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DEPARTMENT OF SUPPLY CHAIN AND INFORMATION SYSTEMS

OPTIMIZING INVENTORY: A PROCESS IMPROVEMENT CASE STUDY IN ORTHOPEDIC MEDICAL DEVICES

HANNAH LOMBARDO
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Reviewed and approved* by the following:

Robert Novack
Associate Professor of Supply Chain Management
Thesis Supervisor

John Spychalski
Emeritus Professor of Supply Chain Management
Honors Adviser

* Electronic approvals are on file in the Schreyer Honors College.

ABSTRACT

The purpose of this thesis is to address medical device inventory optimization as a supply chain solution synergistically supporting both the clinical needs of a hospital and also the business needs of a medical device manufacturing company. Supply chain responsibilities are increasingly becoming stressors for healthcare clinicians and administrators alike. Improper management of supplies and inventory often leads to higher costs and an inefficient use of skilled labor, further taxing an industry increasingly being strained by operational costs and diminishing insurance reimbursements. The bottom line: supply chain is where hospitals should save resources, not further consume them.

This thesis addresses optimizing the inventory management practices of a hospital's orthopedic surgery department. The process, rationale and stakeholders are outlined, from the preliminary meetings to useful data analytics and identifying performance metrics to final recommendations for implementing improvements. These improvements all aim to solve the hospital's primary pain point: periodic inventory stock-outs.

The recommendations addressed in this study can be summarized as follows. Data on the existing inventory should be transferred into an electronic inventory database and maintained as inventory is added or removed for improved real-time visibility to stock availability. The calculated periodic automatic replenishment (PAR) levels should be used to guide optimal supply reorder frequency and quantity. Key performance indicators including real-time inventory consumption, order frequency and order volatility should be monitored with time and used to measure the success of the new process or if adjustments need to be made to the PAR levels.

Finally, as this thesis was a designed case study, future collaborations between hospitals and manufacturing companies may consider the recommendations generalizable and applicable to the broader healthcare industry.

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I would first like to thank The Department for their support and guidance during my co-op. My time with the organization was a period of great personal growth and learning. To my supervisor and team members, your support was unwavering, and you were always willing to teach new concepts and provide real applications making my experience relevant and very fulfilling.

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INTRODUCTION

Business entities are constantly seeking ways to eliminate waste and streamline processes in an effort to improve cost savings. This notion especially holds true for the healthcare industries – particularly hospitals – as their profit margins continue to diminish. With tightening budgets and ever-increasing cost pressures, some hospitals are finding ways to partner with healthcare consumer companies to their mutual benefit. This thesis explores one such partnership. For a certain medical device supply chain solutions division of a leading healthcare consumer corporation (hereafter referred to as The Department and The Company, respectively), these corporate-hospital partnerships are The Department's competitive advantage.

While The Company's medical device sector's primary business model profits through device sales, The Department of interest actually operates under a service model. This service is driven by building relationships with the hospitals and hospital networks who purchase The Company's medical devices. By implementing lean six-sigma projects on behalf of the hospitals, The Department seeks to optimize various parts of the supply chain, theirs as well as the hospitals', to both of their benefit.

Many of supply chain solutions used by The Department are outlined in The Playbook. They are tried and true process improvement guidelines that have been used since The Department was founded in 2016. For example, ordering and invoicing automation, master data maintenance and proactive backorder strategies strive to achieve perfect order performance. Consolidated service centers improve transportation logistics while device kitting, value stream mapping and fees assessments provide opportunities for cost transformations. Finally, to sustain the achieved benefits from this hospital/Department relationship, inventory management solutions are put into place should The Hospital choose to continue ordering The Company's medical devices in future years.

Inventory optimization is of particular interest to hospitals because poorly managed inventory drives so many of the pain points experienced by surgery suites across the industry. Though each case is different, the Department aims to combine common inventory supply chain strategies – such as addressing par levels, suggesting a more appropriate stock-keeping-unit (SKU) portfolio or switching to bulk case ordering – to eliminate waste and synergistically improve the overall supply chain process.

While not immediately obvious to the casual observer, this service model of The Department is a favorable business strategy for The Company. Though they do not earn profits – in fact, they actually spend money in the form of time, technology and labor – the benefits to The Company far exceed these costs. The single most important benefit lies in the thought that customers who operate collaboratively rather than solely transactional with The Company are more likely to sustain future business. The Department's services are not provided with a contractual or even implied requirement that business is expected post-project; however, a successful relationship improves the net promoter score and by extent the probability of sustained future business. Furthermore, The Company can use evidence of their effective supply chain improvement projects to share with other hospitals thus encouraging new medical device customers and subsequently increasing future sales.

While this is all well and good for The Company, the relationships would not continue if they were not symbiotic; The hospitals certainly benefit as well. Even if the scope were limited solely to inventory optimization, the hospitals are likely to experience savings of many kinds: time, as order processes are streamlined; energy, on behalf of the hospital staff as restocking becomes simplified and high-volume medical devices are guaranteed to be in stock thus eliminating any last-minute procurement scramble to fill inventory gaps; costs, for from those overnight orders come expedited shipping fees to third party transportation groups; and finally, if not most importantly, patient care. If a surgery is delayed due to a failed supply chain, the patient ultimately suffers.

The purpose of this thesis is to create a repeatable model for The Department who in partnering with a sponsoring hospital can assess their current inventory status and implement a solution. The scope is tied exclusively to The Company's sports medicine medical device division. It will utilize one hospital (The Hospital) as a case study to draw conclusions and recommendations. In essence, these recommendations might serve as a proof of concept that will ultimately be generalizable to the healthcare industry.

Customary of such discussions, this thesis will begin by addressing those current practices standard to the healthcare industry. What inventory solutions are common across hospitals? How are The Playbook strategies being utilized by hospitals, both as directed by The Department as well as otherwise? Is there an inventory optimization best-in-class practice? This will establish a base of assumptions from which all recommendations of this case study will be based.

Next, a site visit will be required to properly identify the voice of the customer. Stakeholders from The Hospital should be present, including clinical supply chain managers, strategic sourcing administrators and the perioperative nurse manager or support staff. This meeting will shed light on their current processes and why these processes are being used. Then if available, as it was in this study, a review of historical order data is necessary to establish baseline metrics and suggest appropriate key performance indicators. Through lean six sigma tactics, a final recommendation will be made for repeatable inventory optimization applicable to both The Hospital as well as the larger healthcare industry.

BACKGROUND

SUPPLY CHAIN PAIN POINTS IN HEALTHCARE

To understand the increasing need for supply chain improvements at hospitals, consider that physicians and nurses on average spend one-fifth of their work week on supply chain tasks and inventory management (The Company, 2020). In a 2019 spring survey conducted by Cardinal Health, a leading healthcare logistics and solutions company, clinicians reported spending twice the desired time on supply-chain related tasks, and upwards of twenty percent of clinicians reported being stressed out by these supply chain tasks (Paavola, 2019). The attitude toward these critical operational necessities not only impedes the productivity of healthcare's skilled workforce but also is consequently one of the contributing factors to risings costs.

For every dollar a healthcare provider spends on supplies, they can spend up to two dollars in managing resources. It is therefore no surprise to find out that in recent years, supply chain costs can account for up to forty-five percent of a provider's operating budget (The Company, 2020). This poses the question that in today's advanced and tech-infused society, how are materials still being managed so inefficiently? Hospitals have the reputation for being behind the times when it comes to technology, archaic even, and this reputation is for good reason. According to Cardinal Health, forty-nine percent of frontline providers still manually count and track inventory supplies (Paavola, 2019). This leaves three-quarters of providers to feel that looking for supplies that should otherwise be readily available has the most negative effect on workplace productivity (Paavola, 2019).

Inefficient inventory management is just one of many supply chain-related pain points putting unnecessary cost pressures on hospitals. Some cost consequences like the 2:1 cost ratio of supplies to management are obvious, while others are less so. A common invisible supply chain cost is the time wasted searching for specific inventory items or while waiting for a last-minute delivery (LaPointe, 2016). Consider then the further waste of resources as highly skilled clinical and technical staff are the ones who end up looking for missing supplies (Haas and Kaplan, 2014). This time could be reallocated toward patient care, research, medical education or the training of new staff (The Company, 2020).

Due to the nature of healthcare, providers know it is unacceptable to run out of key supplies, and so naturally the tendency is to overstock. Or if supplies are identified to be missing, then higher transportation fees are not even considered by staff when placing an expedited overnight shipment for immediate delivery (LaPointe, 2016). But what if efforts were made to prevent hospitals from being put in these poor situations in the first place? It is this line of questioning that has brought about the need for full industry partnership and collaboration between healthcare and non-healthcare entities.

THE OPPORTUNITY FOR COLLABORATION

Hospitals ultimately need creative non-healthcare solutions to improve upon their existing clinical operations. These views are shared by leading consulting firms like McKinsey: “Clinical care, an important and primary focus for the healthcare industry to date, explains about 15% of overall health outcomes; social determinants, health behaviors and genetics account for the rest…In a data- and technology-enabled world, it is not a stretch to imagine that whole new business models could be created by non-healthcare players to deliver superior health outcomes” (LaPointe, 2016). This is the rationale behind the existence of hospital-interfacing departments within large medical device companies, and it is one of the many partnerships that has come out of the new modern healthcare ecosystem.

This new ecosystem is not just encouraging but demanding a paradigm shift in the way healthcare systems interact with their stakeholders (Coppinger and Meyer, 2018). As healthcare systems grow larger and more complex, their supply chain grows exponentially with it, now touching not just the providers and supply manufacturers, but also group purchasing organizations, insurance companies and regulatory agencies (LaPointe, 2016). And as McKinsey alluded to, these large networks require greater data exchange between the stakeholders which opens up opportunities for partnership and collaboration (Coppinger and Meyer, 2018).

It is no overstatement to say that technology-driven improvements offer one of the greatest opportunities for development. Based on an assessment done in the first quarter of 2019, McKinsey estimates a maximum potential of seven percent total annual technology savings by 2025 (Carlton and Singhal, 2019). This estimate based on potential use cases refers to seven percent of the $3.8 trillion that is the United States' current annual healthcare spending which, if maximized, implies over $250 billion in savings. Now some of these technological savings are directly related to the delivery of medicine, but a significant portion of the savings are derived from non-clinical efficiencies, including the use of advanced analytics and artificial intelligence to automate support functions (Carlton and Singhal, 2019). Medical device companies are beginning to recognize this opportunity and taking action.

Today, collaboration has been established between companies and hospitals to tackle many of healthcare's larger supply chain challenges. However, it is not yet so commonplace that such collaboration always represents a long-term and comprehensive strategy (Coppinger and Meyer, 2018). This is perhaps due to the differing supply chain maturity levels in which the stakeholders are likely to find themselves (Coppinger and Meyer, 2018). While hospital management's responsibility is to ensure healthcare providers have the right supplies when and where they are needed, medical device companies operate with a pseudo consumer mindset, collecting, analyzing and acting on data-driven inputs from their stakeholders (Coppinger and Meyer, 2018).

MAKING THE COLLABORATION SUCCESSFUL

So collaboration is viewed as a positive, but how do medical device manufacturers know when, where and how much to collaborate with healthcare partners? To visualize all the places where improvements could take place, it is important to first understand a generalized medical device life cycle. It is along this process flow that medical device companies and hospitals must reassess how they have traditionally interacted.

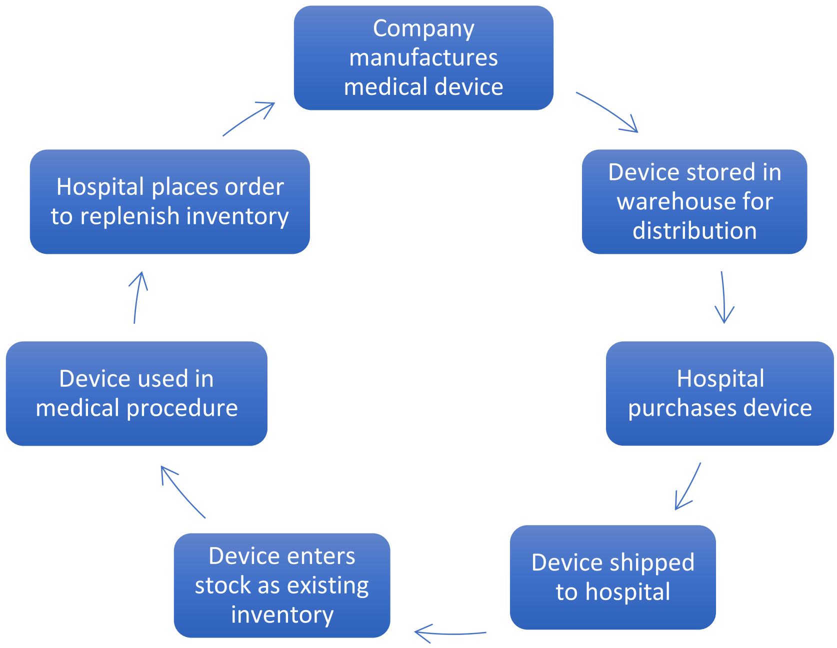


Figure 1: Medical device life cycle.

The challenge for hospitals is in adapting this life cycle seen in Figure 1 to align it to the unique care delivery models of different clinical departments' (LaPointe, 2016). What works for trauma might not work for cardiology and vice versa. That being said, where care delivery models are similar – as are perhaps trauma and orthopedics – consider leveraging similar inventory management practices to gain synergistic advantages.

Additionally, medical device companies should go beyond simply working with healthcare systems' procurement entities. They should include administration at the appropriate levels and the clinical staff who use the medical devices in the interest that the changes made will last (Coppinger and Meyer, 2018). To achieve this, stakeholders must ensure a joint value outcome, one that considers the interests of both the providers who may want certain product brands yet are blind to their cost and also the hospital management who desire the best valued products of highest quality at the lowest price (LaPointe, 2016).

When medical device companies and hospitals enter into a new partnership, there are often two significant mistakes that are made that The Department should be keen on avoiding. The first is failing to benchmark or standardize metrics (Haas and Kaplan, 2014).

Consider the cost of a surgical implant. What does it expletively cost to purchase? What does it implicitly cost to manage as inventory? Now consider the cost of that same implant used in two different surgeries in the same hospital. Do the implants cost the same? Not likely. But it is very hard to know the exact cost as hospital management infrequently keeps track of such metrics. In fact, clinicians rarely know the true cost of their surgical procedures or how the costs can vary clinician to clinician or even day to day. Now it is not important that clinicians themselves know these values since it does not affect how they perform their job; the lack of insight, however, does inhibit the hospital administration from having clear visibility to their total costs.

As stated many times before, data is key. But data does not just mean dollars and cents. Other benchmarking metrics include touchpoints and inventory. Measure the number of touchpoints to quantify efficiency gains from a process change (Cardinal Health, 2019). Measure and update inventory usage to elucidate patterns and opportunities for improvement (Cardinal Health, 2019). By failing to understand and measure both cost and non-cost metrics due to a lack of benchmarking and cost standardization, medical device costs for the hospital will vary greatly without administration being able to identify where, why or how to improve.

The second mistake hospitals should be keen to avoid is focusing too narrowly on procurement prices (Haas and Kaplan, 2014). As pointed out earlier, supply management costs can far exceed the cost of the medical device itself. A better practice long term is focusing on procuring supplies at a better total value, a practice that takes into consideration the actual consumption of supplies by clinicians, not wasting supplies due to expired products or wasting money due to expedited overnight shipping fees (Haas and Kaplan, 2014).

THE RELATIONSHIP SPECTRUM

At this point, it should be clear that the optimization of a healthcare system's supply chain elements is quite broad in nature with many possible spaces for collaboration. Choosing where to focus joint efforts can be heavily influenced by how well established the partnership is. Gartner, a research and advisory firm well respected within the supply chain community, offers the tactical, operational and strategic breakdown seen in Figure 2:

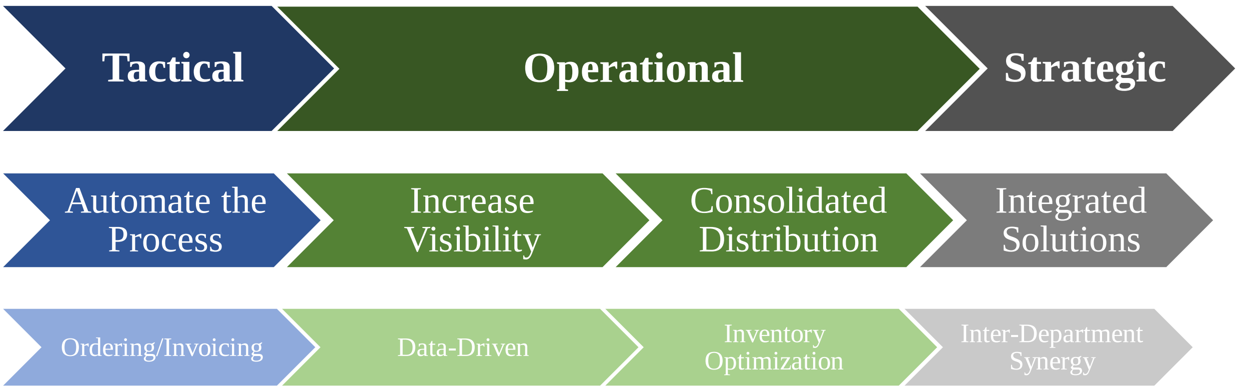


Figure 2: Gartner's collaborative relationship stages.

Tactical – The relationship between the hospital and medical device company is mostly transactional. It is the simplest way of thinking about a medical device's life cycle; the hospital places an order for a product, it is shipped, and the hospital pays for it. To reach the next stage in a collaborative partnership, an appropriate value-add improvement is to automate the base transactional processes of ordering or invoicing (Coppinger and Meyer, 2018).

Operational – This next level of partnership enables end-to-end supply chain predictability. By prioritizing the use of metrics, data brings visibility to administrative operations, particularly inventory. Individual departments can use this increased visibility to make smarter decisions about inventory management and supply flow (Coppinger and Meyer, 2018).

Strategic – Defined by the synergistic integration of one or more of these supply chain improvements particularly as they begin to span across multiple departments of the hospital or health system (Coppinger and Meyer, 2018).

For an operational partnership to grow from tactical to strategic, it requires the hospital's willingness to continue investing the time and human capital resources (Coppinger and Meyer, 2018). Proof that incremental progress is being made can often encourage continued partnership even as projects stretch on for long periods of time. This incremental progress is most easily measured through a return on investment (ROI), and while what exactly the ROI is measuring will vary by project, the metric should be aligned upon at the project's start by supply chain managers and clinicians alike to ensure joint value (Cardinal Health, 2019).

HEALTHCARE SUPPLY CHAIN MANAGEMENT STRATEGIES

Prior to delving into the details of this thesis's specific situation, it is important to first review The Department's philosophies and existing standard practices. Foremost is their doctrine of "Care Advantage" (The Company, 2020). It summarizes that to achieve supply chain optimization, The Department must seek to grow new efficiencies, decrease existing complexities and reduce unnecessary waste along the major supply chain channels of procurement, distribution and delivery (The Company, 2020). Care Advantage is widely applicable across The Company. For The Department, it takes shape as The Playbook, a set of actionable guidelines for best-in-class order performance, logistics and inventory management strategies.

Best-In-Class Order Performance

One of the most fundamental solutions is automating the customer's ordering and invoicing systems. While this may be defined as a tier 1 tactical collaborative relationship, it is often met with great positive feedback from the hospitals, opening up new doors for further partnership (The Department, 2019). Another tool for order performance is proactive backorder visibility. Too often do hospitals place orders for a medical device only to find it is out of stock and on backorder. By proactively providing the hospitals a refreshed list of existing products on backorder along with their clinical equivalency, customers are able to order around products out of stock keeping their inventory appropriately replenished (The Department, 2019).

Logistics

The most common logistics strategy implemented is an in-depth analysis of transportation. This usually involves at least one of the following metrics: on time in full at delivery, a look into the frequency at which the correct quantity of devices ordered is delivered to the hospital or medical facility on time; order day, consolidating shipments to a predetermined day or days of the week; and transportation method, a look into whether a hospital is best served by parcel, less-than-truckload or full truckload shipments (The Department, 2019).

Inventory Management

One of the more common initial inventory clean-up practices is called stock-keeping-unit (SKU) standardization. A clinical department will first review the SKUs currently being ordered for various procedures. Then in consultation with the clinicians who use the products, they identify a new, consolidated list of standard products to use going forward (Becker's Hospital Review, 2019).

SKU standardization also has a host of other benefits, not least of which it supports positive clinical outcomes and patient safety. Fewer product types on the shelves reduces the chance for human error when pulling supplies (Becker's Hospital Review, 2019). Streamlined SKUs also promote greater inventory turnover, reducing the chance that an expired product will be used, as well as simplifies the ordering process (Becker's Hospital Review, 2019). In short, this significantly improves the hospital staff's visibility to potential operational efficiencies, a very helpful strategy to implement prior to attempting any higher order inventory management strategies.

Another inventory strategy is supply mode. Defined as the best way to receive and store product, supply mode can be used to bring efficiencies to the second half of a medical device's life cycle (Cardinal Health, 2019). This looks at the length of time it takes to physically pick up orders from the dock and put them into inventory stock (Cardinal Health, 2019). It looks at the time it takes the procurement teams to order inventory replenishments (Cardinal Health, 2019). Whether this is achieved through order frequency, bulk ordering or electronic management systems, addressing where and how product comes into the clinical department often eliminates much waste (Cardinal Health, 2019).

Finally, periodic automatic replenishment (PAR) values can be set to maintain product SKU counts in inventory at their optimal levels (The Department, 2019). By reviewing average and maximum daily consumption rates and taking into account the required safety stock levels, upper and lower values can cue procurement managers when it is time to reorder and how much to reorder. Depending on how sophisticated a hospital's inventory visibility is, determining whether or not an existing product's current inventory level is within PAR values may be either an electronic or manual process.

Inventory optimization may look different between examples. However in every case, visibility to product inventory is one of the most important keys to unlocking management benefits. As was mentioned earlier, the operational stage as defined by Gartner requires quantified metrics to get full visibility. But are certain data types more useful than others? Absolutely.

The type of data measured is arguably more important than whatever analytics or algorithms are later applied. Consider two competing teams each with the same set of data but differing methods of analysis. While one team's methods may be faster or more efficient, the data will ultimately point both teams in the same direction. As a corollary to this, consider if one team was missing a subset of the original data. They could not hope to reach the same conclusions as the other team regardless of their superior analytical algorithms. If the data set does not contain the right data type, no useful insights can be gained.

So when it comes to inventory optimization, what exactly is the best type of data to collect? Rather than focusing so blindly on purchasing activity, many professionals are now arguing a greater emphasis should be placed on quantifying demand and consumption (LaPointe, 2016). The result is a more accurately described consumption activity rate.

Inventory optimization as mentioned earlier is in the operational or collaborative/strategic stage, and to reach the next stage of collaboration requires implementing integrated solutions. Perhaps by finding ways to add inventory management synergy across different clinical departments (Cardinal Health, 2019). This does not necessarily mean identical processes in all involved areas, but uniquely refining processes specific to departments that are tied together through the same line of thought (Cardinal Health, 2019). For example, trauma and orthopedic suites are both dominated by operating rooms; however, their medical device inventory stocks are made up of slightly different implant types. Furthermore, trauma naturally is for unplanned surgeries while orthopedic surgeries are most often planned in advance. But with the use of more sophisticated inventory management solutions such as electronically managed inventories, it remains plausible that the management of these two departments could be harmonized.

Electronic Inventory Management Systems

An advanced subset of inventory optimization is the use of an electronic inventory system. Both The Department as well as competitors are beginning to implement these solutions more regularly. Medtronic has a web-based platform for healthcare customers to manage their orders and inventory (Coppinger and Meyer, 2018). This gives real-time visibility to stock on hand, identifies SKUs that are problematically low and streamlines order transactions (Coppinger and Meyer, 2018).

The Department also has their own version of a web-based inventory platform, though it is built out only for their trauma medical device products and currently is not yet compatible with the sports medicine product line (The Department, 2019). This is because trauma and sports medicine run off of two different enterprise resource planning (ERP) systems. The Company does have a strategic plan targeted for 2023 to integrate all ERPs under a single order-to-cash system which brings with it the potential to harmonize a trauma and sports medicine web-based inventory platform.

CASE STUDY: THE HOSPITAL

Focusing now on the specific hospital of discussion in this thesis, an in-person visit was necessary to gather two very important pieces of information. First, a true account of The Hospital's pain points related to the management of sports medicine medical devices as felt by the administrators, procurement specialists and clinicians. Second, understanding The Hospital's current order and inventory management processes.

To achieve these insights, a meeting was held between key stakeholders of The Department and The Hospital. Targeted stakeholders from The Hospital included the senior procurement specialist, the strategic sourcing and contract administrator, the contract analyst, the regional director of supply chain, the logistics and distribution supervisor, the perioperative nurse manager, the assistant nurse manager and the registered nurse for sports medicine case preparation.

Having these people in the room together directly confronting the inventory issues at hand, it was immediately evident that this meeting was the first time these problems were being talked about openly and bluntly by much of The Hospital staff. All had been aware that a problem existed, but few had made the effort to dig into the issue to identify a root cause, let alone begin to offer possible solutions. This is where the support from The Department was critical as spearheading such discussions is their competitive advantage. The complete list of questions used to guide this stakeholder meeting can be found in Appendix A.

Current Pain Points

Too frequently, The Hospital is put in the precarious situation where a nurse or other clinician realizes an implant for an upcoming surgery is not in stock. If this happens the day before a surgery, there is still time to place an expedited overnight shipment of the medical device. However, if it happens the day of surgery, the nurse must call the medical device company's sales representative to check if trunk stock is available. If not, the surgery is delayed. While the latter scenario is an extreme case and rarely occurs, it can and does happen on occasion.

According to the nurses, a stock-out is most likely to occur with high-volume implants. Generally speaking, stock-outs are not a problem. Current inventory practices keep the shelves stocked appropriately and without issue the majority of the time. However, in the instances where this is not the case – and The Hospital staff say implant stock-outs occur maybe a handful of times a month – serious stress is placed on staff to rectify the issue. Recall the many pain points discussed by Cardinal Health in their survey of supply chain-related stressors on the healthcare industry. This problem must be addressed.

Current Order and Management Processes

Inventory management for the orthopedic surgery department of The Hospital is a manual process. To know at any given time how much of a particular implant device is on hand, a nurse or other staff member physically counts the items present on a shelf. There are no barcodes being scanned into an electronic database to track inventory levels. In short, there is no visibility and as discussed previously, a lack of visibility significantly hinders the ability of a department to take any corrective action towards optimizing their inventory.

At present, nurses and procurement specialists are utilizing a sub-optimal version of PAR levels to manage both when and how many implants to reorder. These PAR maximums and minimums are not being recorded anywhere, nor are they strictly being abided by. Rather, the PAR levels exist as tribal knowledge to staff, indirectly cueing staff when replenishment action should be taken. Put another way, the current inventory management strategy is reliant upon someone "eyeballing it." It takes little imagination to then conceive how periodic stock-outs continue to occur.

The ordering process for the medical devices is in a better starting point. The current process is a mix of electronic and manual steps. The act of placing a purchase order to The Company is entirely electronic, processed through the web-based healthcare supply chain management platform, Global Healthcare Exchange (GHX). The automation of this step shows an effort has been made to improve upon the base tactical relationship between hospital and medical device company and begin moving towards the operational stage of the Gartner model.

That being said, there is still a significant piece of the ordering process that remains manual. When an implant is used in a surgery, a sticker from the implant's container is placed on the paperwork that is used to track all elements of a surgery for billing purposes. Within 24 hours of the surgery, the charge poster collects these paper hard copies and records by hand implant consumption into the computer order system. Consider this to be like adding items to one's shopping cart on Amazon. Within the next 24 hours, the senior procurement specialist reviews and validates the cued items in the order system. A purchase order is automatically placed for any cued and validated items once an hour when the system refreshes itself.

The current state process map of The Hospital's order and inventory management practices can be found in full in Appendix A.

From the point of implant consumption to the time a new purchase order is placed to replenish stock, the average order cycle takes three to four days. Best case scenario is two days, and the worst case scenario is seven days. The manual nature of reviewing the implant stickers and cueing them up in the order system – a task that involves at least two different individuals – contributes to the time variability of this process.

The implications of the current ordering and management processes must be addressed in any potential solution going forward. Foremost, the inability to know real-time inventory levels is unacceptable. Relying on nurses to catch stock-outs brings unnecessary stressors to the workplace and is costly to The Hospital. Secondly, while The Hospital is already capturing implant consumption, this information is delayed up to three days as paper copies pass between at least two people before ever being recorded in an electronic system. Furthermore, consumption data as an inventory metric is only useful if it is combined with real-time inventory levels, actively subtracting from the count of available product in stock. Otherwise, the clinical department can still fall prey to occasional stock-outs as is occurring at The Hospital.

The Hospital's Goals for Supply Chain Improvement

Following the dialogue between The Hospital's key stakeholders and The Department, the main goals of the collaboration were aligned upon. First, The Hospital wants to prioritize an electronic inventory database providing real-time visibility to available stock levels. Second, they are seeking to eliminate stock-outs of high-volume implants. Initial suggestions to achieve these goals include establishing better PAR maximums and minimums or consolidating inventory management to a single procurement individual who has access to the electronic inventory database. Finally, The Hospital would like to reduce the end-to-end time and energy that it takes to reorder and manage inventory for their sports medicine medical devices.

In collaboration with The Department and The Hospital, this thesis will consider these stated goals and apply The Department's supply chain solutions to find a suitable inventory optimization strategy for The Hospital that benefits all involved stakeholders.

METHODOLOGY

The goal of this thesis is twofold: To provide recommendations for The Hospital to optimize their sports medicine implant inventory, and to create for the Department a repeatable case study model for future inventory-based health system supply chain improvements. The planning and action steps taken to create this model utilized many of the industry standard six sigma guidelines.

It began with understanding the voice of the customer. A site visit was conducted and a meeting held between the members of The Department and key stakeholders from The Hospital to understand The Hospital's pain points and current challenges. Visiting in person is ideal for any project as it allows analysts from The Department to view the physical structures where inventory stock is kept and visualize their processes. It also allows for a better comprehension of the spatial layout. An in-person visit is also valuable to The Hospital's stakeholders because addressing the pain points from the point of view of administrators as well as clinicians is more likely to increase the buy-in necessary for success, reveal hidden patterns and highlight the maximum number of opportunities to target for improvement.

Following the site visit, a current state process map was created. The most applicable for this case study was of The Hospital's order and inventory management processes. This process map serves as a side-by-side comparison for post-implementation changes. See Appendix B for the completed map.

The next phase employed two six sigma tools to identify the underlying root cause: the five whys and the fishbone diagram. The Hospital and The Department must fully understand the root cause prior to a data deep dive. This is critical for ensuring that any recommendations or conclusions drawn are targeted to solve the root of the problem rather than superficial or non-issues. See Appendix C for the completed tools.

The Department then completed their data analysis. This included eighteen months of historical order data. Project scope was set by identifying which implants were high-volume, order frequency over time was mapped and calculations were made to set preliminary values for the minimum and maximum periodic automatic replenishment (PAR) boundaries. See Appendix E and F for the completed PAR calculations.

Using these data points as reference, performance metrics were identified to measure the progress and success of any implemented changes. These quantitative performance metrics include the visibility to real-time inventory consumption, order frequency stabilization, order volatility minimization and a touchpoint count.

Final recommendations for the process improvement were then shared back to The Hospital. An ideal future state process map for their order and inventory management processes was designed. Guidelines for tracking a return on investment were outlined. Finally, long-term considerations were discussed.

ANALYSIS

ROOT CAUSE

The most efficient way of identifying the underlying root cause of an issue is to use a combination of the fishbone diagram and the five whys. These lean six sigma tools give structure to brainstorming ideas, recognizing common themes and ultimately visualizing the issues driving the problem where corrective action steps should be focused. In this study, the root cause tools were used to take the information gathered from the in-person visit between The Hospital stakeholders and The Department supply chain professionals and translate that information into targeted actionable strategies for process improvement.

Starting with the fishbone diagram as it is slightly broader in scope, five categories were selected to brainstorm reasonings for periodic implant stock-outs: physical labor, process, inspection, technology and measurement. The full fishbone diagram can be found in Appendix C.

Using insights from The Hospital, several important reoccurring themes became clear. There is an underutilization of technology hindering the full potential of any inventory management improvement. Corrective actions taken on account of a stock-out are solely reactive rather than proactive costing The Hospital time, energy and money. Finally, the current process heavily relies on the tribal knowledge of staff which has unavoidable drawbacks: it is vulnerable to human error and staff turnover. An appropriate inventory optimization solution will take into account these themes and wherever possible, qualitatively and quantitatively measure their improvement over time.

Complimenting the fishbone diagram is the five whys tool. This tool reaches a root cause by successively breaking down and answering why a problem is occurring. By repeating the process five times rather than just once or twice, it reaches beyond the superficial conclusions that are mistakenly arrived at too early. The five whys process enables the user to reach deeper, finding the true source of the problem. The full five whys diagram can be found in Appendix C.

Again using insights from The Hospital, the five whys was used to break down why The Hospital is experiencing stress related to supply chain tasks. Likewise with the fishbone diagram, themes of limited technology use and a lack of inventory visibility are clearly prominent. The final why statement is that implant barcodes are not being utilized nor are they cataloged in an electronic inventory database. This lends itself to a general recommendation of investing in an electronic inventory management platform.

DATA ANALYSIS

High-Volume Implants

From the beginning of the collaboration, The Hospital was clear that they were looking to focus their inventory strategy on their high-volume implants, those that were used in nearly every surgery case. To The Hospital, this meant they were on average consuming one box of these implants per week over the course of a year.

Taking the implant order history from January 2018 through June 2019 (eighteen months), aggregate order and box counts were summed for the twelve month period of January 2018 through December 2018 (twelve months), January 2019 through June 2019 (six months) and January 2018 through December 2019 (eighteen months), respectively. This data was used to find the average number of boxes per order and the average number of boxes ordered per week over those same twelve and eighteen-month time periods.

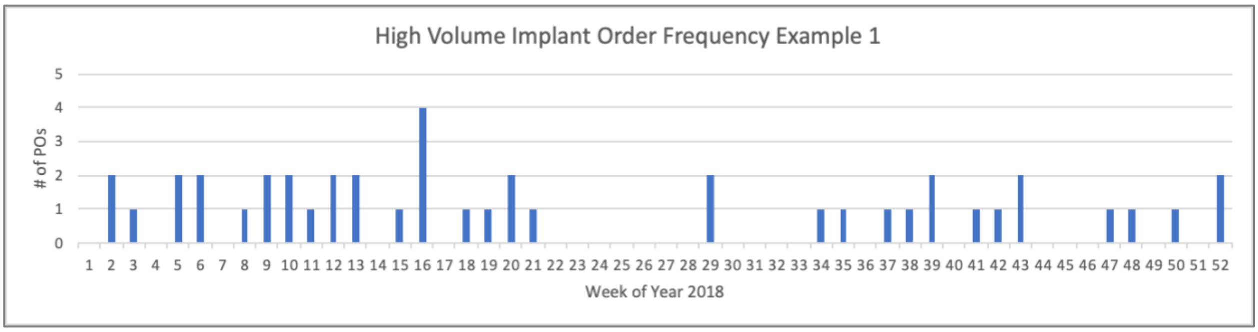
The results indicated five implants that had at least an average of one box ordered per week. Complete calculations to identify implants are found in Appendix D. These five implants hereafter are referred to as the high-volume implants and considered to be in-scope for the remainder of this inventory analysis.

Order Frequency Volatility Mapping

In process improvement implementations, it is important for The Department to assist The Hospital in visualizing how their current practices are not leading to the most efficient outcomes. Quantifying what a poor management practice looks like offers The Hospital a metric to use to benchmark improvement in the future. It also emphasizes to The Hospital staff the importance of why changes need to be made, helping The Department secure cooperation and buy-in from key stakeholders at The Hospital.

Consider order frequency over time. It follows logically that inconsistent or volatile ordering patterns suggest underlying inefficiencies. The bar graphs in Figure 3 measure how many unique purchase orders a high-volume implant is listed over 2018. For example, implant one appears on two different purchase orders the second week of the year, four different purchase orders the sixteenth week of the year, but on zero purchase orders for seven consecutive weeks in the middle of the year.

High-volume implant example two also shows volatile ordering patterns with the implant appearing on three different purchase orders in a single week three different weeks during 2018 while once again intermixed with weeks of zero orders.



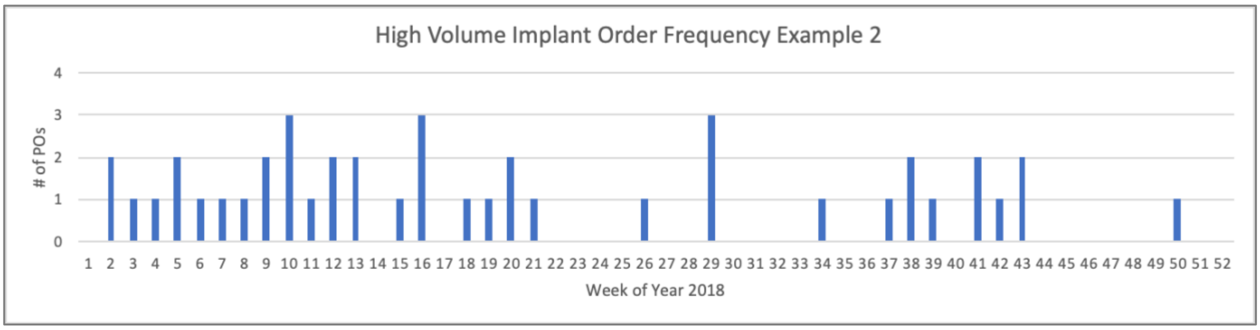


Figure 3: Two examples of high-volume implants with visible volatility in their order frequency over 2018.

One notable clarification: these graphs do not have the level of detail to say how many boxes of implants are ordered on each purchase order. One purchase order could be for a single box, or ten; this information is not measured by The Hospital nor readily inferable from available data. Ideally this metric should be measured in future states.

These two examples of high-volume implants that periodically experience stock-outs are indicative of where order habits need to be addressed in the final recommendation to The Hospital. The inventory management solution should yield more efficient ordering.

PAR Maximums and Minimums

As discussed in this thesis background, the periodic automatic replenishment (PAR) maximums and minimums are used to efficiently manage the timing of reordering inventory. The minimum level, otherwise known as the reorder point, is the stock level that when reached triggers the procurement managers to place an order to replenish inventory (The Department, 2019).

Equation 1: $Reorder\ Point = (average\ demand\ \times\ lead\ time) + safety\ stock$

The reorder point for high-volume implants will vary according to their individual average daily usage demands. Inserting this variable into Equation 1, the general form for The Hospital's high-volume implants is reorder point = (*variable* x 4) + 1, with lead time and safety stock levels both provided by The Hospital. Variable average demand is calculated as the total number of boxes consumed in one year divided by 365 days. Complete data and calculations of reorder points for each high-volume implant can be found in Appendix E.

On the other end, the maximum level is adapted according to the needs of the clinical department. It is the total inventory count that a replenishment order brings stock levels up to. For example, if an implant reaches its reorder point of three and has a maximum level of ten, then the clinical department will place an order for ten new implants. Note that because of lead times, some or all – depending on safety stock – of the original three available implants are likely to be consumed while the new ten implants are in transit to the hospital. This is of little consequence. Available stock does not necessarily need to reach the PAR maximum level, rather the maximum level is a number set to guide how frequently the clinical department places replenishment orders. A higher maximum level will require less frequent ordering. Conversely, a lower maximum level will require more frequently. Thus, maximum levels are set according to the needs and preferences of the procurement team. Maximum levels for the high-volume implants in this case study can be set following recommendations made by The Department to The Hospital guiding ordering frequency goals.

RECOMMENDATIONS

Following the careful analysis of dialogue and data presented up to this point, it is recommended that The Hospital implement the following immediate actions in order to achieve the desired inventory optimization.

SET PERFORMANCE METRICS

A critical step of the lean six sigma measure phase, performance metrics are the often the best way to measure the success of a process change. The most effective measurements will offer a before and after snapshot for direct comparison. If the most appropriate metrics for the project are being used, then the combination of all of the performance metrics will tell the unbiased story of how successful the process improvement actually was.

Real-Time Inventory Consumption

The most important measurement from the perspective of The Hospital is whether or not inventory consumption is being captured in real-time. By extension, this also includes whether the clinical department has visibility to real-time inventory stock levels. The Hospital can achieve this measurement by creating an electronic inventory tracking database with the currently unused barcodes on the implant packing. When a new shipment arrives, scan the box and enter the total count of implants inside that are being added to stock. When consuming implants for surgery prep, scan the individual implants being consumed.

This strategy will give comprehensive and real-time visibility to inventory levels and consumption. Extrapolating this data could further provide the Hospital with consumption activity rates which would be useful in any future, more advanced inventory optimization projects.

It should be noted for clarity that once these systems are implemented, implant ordering should be driven by inventory consumption rather than historical order data. Up to this point, this thesis has used historical order data as a metric several times to identify high-volume implants or periodic automated replenishment (PAR) values. Given that inventory consumption can provide more advanced insights than order history, historical order data should no longer be used in guiding future implant purchases.

Stabilizing Order Frequency

As shown by Figure 3 in the Analysis, implant order frequency has been historically volatile, oscillating between weeks with multiple orders followed by gaps with weeks of no orders. This poor practice of heavily stocking up for longer periods of use is inefficient and susceptible to unintended wasteful consequences. With medical device inventory, consistent and smaller frequent orders is often better than infrequent, large orders.

As such recommendation to The Hospital is to stabilize and consolidate order frequency for high-volume implants to a single biweekly purchase order. This more stable order pattern promotes optimal inventory turnover, inventory shelf organization and is less likely to result in wasted inventory due to unused, expired product which is a common consequence of buying medical devices in bulk.

There may be an initial uncertainty of how The Hospital's reordering of implants can be driven by both PAR levels and also the knowledge that procurement should be placing just a single biweekly order per high-volume implant. The implementation of both of these recommendations is likely to require trial and error on the part of The Hospital's procurement team. The priority should be to use inventory consumption and the PAR minimum point (see Appendix E) to drive the timing of when to reorder. But as addressed earlier in the analysis, the maximum level can be set according to the needs of the clinical department. In this case, since the maximum level influences order frequency, the order history can be used to set an initial maximum level that would necessitate a biweekly replenishment. The calculations for finding initial maximum levels for each high-volume implant can be found in Appendix F.

There are two important callouts to the use of PAR levels as stated here. The first is that The Hospital should be aware that the initial maximum level set by order history may not be the best PAR maximum to keep in practice. After a month or two of use, The Hospital should reassess if that initial maximum level is in fact yielding a biweekly reorder, and they should adjust with trial and error as necessary.

The second calls into scrutiny the level of detail that the PAR minimums and maximums were calculated. In this thesis, the PAR values were aggregated at the "box" level. This was a decision made based on the data types available at the time. However when available, it is highly recommended to calculate PAR values at the "eaches" level instead. PAR values based on eaches rather than boxes is a more specific level of detail and will provide the procurement team with greater specificity on when the reorder point is reached.

Minimizing Order Volatility

If The Hospital is successful in stabilizing order frequency, then order volatility should be minimized as a consequence. Recall in Figure 3 where some weeks recorded three or four unique purchase orders for a single implant. The Hospital should continue to monitor this measurement. If they continue to record weeks with multiple orders for an implant, this is indicative of an unsuccessful project implementation.

Touchpoints

Touchpoints are the final performance metric The Hospital should use to measure efficiency gains from the process change. There is a savings of both time and energy when fewer steps are required to get from start to finish. The most applicable area to measure touchpoints in this case study is related to the supply mode. Recall that Cardinal Health defines an optimized supply mode as the best way to receive and store product. Additionally, as this specific process change includes a major transformation in the reordering process, The Hospital should also consider those earlier steps in the touchpoint count as well.

The change in the number of touchpoints can be easily visualized using a before and after process maps. The initial state process map is detailed in Appendix B. Assuming all recommendations outlined in this thesis are applied, the anticipated post-implementation process map (included in full in Appendix G) can be used to directly compare the decreased number of touchpoints.

Time savings are often implicit when there is a decrease in touchpoints. Notably with this case study, there is a time savings between when an implant is first pulled from stock for a surgery to when its replenishment order is placed. Initially, the implant was generally pulled for surgery the day prior. Then once it was used in surgery, the sticker on the packaging was placed onto paperwork in a folder. This implant consumption information would proceed to pass through two people and take up to three days before it was recorded into a computer and validated for reorder.

In the improved process, the major change is the time at which implant consumption is recorded. By using an electronic database and scanning out implants when removed from the stock shelves, consumption is recorded in real time. This is an improvement of upwards of seventy-two hours per implant order and will positively contribute to the mitigation of high-volume stock-outs.

QUALITATIVE RECOMMENDATIONS

Recommendations should go beyond monitoring performance metrics alone. There are qualitative strategies that are equally important for a complete and successful inventory optimization.

Product Stock-Keeping-Unit (SKU) Standardization

One of the inventory management strategies addressed in the Background was the use of a product SKU standardization to consolidate the number and variations of products being maintained on stock shelves. This is a useful cleanup strategy to implement prior to any higher order inventory process improvements since it helps the clinical department to get organized thus making it easier to identify potential opportunities for optimization.

From the initial discussions with The Hospital, this thesis assumes The Hospital has already agreed upon inventory product type and brands. In short, they have already undergone a product SKU cleanup; no additional action here needs to be taken. However, as this thesis's purpose is also to create a template for inventory process improvements in general, a product SKU standardization should be mentioned as a recommendation. It is frequently valuable and advisable for a clinical department to implement this action at the beginning.

Collaboration Relationship

The most successful process improvements come from the strongest collaborative relationships between medical device company and healthcare entity. Therefore, it is strongly recommended that The Department and The Hospital maintain continued efforts to improve upon their collaborative relationship, thereby not only maximizing the success of this specific process improvement, but also any future supply chain collaborative projects.

This can be achieved by continuing to advance along the Gardner relationship model. Progressing from tactical to operational and ultimately to strategic is an evolution requiring willingness from the consumer – or healthcare system – to maintain engagement. An abstract concept, willingness on the part of the healthcare system might best be estimated by The Department through use of a net promoter score[1] which could be measured on a monthly, bimonthly or quarterly basis.

RETURN ON INVESTMENT

By taking action and implementing these quantitative and qualitative recommendations, The Hospital can expect to see a positive return on investment (ROI). How the ROI is measured varies project to project, but it should always be identified at the beginning and aligned upon by all stakeholders. A useful ROI will measure whether a project is improving upon the initial pain points and meeting the project goals set by The Hospital.

Most ROI elements should be measurable. In this thesis, it would include the number of times a month that a nurse identifies a high-volume implant stock-out requiring overnight expedited shipping and additional fees. Overtime, this number should decrease. The ROI would also include the successful creation of an electronic inventory tracker using barcodes. It would count the number of visits nurses have to make to the receiving dock to pick up high-volume implants on a weekly basis. By stabilizing order frequency, this number should also decrease. And of course, monitoring all of the performance metrics listed above.

The ROI should ultimately identify where waste has been eliminated according to the definitions of lean six sigma principles: the waste of non-utilized talent of clinicians when they spend time looking for missing implants or traveling to the receiving dock to pick up orders

[1] Net promoter score – This scalar metric is most commonly used to benchmark consumer loyalty to brand or product. It is an alternative method for considering a customer's satisfaction.

more frequently than necessary; the waste of money from the inefficient, overnight expedited ordering of out-of-stock implants; the waste of time it takes for clinicians to complete supply chain tasks, taking away from their time with patients; and the waste of inventory from inefficient processing and product expiration. The ROI can describe to stakeholders, notably The Hospital leadership, the increased value of their medical device purchases on account of the process improvement. All of these improvements contribute to decreasing the supply chain related stress on clinicians that would otherwise lead to an inefficient workplace.

LONG-TERM FUTURE RECOMMENDATIONS

The Hospital should be cautioned against making too many changes at one time. Incremental, successive steps are more successful than an overwhelming number of large, simultaneous changes at creating lasting improvement and maintaining the buy-in of key stakeholders. Thus the final recommendations listed below are not necessarily to be made now, but rather to be remembered by The Hospital as considerations for long-term continued improvements.

There was a comment from The Hospital's procurement specialist during an early brainstorming session that should be addressed. This comment was to recommend consolidating future procurement activities – to include the inventory stock management and implant ordering processes – under a single staff member. This recommendation could be considered by The Hospital, but it is not immediately necessary with their use of a fully-automated electronic inventory database. During an early meeting between The Hospital and The Department, The Hospital described the process of how staff managed the order and inventory processes to be based on tribal knowledge with guidelines neither recorded nor strictly adhered to. An electronic inventory database takes the guess work out of the process, in essence error-proofing it and making it possible for any trained staff member to be equally effective. Therefore, it does not make sense at present time to introduce the additional complexity of consolidating all procurement activities under a single person. At least not at the present time.

Web-Based Inventory Management Platform

Finally, The Hospital might consider partnering with The Company to pilot the creation of a web-based inventory management platform that can integrate demand insights and offer other curated inventory metrics. This solution would take The Hospital's collaborative relationship to tier three, integrated solutions. It would be a more sophisticated tool than this phase one electronic inventory system created by The Hospital to track PAR levels and stock availability.

This solution at a minimum is still several years out from becoming a reality. The Company's trauma medical device web-based platform was feasible due to the existing compatible enterprise resource planning (ERP) system. As of now, The Company's sports medicine medical device line operates under a different, noncompatible ERP. The Company does have plans to consolidate all medical device ERPs under a single ERP by 2023, thus bringing the sports medicine line under the same electronic governance as the trauma line. This would make it possible for a sports medicine web-based inventory management platform to follow shortly thereafter.

Continuing this line of thought, the care models between trauma and orthopedic surgery have several similarities. While they may use different categories of surgical medical devices – trauma and sports medicine respectively – the order and inventory management of these surgical devices are remarkably similar. This argument lends itself to a very progressive line of thought within today's modern healthcare: When seeking the synergy of inventory management solutions across departments, can they be digitally integrated? It is too soon to tell today but remains a possibility for tomorrow.

CONCLUSION

From the outset, this thesis served two purposes. Foremost was its work as a case study at the Hospital, a detailed look into their orthopedics surgery medical device inventory management practices. Through a collaborative partnership with The Department, a process for change was recommended, emphasizing the use of an electronic inventory management system and reorder boundaries to establish clear visibility to stock and optimize implant reorders, respectively. A successful implementation of these recommendations aims to solve The Hospital's original primary pain point: periodic implant stock-outs.

The second purpose of this thesis was to create a repeatable model for The Department for future inventory process improvements. Many of the strategies and supply chain solutions discussed are generalizable and applicable to the broader healthcare industry. The work here in this study offers a guideline for future collaborations between healthcare systems and medical device companies.

Collaboration is the key. In a highly specialized and technologically advancing society, no single entity can, nor should, do everything themselves. These partnerships are mutually benefiting, and when targeted at healthcare supply chain tasks, save time, money and most importantly promote better patient care.

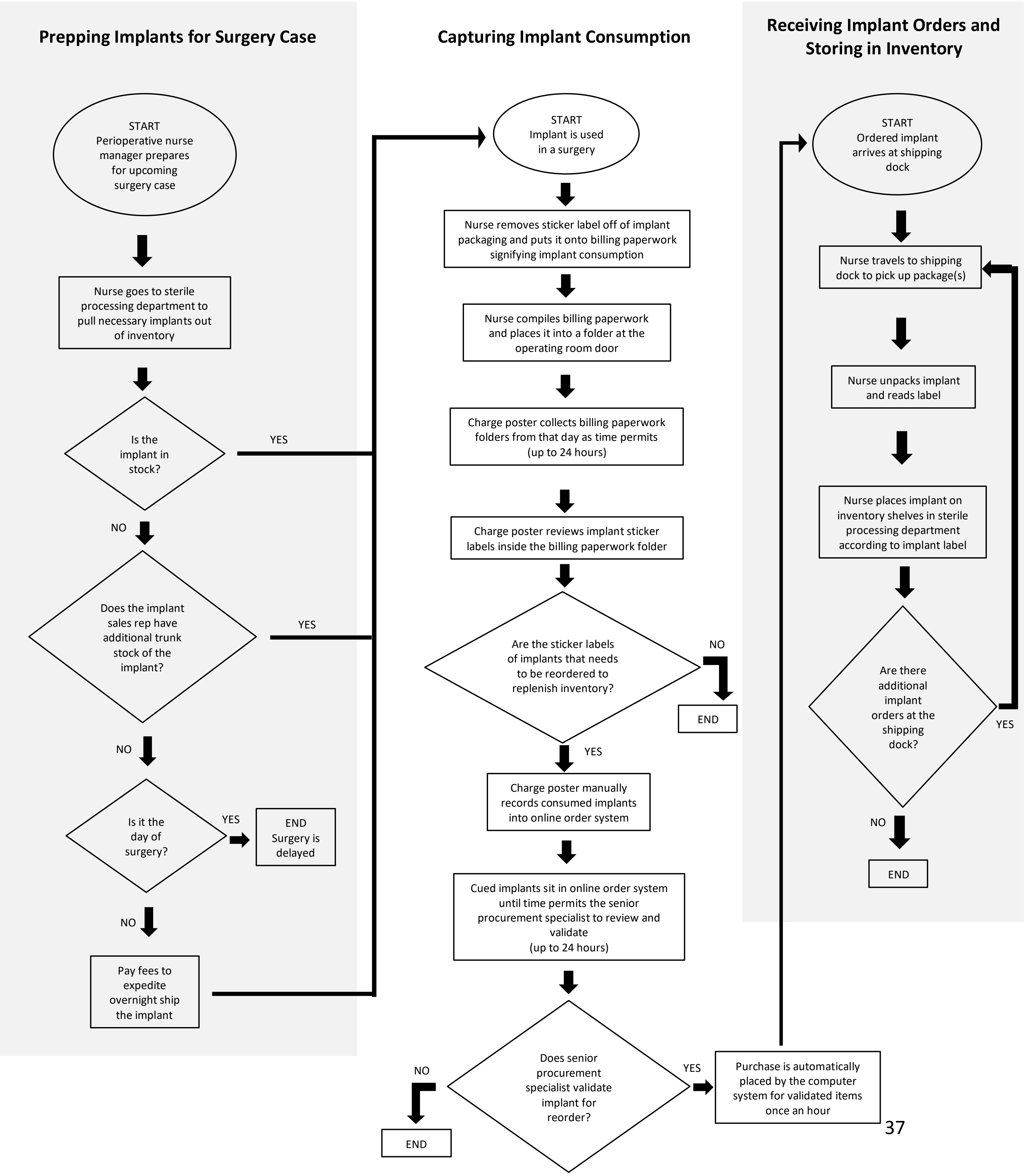
APPENDIX A

Interview Questionnaire Guide

1. Who is in the room? What is their job tasks for The Hospital?
2. What is the specific function of this clinical department respective to The Hospital?
3. What are the pain points being experienced?
4. What is the process for prepping an implant for use in surgery? Who is involved?
5. What is the process for ordering new implants? Who is involved in this process?
6. What is the process for restocking the implant shelves? Who is involved in this process?
7. What is the process for monitoring inventory levels? Who is involved in this process?
8. Who is usually the first to realize if an implant required for an upcoming surgery is out of stock? What happens immediately thereafter to rectify the issue?
9. Are there different types of implants that are differentiated either by use or procurement?
10. What is the state and use of technology in this department relevant to implant procurement?
11. What is the lead time for implant orders? How long is an order cycle?
12. Why do staff think the pain points are reoccurring? Are there any initial suggestions?

APPENDIX B

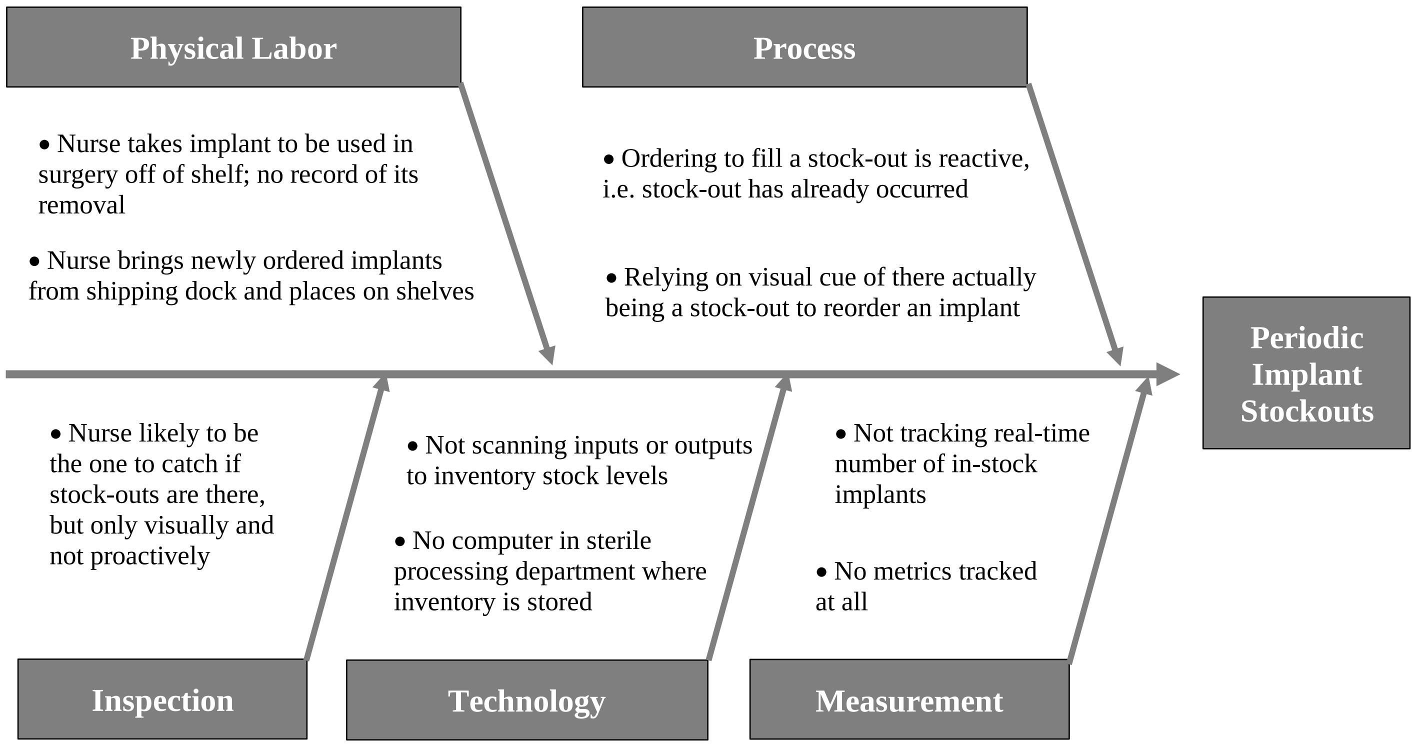
Pre-Implementation Process Map



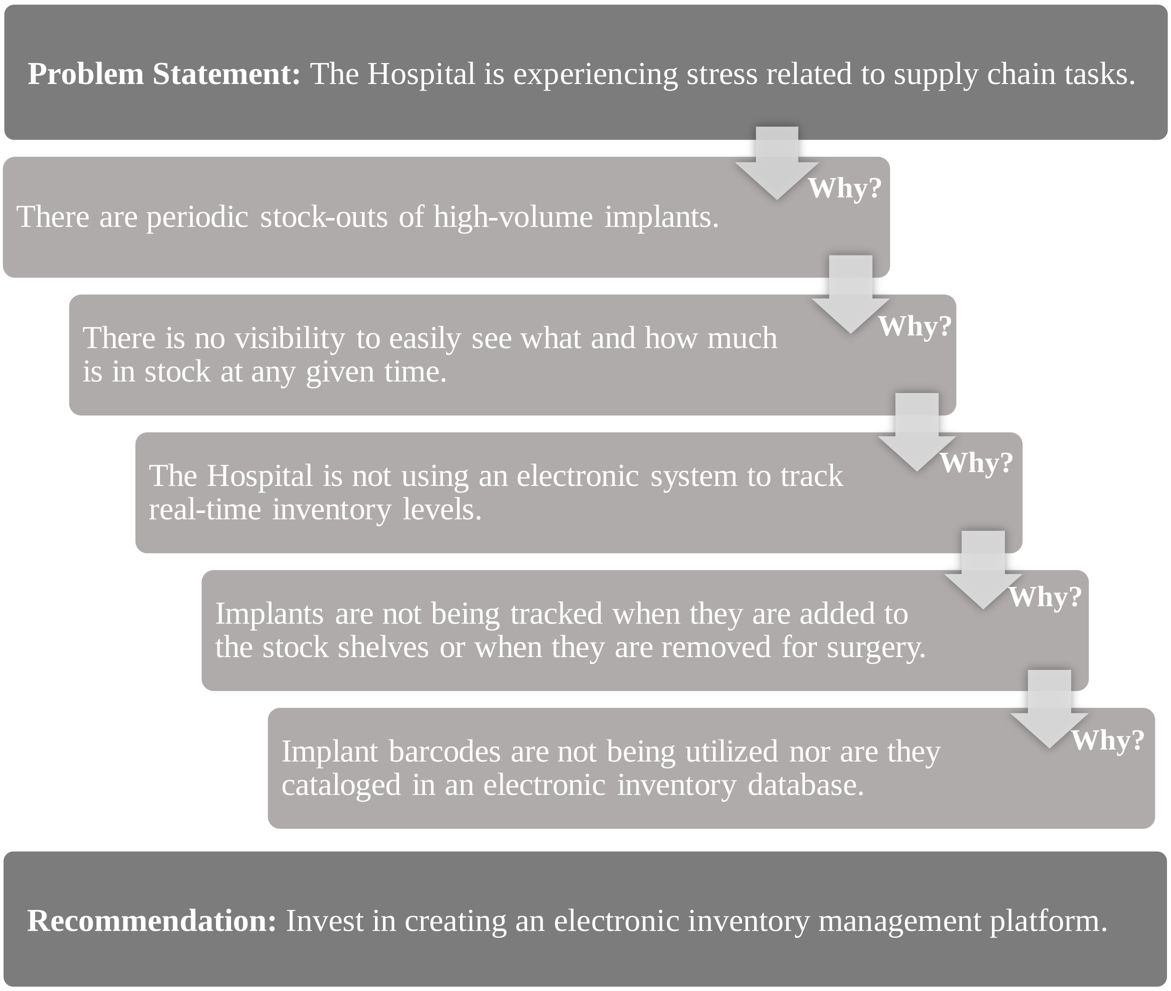
APPENDIX C

Root Cause Analysis

Fishbone Diagram – Root Cause Analysis



5 Whys – Root Cause Analysis



APPENDIX D

High-Volume Implant Calculations

Notes	Product SKU	Number of Orders			Number of Boxes			Avg. Boxes Per Order		Avg. Boxes Per Week		High-Volume
		Jan-Dec 2018	Jan-Jun 2019	18-Month Total	Jan-Dec 2018	Jan-Jun 2019	18-Month Total	Jan-Dec 2018	18-Month Total	Jan-Dec 2018	18-Month Total	
Example 1	210808	44	22	66	128	118	246	3	4	2	3	Yes
Example 2	222297	43	13	56	117	82	199	3	4	2	3	Yes
	210813	14	6	20	54	41	95	4	5	1	1	Yes
	222299	15	2	17	45	8	53	3	3	1	1	Yes
	232447	19	5	24	34	9	43	2	2	1	1	Yes
	222331	8	2	10	24	14	38	3	4	0	0	No
	212035	6	4	10	11	14	25	2	3	0	0	No
	232009	8	1	9	8	3	11	1	1	0	0	No
	222993	3	0	3	10	0	10	3	3	0	0	No
	231816	5	3	8	5	4	9	1	1	0	0	No

Table 3: Eighteen-month breakdown of most utilized implants to identify project's in-scope high-volume implants.

The Hospital provided data for the nearly twenty-five implants that they have ordered from The Company since the beginning of 2018. This data included an order count and total box count for each implant. From this, average counts per order and per week were found. The most important computation is the average boxes per week metric. The Hospital emphasized this number as an indicator for identifying which implants are high-volume (see Table 1).

The table is a subset of the data provided by The Hospital. The eighteen-month totals were summed and sorted by value high to low. Table 1 is a snapshot of the top ten of which five are considered to be high-volume based on the calculations. These five implants will continue to be the focus throughout the remainder of this case study.

Finally, note the comments on the left of the table. These two examples, Example 1 and Example 2 respectively, are the implant examples referred to in Figure 3 of the Analysis chapter and the discussion of order frequency volatility.

APPENDIX E

PAR Minimum Calculations

Equation 1: $Reorder\ Point = (average\ demand\ \times\ lead\ time) + safety\ stock$

High-Volume Implants	Average Demand		Lead Time	Safety Stock	Equation 1: Reorder Point	PAR Minimum
	Boxes Ordered 2018	Divide By 365				
210808	128	0.35	4	1	= (0.35 x 4) +1	2
222297	117	0.32	4	1	= (0.32 x 4) +1	2
210813	54	0.15	4	1	= (0.15 x 4) +1	2
222299	45	0.12	4	1	= (0.12 x 4) +1	1
232447	34	0.09	4	1	= (0.09 x 4) +1	1

Table 2: PAR minimum, or reorder point, calculations for the high-volume implants.

Equation 1 defines the PAR minimum, or the stock level at which an implant should be reordered. For all high-volume implants in this case study, the lead time and safety stock levels provided by The Hospital are consistent at four and one, respectively. The variability in the reorder point between implants is thus derived from their specific average demands.

The average demands for the high-volume implants can be found in Table 2. It was calculated by dividing the total number of boxes ordered during the year by 365. The total box count is based on January through December 2018 because it was the most complete full-year data available at the time.

APPENDIX F

PAR Maximum Calculations

High-Volume Implants	Number of Boxes		PAR Maximum Calculation	PAR Maximum
	Jan-Dec 2018	Consumed Biweekly		
210808	128	5	= biweekly consumption	5
222297	117	5		5
210813	54	2		2
222299	45	2		2
232447	34	1		1

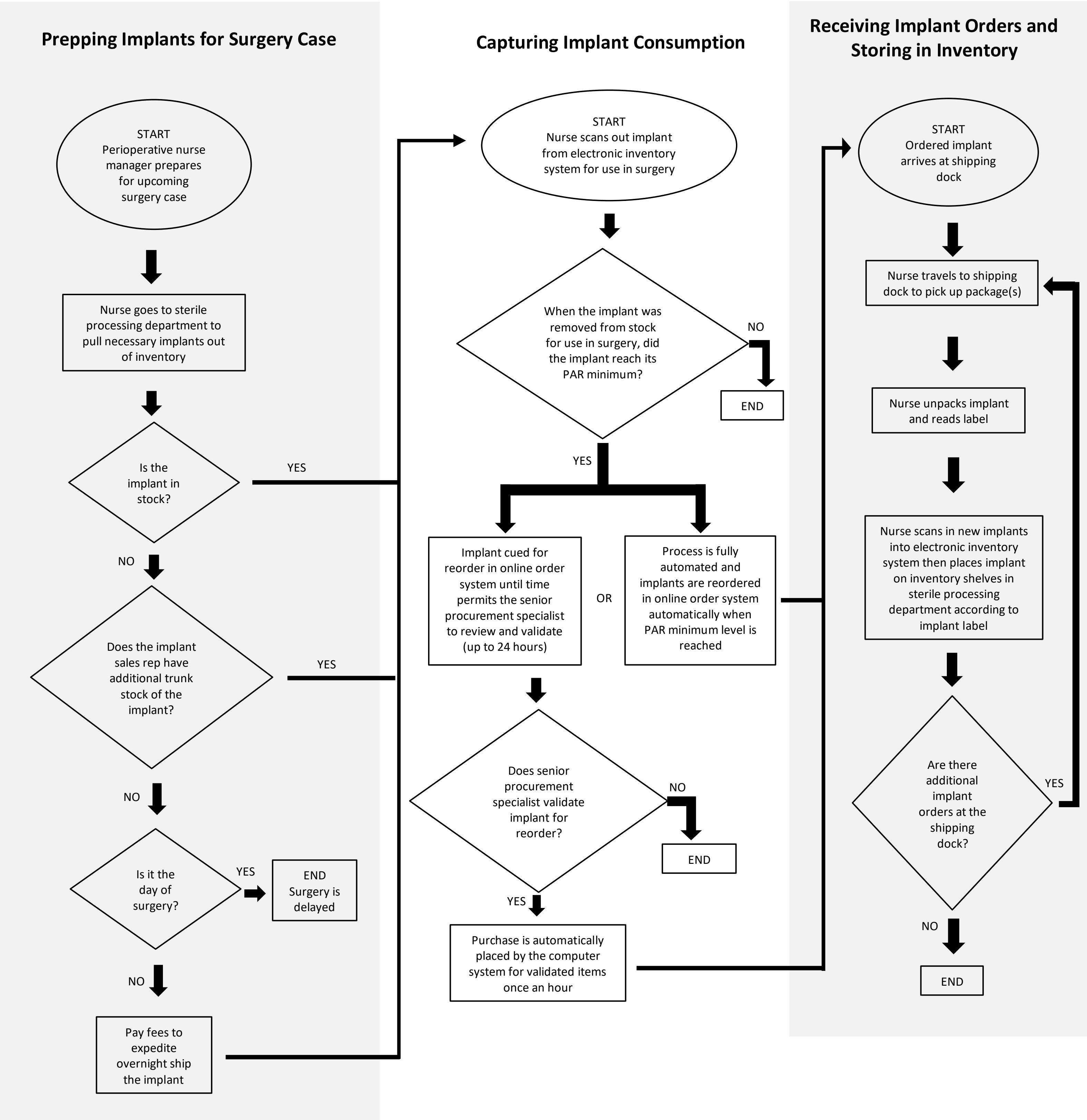
Table 3: PAR maximum calculations for the high-volume implants.

Table 3 outlines the process for finding the PAR maximum for each high-volume implant. Recall PAR maximums can vary based upon the needs of the department and the desired reorder frequency. Generally speaking, the PAR maximum should be the average consumption quantity based upon a defined period of time.

In this case study, a biweekly reorder was recommended to The Hospital. The biweekly consumption total was calculated by dividing the total number of boxes ordered during the year by 26. This represents each implant's PAR maximum. In application, the PAR maximum value functions as the biweekly reorder quantity triggered when the PAR minimum reorder point is reached.

APPENDIX G

Post-Implementation Process Map



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ACADEMIC VITA – HANNAH LOMBARDO

EDUCATION

THE PENNSYLVANIA STATE UNIVERSITY, Smeal School of Business **University Park, PA**
Master of Business Administration, Supply Chain Management *May 2022*

THE PENNSYLVANIA STATE UNIVERSITY, Eberly College of Science **University Park, PA**
Bachelor of Science in General Science *Dec 2020*

- Schreyer Honors College

EXPERIENCE

THE COMPANY **Skillman, NJ**
Strategic Procurement Co-Op *2019-2020*

- Mapped $125 MM in contracted spending with feedstock forecast pricing to streamline process for identifying optimal timelines to renegotiate future strategic contracts.
- Identified $2.5 MM in cost improvement project (CIP) risk and collaborated with portfolio managers to mitigate potential loss of CIP realization.
- Reconciled over $5 MM in missing CIP financial data during software system transition.

Supply Chain Customer Solutions Data Analytics Co-Op *2019*

- Developed interactive dashboard for best-in-class benchmarking and scorecard metrics to highlight opportunities for supply chain process improvement collaborations with strategic healthcare delivery networks.
- Partnered with five analysts to present process improvement opportunities to hospitals and healthcare systems.

PENN STATE SCHREYER HONORS COLLEGE **University Park, PA**
Student Orientation Communications and Logistics Team Leader *2018*

- Executed program for 330 incoming first-year Schreyer Scholars in collaboration with eight student leaders and ten administrators.
- Led 80 upperclassmen Schreyer Scholars in mentorship of incoming Scholar class.

Medical Career Development Team *2017-2018*

- Executed 12 health-related seminars and practicums with leaders in the medical field to provide interactive and hands-on educational opportunities for Schreyer Scholars seeking careers in the healthcare industry.
- Co-led annual New York City Weill Cornell Medical School career exploration weekend.

THE PENNSYLVANIA STATE UNIVERSITY **University Park, PA**
Organic Chemistry I: Teaching Assistant *2018*

- Developed learning materials, helped students gain an understanding of the curriculum and graded examinations for 600 students.

CARNEGIE MELLON UNIVERSITY **Pittsburgh, PA**
Pennsylvania Governor's School for the Sciences: Teaching Assistant *2018 & 2020*

- Introduced organic chemistry to 60 high-achieving high school seniors in collegiate STEM summer program.
- Assisted in organic chemistry lecture, laboratory course, and team research project.

SKILLS

Lean Yellow Belt Certified   Microsoft Excel   SAP   Tableau   Communication   Adaptability