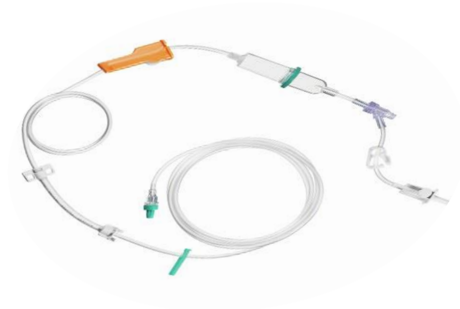

Figure 12 Bbraun Infusion Set

This item is the fastest moving item and vital for lifesaving as per ABC-VED analysis. Its lead time is normally 1 to 2 days and up to 7 days based on the sponsor's experience. We compute days in inventory based on the purchases and the sales with the known ending inventory rather than with the calculated ending inventory. This is because we note a discrepancy of around 26% the calculated ending inventory with the cycle count ending inventory. Using the true ending inventory, we can say that true average days in inventory may be between 15 to 18 days. With an average dollar in inventory between 10 thousand to 25 thousand dollars.

We also provide the sponsor with an estimate of the ROP, and Safety stock. As we can see from the graph in Figure 13, the sponsor can improve their reorder point, by maintaining it constant, rather having always overstock of the item, taking up to 2500 which is the peak. This accounts for huge space in the warehouse.

$$\boldsymbol{Safety\ Stock\ (SS)} = Z\ (99\%\ Service\ Level) * sqrt\ (Average\ LT * (Std\ D)\ \text{^}2 + (Average.Sale * (Std\ LT)\ \text{^}2)$$

$$\boldsymbol{Reorder\ Point\ (ROP)} = (AvrgDailySales * AvrgLT) + SS$$

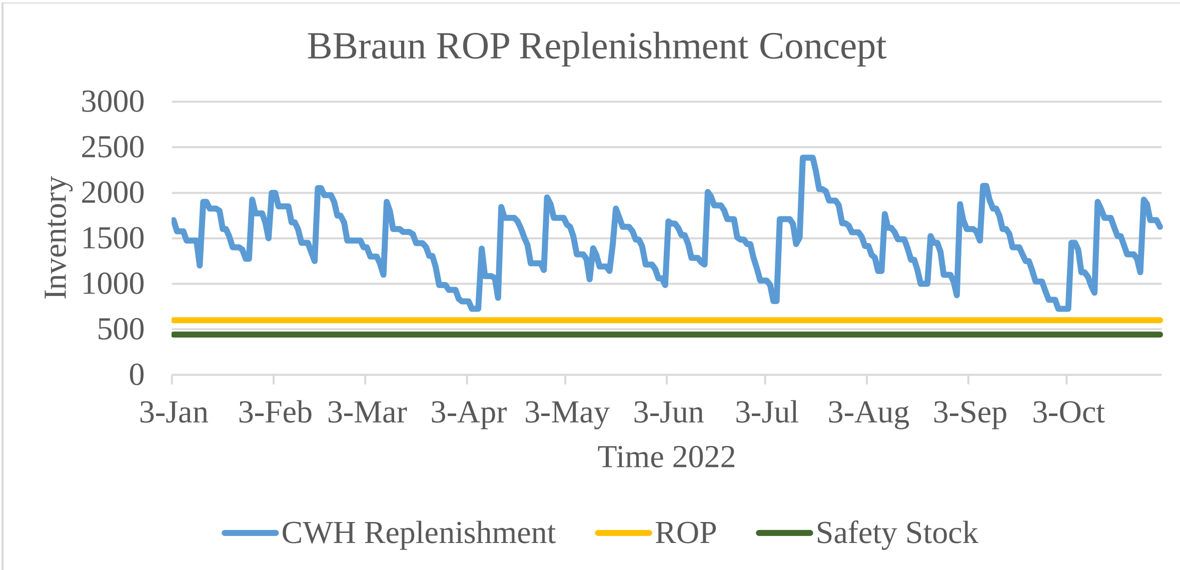

Figure 13 Bbraun Infusion Set Replenishment Concept

To find out the true demand, we needed the real ending inventory from the cycle count. We got the numbers for the cycle count at the end of the period of ending inventory just for this item. The ending inventory isn't available generally. If that ending inventory is accurate and came from the IT system but is difficult to get that information to the people who need this. Our project shows the value of having this information available. With this ending inventory we got that True demand saying true demand refers to the sales plus used items plus loss items.

Recorded Sales represent only 84% of true demand. So, we are missing 16% of the demand. We might also compare the true demand with our purchases with a result of 101% , which is very close to true demand. So, in this case we would use purchases as the representation of true demand. Sales are a very bad estimate of demand. So is more reliable to calculate days in inventory with purchases instead of Sales. With purchases as true demand, the sponsor are requiring 80 units/day and this inventory spends almost 15 days in the warehouse representing an average dollar of ten thousand dollars.

With the results, the sponsor seems to be doing a pretty good job of managing inventory for this specific item, but there is still room for improvement. This same exercise can also be done with the 5 TOP items mentioned above.

$$True\ demand = Beginning\ inventory + Purchases - Ending\ Inventory$$

Comparison of True demand with Sales

$$X = \frac{Total\ Sales}{True\ Demand}$$

Comparison of True demand with Purchases

$$Y = \frac{Total\ Purchases}{True\ Demand}$$

Improved days in inventory and risks to take into consideration.

Today days in inventory are 15 days and lead time from 1-2 on average and up to 7 days on rare occasions. We don't have much impact if we improve to 14 days, but as we can see the impact for each day improved on the average investment in inventory as shown in Figure 13. Creating huge savings for the sponsor over time as shown in Figure 15. But we need to also consider the risks when improving days in inventory such as narrowed uncertainty being aware of delays, traffic, and strikes. Uncertainties might cause stockouts creating cost increases such as in transportation for urgent cargo, suppliers can charge the hospital more, and benefits for bulk purchasing should also be considered. The sponsor must also evaluate how reliable are their supplier on more frequent and smaller orders to be delivered on time while ensuring the quality of the products received.

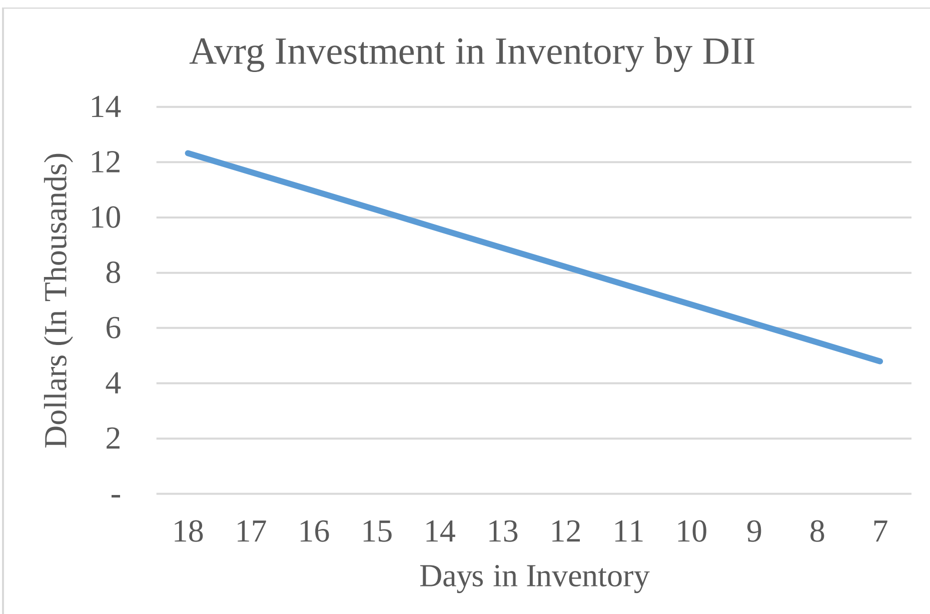

Figure 14 Average Investment in Inventory by DII

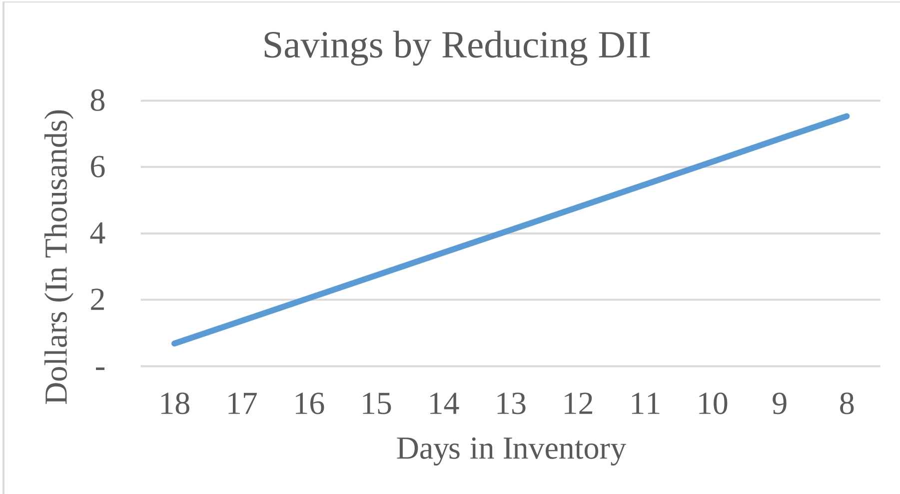

Figure 15 Savings in Dollars by Reducing DII

7. Inventory Deploy to Care Units storage rooms.

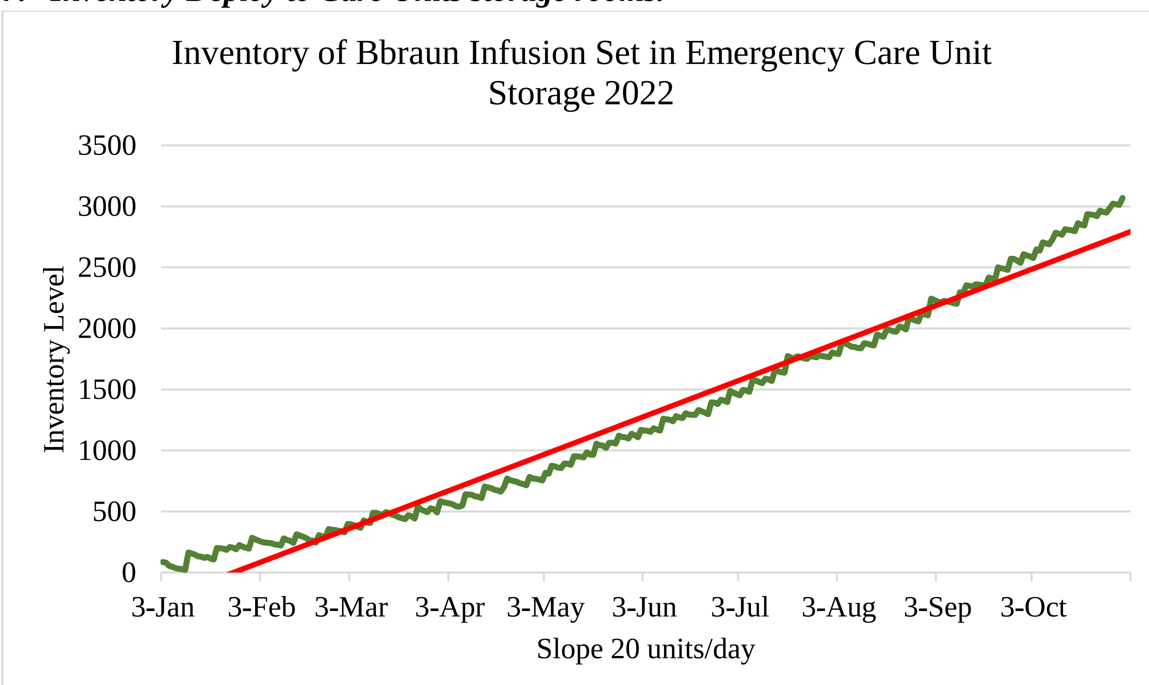

Figure 16 Inventory analysis for single product in Care Unit Storage

For this section, we wanted to study more in detail one Care Unit Storage Room, for this we chose the emergency care unit. As we can see in Figure 16, the care unit inventory is growing, and this is much faster than in the system inventory with a slope of 20 units/day. Because these care unit storages are getting more crowded and messier, we found a huge opportunity here by targeting Bbraun Infusion Set. The improvement that we suggested to the sponsor will be shown in the following section.

VI.Recommendation of Implementation

1. 2-Bin Kanban System

a. Definition

Kanban emerged at the end of the 1980s, in Denmark and Holland. 2-bin Kanban system is a variation of the industrial version for the 2-bin idea adapted to hospitals for managing the inventory of medical supplies. The Kanban system works as a visual version of the basic (Q,r) inventory model for inventory control. In the (Q, r) model, Q is denoting the order quantity and r is representing the reorder point. This specific model is widely used in inventory management and assumes a constant demand rate. This specific (Q,r) system works as follows: given a demand rate of D units/period, an Q (order quantity) is placed whenever the inventory reaches the reorder point, r).

Visual control is noticeable in the JIT movement in industry which looks toward simplification and transparency. In the past, this system has been used for the replenishment of high-volume, low-cost components which we can say could be applicable for Category I items from the ABC-VED analysis. This version of 2-bin Kanban set two bins in equal quantities instead of maintaining two different-sized bins. [4] This 2-bin Kanban visual version of (Q, r) works as the following having two bins:

The first and second bins will conform to the same capacity Q, Q=DL+SS, where D is the demand, L is the Lead time until the order is received, and SS is the safety stocks that are computed conventionally. When the first bin, or control bin which is in use is issued to zero then, an order is issued to replace it and is expected to arrive L periods later. The order quantity is set to the Economic Order Quantity equal to Q. When the order is received, the bin is filled.

As we found in our research, some hospitals are moving toward a 2-bin Kanban system. which is suggested as better as a reorder point replenishment system and obviously as an ad hoc way of replenishment. The two-bin Kanban system is a visual version of reorder point replenishment which uses equal capacity bins for the replenishment of medical supplies.

b. How does it work?

The system relies on two identically stocked bins for each item, one placed in front of the other. When the technician takes the last item from a bin, remove the bin, and place it on the top shelf in the empty bin collection area then pull the back bend forward. If an incorrect or extra item is collected and wants to be returned to it, it must be placed in the bin labeled returns on the right top so that it can be returned to the proper bin. When a bin are only a small number of items remaining, do not consolidate them with the back bin.

Items can be ordered in alphabetical order for easier finding and labeled with categories with unique colors such as wound care, EPP, Patient care, patient safety, respiratory, Cardio, and IV supplies. For oversize items may be stored outside of the bin. In this case, a reorder card is used to signal the need for stock replenishment, when a card is uncovered then is placed on the top shelf to ensure is restocked.

When one bin is emptied is removed from its position and placed on the top shelf in the empty bin collection area and the rear bin is pulled forward into the front position when you take the last item from the bin.

c. How easy is this system?

- It doesn't require that the technician or nurse that manages the storage room is well trained in inventory management because is simple and visually intuitive.
- There is no need to count the remaining quantities in bins to know when to reorder.
- Reorder point, Order quantity, and bin capacity have equal values.
- Ensure first-in-first-out cycling since most of the medical supply can be considered perishable.
- Some hospitals may implement this system with RFID, but we found that this system can also be applied without a sophisticated information system.

d. How does it control growth inventory?

- By visual trigger
- This system ensures that a fixed inventory level is accomplished.
- And only replenishment is done when necessary.

Figure 17 2-equal-bin Kanban Example

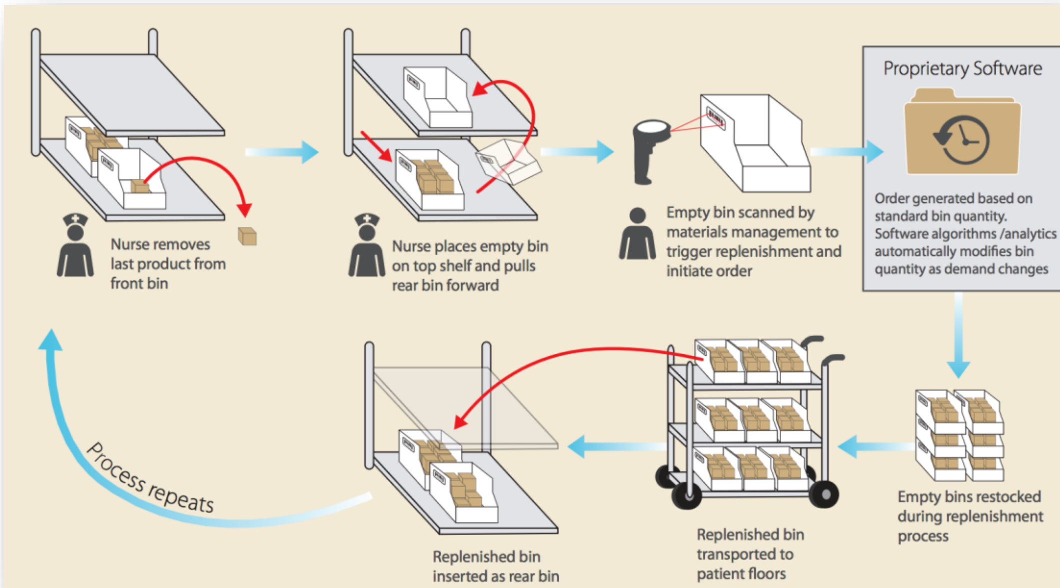

Figure 18 2-Bin Kanban process description

e. Simulation

- We did a simulation of a 2-equal bin Kanban is implemented and described as follows:

1- we use historical data in 2022 from emergency room outbound translated as sales charges to patients.

2- we set two equal bins

3- calculated the reorder point, with 30, so 30 for each bin. With a total of 60 in inventory. LT is 1 day.

4- then once the bin is emptied, is replenished the next day. And repeated

- What impact did we get from this?

Using Kanban represents approx. 2% of the space needed back then in 2022, we could take advantage of this space to set more items to 2bin kanban.

To calculate the space used, we assume that each infusion set has a volume of 53 inch3, then with the average inventory in 2022 compute the total volume used which result of 83634 inch3, and when implementing the 2-bin Kanban system the total volume was of 2491 inch 3. We can see clearly that with the implementation of the system is of 2%.

Days in inventory went from 84 days to 3 days.

- Risks to consider.

The sponsor must evaluate and create a plan when CWH is low replenishing, and not accomplishing in 1 day as it is established.

The space would be reduced but we should also evaluate unforeseen demand variability, so this system also demands constant evaluation on what items to keep and which new items to add for the implementation. Normally are high rotation, low-price items.

To expand we recommend the sponsor try with the TOP 5 items of category I as shown before to estimate impacts.

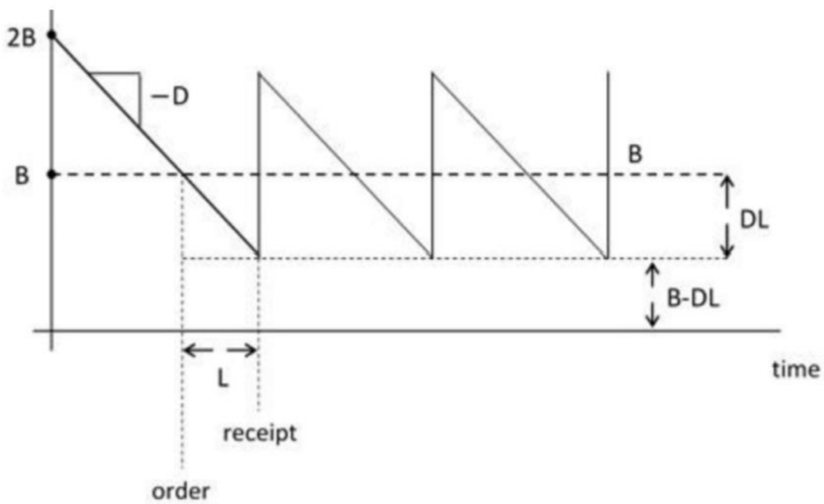

Figure 19 2 bin replenishment concepts

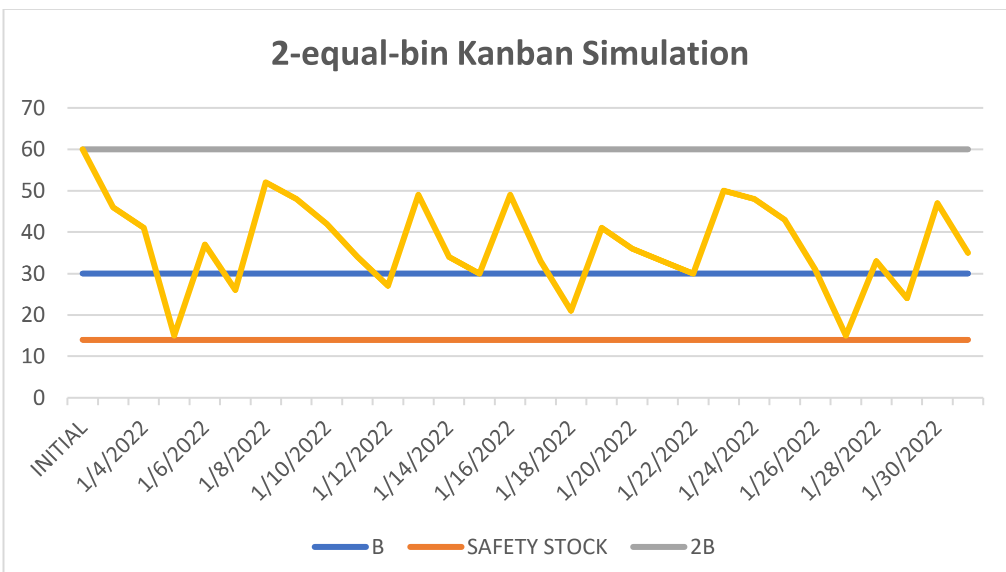

Figure 20 2 - equal - bin Kanban simulation

- Benefits of implementation

The implementation of 2-bin Kanban as we can see in Figure 19, controls the inventory to maintain within the stablish maximum limit. By establishing a limit, it reduces overstock. Also having a second bin, this system ensures that there is always a backup bin available. Additionally, this improve the efficiency at the reordering process, creating a pull principle, based on actual consumption or real demand.

VII. Conclusion

1. *Value of the Solution*

The efficient management of medical supply inventory is vital for hospitals to provide a high-quality service to patients. Our project aimed to implement a data-driven approach guided by identification of the inventory data discrepancy, finding that purchases represent a more accurate representation of the True demand, the successful implementation of a 2-equal-bin Kanban system in the care units.

The in-depth analysis of the inventory data, with the Days in Inventory, we assess to the variability on the time spend on system for the demand. This uncovered discrepancies between predicted demand and actual outbounds from the system, leading us to further address the underlying cause by applying an ABC-VED rotation, vitality analysis to categorize the items, and then narrow our attention to one item.

Traditionally, hospitals relied on purchases as True demand, and as validated with our project. But this data often fails to capture the variations in consumption patterns. For this we estimated the gap between the real and the calculated enabling to obtain more accurate demand estimate.

The implementation of a 2-equal-bin kanban system successfully curbed stockout and ensured constant availability of vital medical supplies, reducing the delay while ensuring no overstock.

2. *Final Conclusions*

In conclusion, targeting one product can help visualize the problem and then replicate it to others creating a major impact. Just looking at one product data provided us with data-driven insights and then we had the opportunity to create innovative solutions so that the sponsor can keep delivering high-quality patient care. By identifying the discrepancies, leveraging consumption data, and the simulation of 2-equal-bin Kanban system, we achieve significant help to the improvement of the inventory process effectiveness. This implementation can be successfully replicated within other items and hospitals.

As it can be expanded for the hospital to continue providing exceptional service to patients by optimizing their resources and processes, An extension of research on optimal n-equal-bins and account for probability in lead time. Future Studies on the Implementation of Data Capture of demand Models are needed.

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