Improving Supply Chain Agility of a Medical Device Manufacturer

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Abstract

This thesis focuses on a medical device manufacturer, DeCo, which offers surgical instruments to customers at no cost in order to facilitate the sale of implantable products that require the use of such instruments. DeCo is facing challenges in managing the supply chain for these outsourced instruments, such as long lead times, inaccurate forecasting, and excess inventory. DeCo is interested in building a more responsive supply chain. To this end, our thesis investigated strategies to increase the supply chain agility by realizing opportunities in information flows, material movement, and channel alignment to achieve shorter lead time, lower inventory levels, and higher levels of service. We conducted interviews and analyzed forecast, inventory, and lead time data files to evaluate the company’s supply chain agility in terms of key attributes such as: Inventory management, supply chain visibility, forecast, distribution channel management, supplier manufacturing flexibility, forecast, level of service, lead-time, and product lifecycle. Gaps between the current state and an agile supply chain were identified, and recommendations were made based on these weaknesses. Gaps in the supply chain were divided into three categories: information barriers, operational inflexibilities, and supply chain misalignments. Similarly, our recommendations were broken up into three main groups: Distributor strategies, supplier strategies, and DeCo’s practices. By improving supply chain visibility, DeCo can cut lead time to customers and significantly lower inventory. By gaining operational flexibility, DeCo can cut lead time from suppliers by 50%, avoid excess ordering due to minimum order quantity, and cut cost per unit. Key recommendations to achieve agility were to build a database of inventory at distributors’ warehouses and implement a process to ship instruments between these warehouses; and to work with suppliers to build dedicated capacity on the production floor.

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1 Introduction

The latest business trends of increasing competitive pressure and market globalization are forcing firms to respond quickly to customers' needs - an idea known as agility. Agility is considered one of the fundamental characteristics needed for a supply chain to survive and thrive. This agility is especially true in today's business environment which is characterized by shortened product life cycles, increased demand for customized products and services, reduced visibility of demand, and constant change. Furthermore, flexibility is needed in the supply chain to counter uncertainty in decision parameters (Agarwal, Shankar & Tiwari, 2006). Companies with agile supply chains respond better to changes in demand signals as they are able to better coordinate supply with demand (Swafford, Ghosh & Murthy, 2006). Improving the agility of a supply chain can have a positive effect on a company through increased level of service (LOS), reduced inventory level, lower inventory cost, and ultimately a faster lead time. Moreover, supply chain agility can also lead to a firm's superior financial performance (Filho, Moacir & Saes, 2013).

1.1 An Overview of the Problem

As changes in global healthcare steer the industry toward commoditization, the ability to respond quickly to market opportunities while addressing increasing cost pressure is critical to supply chain strategies. This thesis aims to provide a framework for medical device manufacturers to handle variable demand and business operations, which should help the companies to achieve an agile supply chain.
We pursued an empirical approach, using the data and practices of a medical device manufacturer we refer to as DeCo. DeCo provides hospitals around the world with implant materials for patients. To provide consistent service afterward, DeCo delivers over 12,000 types of free surgical instruments to the hospitals for replacement, maintenance, upgrade or new uses.

This thesis focus on the instrument supply chain due to its variable stock keeping units (SKU), short product life cycles, invisibility of demand, endless demand for retired products, and constant products upgrade, etc. We evaluated DeCo’s current instrument supply chain and analyzed its performance. The current average lead time is more than 90 days, while the target is 40 days, from over 75 suppliers to 36 distributors. Therefore, the research focused on understanding the causal factors of the long lead time within the current supply chain process and its impact on DeCo’s operations, and developing recommendations to achieve an agile supply chain.

1.2 Motivation

Through data analysis and interviews, what we presented in Chapter 4, we found the value added service is the key to DeCo’s operation strategy to keep good relationships with its clients, such as instruments in medical device. The characteristics of instrument supply chain contain high demand variation, out-sourcing contract manufacturing, rigorous regulation, etc. The thesis is intended to determine how data and process capability measures can be leveraged to optimize supply and demand processes, and execution.

The research looks for opportunities to reduce total working order lead time, achieve a reduction in working inventory, and increase the current DeCo service level. At the same time,
it is also valuable to improve supplier delivery performance for a long-term sustainable
development through building up a better relationships between DeCo internal collaborations
between DeCo and its distributor and clients, between DeCo and its suppliers through improve
its instrument chain agility.

1.3 DeCo and its Supply Chain

Introduction of DeCo

DeCo is a franchise of orthopedic and neurosurgery companies. It offers the world’s most
comprehensive portfolio of orthopedic and neuro products and services for joint reconstruction,
trauma, spine, sports medicine, neuro, cranio-maxillofacial, power tools and biomaterials. About
half of DeCo revenues are generated in the United States, with most of the remainder
concentrated in Europe, but with growing sales in many Asian, African, Middle Eastern, and Latin
American countries. In this thesis, we were working with two main divisions of DeCo: joint
reconstruction and spine. DeCo’s joint reconstruction division is one of the largest orthopedics
companies in the world, with leading solutions for hip, knee and shoulder replacement. DeCo’s
spine division offers one of the world’s most diverse portfolios of spinal-care solutions for both
traditional and minimally invasive spine surgery.

DeCo provides two categories of products to the hospitals, the implant to earn profits and
the instruments to add value. In order to build up good relationship with their customers, DeCo
delivers free instrument kits and replenishes the new instrument once the previous one is broken.
The implant supply chain is simple and DeCo does well because every process can be managed
and tracked. The instrument supply chain has a more complex structure and is not completely
controlled by DeCo. For example, the current instrument supply chain have long lead time and low service level problems. Therefore, our sponsor, DeCo asked for us to help them develop an agile supply chain for its instrument supply chain. Those two supply chain within DeCo will be described in Chapter 4.

Supply Chain Strategy of DeCo

Through interviews, we observed the current instrument supply chain has no obvious deployment and execution strategy but follows the demands delivered from distributors and hospitals. Therefore, these behaviors explain the poor performance and high operation costs showed in Chapter 4. In order to improve it, DeCo started this project to find out problems of the current supply chain and optimize the whole chain agility.

1.4 Scope of Research

The aim of our research is to increase the agility of DeCo’s instrument supply chain. We divided the current process into four main phases to seek out the root causes of the long lead time and inefficient response to customers under investigation. There are four steps in DeCo’s instrument supply chain. They are demand stage, planning stage, manufacturing stage, and inventory and delivery stage (see Figure 1 shows). We stated the problems and gaps between the current operations and ideal one, through studying DeCo’s operation strategy, its organization structure and process, its supplier’s manufacturing process, and the communication channels. The communication channels include ones between DeCo’s internal supply chain staffs, between DeCo and its suppliers, and between DeCo and its distributors. By doing so, we made
recommendations to improve DeCo’s supply chain agility based on our data analysis and process investigations.

In this thesis, we focused our attention on the spine and joint reconstruction business units because their important roles to the DeCo, and the availability of the information. Those information includes the historical data and interview opportunities reaching out both the internal personnel and external suppliers.

1.5 Structure

This thesis is organized as follows: Chapter 2 discusses the existing body of literature on the topics of supply chain agility and lean manufacturing management. Chapter 3 outlines the methodology we used and describes the data. Chapter 4 provides a study of DeCo’s two supply chains, its product life cycle, and its suppliers manufacturing process. In addition, we studied the challenges by eight agility attributes. Chapter 5 offers the recommendations that can be drawn from our analysis and the direction for further study. Chapter 6 provides conclusions.
2 Literature Review

There is abundant literature that deal with agility, but there is no consensus on what makes a supply chain agile nor an approved way of measuring agility. In this literature review, we bring forward few of the more notable studies of agility, including a discussion on the definition of agility and identification of approaches of designing and measuring an agile supply chain.

The literature review is structured as follows: the first section provides the reference definition of agility. The second section describes the existing measurement methods of supply chain agility. The third section suggests other considerations.

2.1 Definition of Agility

To understand supply chain agility, clarification of the meaning of agility is needed, as a multi-disciplinary concept and involves diverse aspects of an organization (Swafford et al., 2006). Supply chain management researchers claim agility is an attribute closely related to the effectiveness of strategic supply chain management (Ketchen & Hult, 2007; Lee, 2004).

Swafford, et al., (2006) view supply chain agility as an externally focused capability that is derived from flexibilities in the supply chain processes, which are viewed as internally focused competencies.

Christopher and Towill (2000) and Fisher (1997) define quality, cost, and lead time as attributes of agile supply chain with service level as the gauge of that agility. Christopher, et al., (2000) also acknowledges that, to be truly agile, a supply chain must be capable of reading and responding to real demand. While many articles deal with agility, there is no consensus on the
definition. As a result, only a few articles discuss possible measures of agility. In section 4 we study the literature of agility metrics.

2.2 Agility Measurement

The literature dealing with the measurement of agility is limited because the lack of consensus on the definition of agility. A few articles recommend cost, time, robustness, and scope as important attributes of agility (Quinn, Causey, Merat, Sargent, Barendt, Newman, Velasco, Podgurski, Jo, Sterling, & Kim, 1997). Kumar and Motwami (1995) suggest a formula based on the weighted sum of the firm’s performance on each element of a matrix, taking the same ‘attributes’ approach as Quinn, et al. (1997) mentioned. The matrix represents all combinations of time-segments and agility determinants (material and information flow, state of technology, specialized functions, human resource factors, quality and flexibility).

The lack of validated agility metrics hinders researchers’ attempts to conduct empirical studies to find a relationship between agility and the different variables (Sherehiy, Karwowski & Layer, 2007).

2.3 Inventory

Through the analysis of case studies to identify the best practice to reduce the lead time, Baker and Peter (2007) observe that demand should be supplied from inventory with the exception of new product lines. Inventory is a common risk mitigation strategy against the possibility of random demand variability and transportation delays. Based on these findings, an
exploratory framework was developed by Baker, et al., (2007) to integrate such factors as inventory reduction strategies, risk management and inventory control theory.

Inventory planning to optimize the final inventory level is investigated by Bonney, Ratchev & Moualek (2003) who suggest that the relationship between production and inventory needs to be reviewed to determine whether and how it responds. They suggest that production, and inventory planning and control, should be included.

2.4 Variety production and the challenge of effective variety management

Bonney, et al, (2003) studied high-variety productions such as mass customization. The methodologies they present relate to a computer aided management system. The method was validated in the conditions of best practice for unit and small batch production to deal with numerous variants of both product and process in order to accommodate diverse customer requirements.

Childerhouse and Towill (2004) studied reducing supply chain uncertainty in Europe. Although in our research we focused on the US, as we introduced at sub section 1.3.1, their supply chain audit methodology and the uncertainty reduction principle is transferable. Their research is validated by establishing readily assimilated "best practice" guidelines via the study of "exemplar" operating characteristics.

Aronsson, Håkan, Abrahamsson, Mats Spens and Karen (2011) explored the divergences and commitments between the lean, agile, resilient and green paradigms while investigating the effect of paradigms' practices within supply chain attributes. The synergies between paradigms
are related to "information frequency" and "integration level" increasing as well as reduction of
"production lead time" and "transportation lead time".

2.5 The impact on the internal operations

Mikati (2010) examined the impact on manufacturing companies of reducing lead time. It not only can increase the companies’ efficiency and effectiveness, but also make them more responsive, committed, and pioneering by bringing the new products to market quicker than their competitors. Similarly, Treville, Suzanne, Shapiro, and Hameri (2004) used a framework to prove that it is better for parties in a supply chain to focus first on lead time reduction in order to improve demand chain performance.

Danese (2011) focused on collaborative planning initiatives adopted to support demand and supply planning in supply networks. His paper examined the specific contextual conditions, i.e., goals of the collaboration, demand elasticity, product diversity and supply network spatial complexity, which can affect the level of service and lead-time reduction.

2.6 Other Considerations

Supply chain responsiveness is associated with enhanced firm performance (Wu, Yeniyurt, Kim & Cavusgil, 2006). This review of literature on supply chain agility found numerous articles dedicated to this relatively new concept. In these articles, the concept of agility was noted as a means for handling change, increasing customer responsiveness, and mastering market turbulence. Wu, et al., (2006) also found that the agility was regarded as a necessary element for improving firm competitiveness in a volatile environment.
This literature suggests that much can be achieved by focusing the effort on improving the agility of a firm’s supply chain. Potential improvements can be gained by evaluating the firm’s current supply base (segmentation and long term relationships) and product portfolio, all while aiming to improve variables linked with agility, namely inventory levels and cost, level of service and lead times. In this project, we apply the ideas from a rich body of knowledge to analyze and propose changes to increase the agility of a medical devices supply chain.
3 Data and Methodology

As discussed in the literature review section, there is no agreed way of measuring agility. In our study we used two of the five dimensions of agility suggested by Gilgor, Holcomb and Stank, (2013). Those five dimensions include alertness, accessibility, decisiveness, swiftness, and flexibility. We found that accessibility and flexibility are most relevant to DeCo’s instrument supply chain. In this chapter, we layout the framework we used to evaluate DeCo’s agility.

The first section of the research is dedicated to gain understanding of DeCo’s instruments supply chain. Specifically, we were interested in to learn about ordering processes, inventory management practices, and distributors and suppliers strategies.

In the second part, we identify and analyze the key attributes of agility which were discussed in the literature review and that came up during the first step as being more relevant to DeCo’s instruments supply chain.

In part three of our research, we pointed out to current practices that, based on our analysis, have a negative impact on the ability of the company to respond quickly and efficiently to market demand.

In the last and fourth section we recommend on step that in light of the analysis, interviews, and literature, would improve DeCo’s agility.

3.1 Build Understanding of the Current Supply Chain

The capture phase of our research consisted of data collection by means of series of interviews and data files analysis.
The first part of the research was undertaken by a round of semi-structured interviews with demand planners and supplier relationship employees to gain understanding of the current practices as they relate to forecasting, inventory management, and suppliers and distributors management. During the interviews, we were particularly interested in understanding how information and material flow through the chain. Special attention was given to evaluating the five dimensions of agility as suggested by Gilgor, et al., 2013: alertness, accessibility, decisiveness, swiftness, and flexibility. These dimensions were the platform at which we mapped the current practices and isolate a list of attributes for our analysis.

3.2 Selection and Analysis of Attributes to Focus in our Research

To build a platform for our analysis, we selected attributes of agility that, based on the first stage of interviews, were observed as relevant to DeCo’s instruments supply chain.

Key attributes that were selected are: supply chain visibility, forecast accuracy, distribution channel management, supplier’s manufacturing flexibility, inventory lead time; information flow, and level of service.

3.3 Analysis of interviews and data files

Analysis of Interview

Through a second round of interviews and analysis of data files, we examined the performance of the company as it relates on the identified attributes.
Interviews with DeCo’s staff were conducted to further our understanding of DeCo’s practices. In this round of interviews, we were interested in looking for barriers in information flows, channels of material flows, and the extent knowledge is shared across the supply chain.

Supplier interviews were conducted during a visit at a supplier production facility. The VP of Operation and the CEO were interviewed.

Analysis of Data Files

Data files were analyzed to validate and quantify findings from the interviews. We evaluated DeCo’s forecasting performance, reviewed the types of ordering strategies currently exercised, calculated the inventory levels at warehouses, and examined the backorders to customers and the lead time from suppliers.

Factors that were calculated from data files are:

- **Inventory** – Inventory levels and cost calculated.

- **Demand** – a 12-month actual orders from the end user was collected. Average demand was calculated as well as variability of demand.

- **Lead time** – reported lead time was used in our analysis. In the absence of documented inbound lead time, we used the lead time in the files and verbally validated those numbers with our sponsor company’s staff and the supplier’s.

- **Forecast accuracy** – MAPE for the last 12 months was calculated.
3.4 Identification of Pitfalls in the Current Process – What Hinders Agility?

Borrowing from Herera, Tzurb and Yücesanc (2002) observations that effective and agile supply chains combine range of approaches from operational flexibility, channel alignment, and information deployment, we broke this section into three categories: information barriers, operational inflexibilities, and general supply chain misalignments. For each category we point out pitfalls in current practices that prevent DeCo from having an agile instruments supply chain.
4 Results and Analysis

Based on the methodology introduced in section 3, we present our results in this chapter. First, we layout DeCo’s instrument supply chain. Then, we analyze and evaluate each agility attribute, which hinder the supply chain agility, through the interview findings and results of data analysis. Next, we used the implant supply chain as a benchmark to test or to supplement those attributes. Because we learnt that the implant supply chain runs more effectively than that of instrument during the interview. Finally, we briefed the key findings preparing for the recommendations in Chapter 5.

4.1 Insights from an Instrument Supply Chain

We bolstered our understanding from the data analysis and the interviews with DeCo’s employees and its suppliers. Given by resource provided by DeCo, we interviewed Supplier A and analyzed the data of Supplier B without interview. We realized that the agility indicators such as lead time, inventory level and level of service cannot be optimized by single stage improvement, as mentioned in Chapter 1. All the stages and their agility attributors are complemented each other.

The internal interview includes the semi-structured interviews with over ten DeCo staffs to understand the current practices related to forecasting, inventory management, and suppliers and distributors management. We interviewed internal employees with the questions presented in the Appendix A in both Spine and Join Reconnection division. A list of people DeCo provided include demand planners, senior supply & planning analyst, external operation supervisor,
Sourcing & purchasing manager, supplier relationship manager, demand manager, designer, and supply chain team member.

The external interviews was conducted during a visit in a supplier production facility — a semi-structured interview and a site inspection were done with supplier’s senior VP of Operation and the CEO. The interview questions are summarized, as Appendix B presents.

4.1.1 Current Instrument Supply Chain Management

We draw the current supply chain presenting the real working flow and the key entities within this supply chain as Figure 1 showed. As mentioned in Chapter 1, instrument supply chain involves four steps.

![Figure 1 – DeCo’s instrument supply chain](image-url)
**Demand Stage:** Instruments’ demands come from hospitals. There are two distribution channels for DeCo’s products sales, hospitals and distributors. The demands that come from hospitals directly account for less than 10% of the total demand, according to the DeCo’s demand manager. The remaining 90% of the demands are transferred to DeCo by distributors.

Hospitals drive the demands for the instruments through two needs: new instrument set deployments and replenishments. First, new instrument sets are required either by existing customers to expand their capacity for implant surgeries, or by new customers to add additional platforms to their offerings. Second, replenishments are ordered to replenish the loss or to replace the damage due to occasionally wear out or break. Distributors manage the demands and order new sets or replenishments demands though DeCo’s sales and customer service team. When distributors receive the instrument kits, they keep the kits and borrow them to the hospitals when they order for surgery. There are few hospitals that are keeping instruments in their storage due to high number of implant transplants.

**Planning Stage:** DeCo’s supply managers and planners develop strategies to forecast the demands and manage resources for timely product delivery. DeCo delivers two kinds of purchasing requests to its suppliers for manufacturing. The first one is the Discrete Purchase Order (PO), the PO created for low volume without annual planning, such as uncertain demand SKUs, and customized SKUs.

Another purchasing method is the Vendor Management Inventory (VMI) Order. VMI is a process through which the suppliers collaborate with the DeCo to manage the flow of instruments into DeCo’s system. The suppliers and the customer jointly agree the desired stock levels that need to be maintained in the DeCo’s warehouse. DeCo’s inventory data is sent on a
regular basis to the suppliers who then use that information to plan replenishments. Based on interviews made with DeCo's planner, instrument under VMI account for 10% code of products and 70% value of total SKUs.

**Manufacturing Stage:** DeCo manages the suppliers to schedule manufacturing activities necessary for production, testing, packaging and preparation for delivery of goods or services to DeCo's distribution centers. Suppliers produce the instruments when they receive the orders.

**Inventory and delivery stage:** DeCo's distribution centers do kits assemble, manage inventory and choose their carriers to deliver instruments to distributors. DeCo's planners manage the monthly inventory level to leverage the backorder and the inventory level, as well as to leverage the small volume SKU quantity and inventory cost.

After analysis of each stage, We summarized the lead time percentage consumed in each stage, as Table 1 shows.

<table>
<thead>
<tr>
<th>Stage Name</th>
<th>Lead Time %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Stage</td>
<td>10%</td>
</tr>
<tr>
<td>Planning Stage</td>
<td>10%</td>
</tr>
<tr>
<td>Manufacturing Stage</td>
<td>70%</td>
</tr>
<tr>
<td>Inventory and Delivery Stage</td>
<td>10%</td>
</tr>
</tbody>
</table>

Therefore, a large focus of the interviews is on identifying approaches to effectively managing external suppliers' manufacturing capacity and responsiveness. Because we realized this process step takes majority of time in total instrument supply chain long lead time, which has a large influence, and it is easier to be controlled by DeCo. In the next two sub-section, 4.1.2
and 4.1.3, we studied DeCo’s instrument product lifecycle, supplier manufacturing process, and DeCo’s internal and external communication channels.

4.1.2 Findings from DeCo’s Supplier A

After the interviews with the internal staff, we surveyed and organized a meeting with the Supplier A to find the efficiency and quick response driver from the suppliers’ perspectives. To help us understand the supplier side, DeCo’s supply chain team recommended we spare time with Supplier A, a contracting manufacturer. This sub-section analyzes the interview results collected by four aspects.

- Overall Supplier Background and history
- Supplier A’s company background
- Product life cycle and manufacturing system in Supplier A
- External contract manufacturing operations

Overall Supplier Background and History

The DeCo Supply Chain currently has more than ten tier-one suppliers working on its implant and instrument manufacturing. Decades before, the implants was wholly in-house manufacturing. DeCo had determined that its core competency lay in the design and manufacturing of Implants. For this reason, and due to the economies of scale associated with manufacturing of instruments, DeCo elected to outsource the manufacturing of the majority of instruments to third party suppliers.

Supplier A’s Company Background
The DeCo Supply Chain is currently carrying $12 Million of Supplier A’s products. DeCo’s product revenue share accounts for 30% – 45% of Supplier A’s total capacity. It manufactures over 200 implants and 1000 instruments of Spine and Joint Connection products. Within them, there are 1.5 million for implant SKUs and 10.5 million for instrument SKUs, some of them are customized, which manually are made in a customized cell, which described in 4.1.3.

There is no dedicated product line for DeCo at the supplier’s production floor. Even though the capacity is not enough, Supplier A has not outsourced any step of the work to a secondary supplier yet. That because It is impossible to outsource any medical device products due to their stick process. Food and Drug Administration (FDA) and DeCo manages the manufacturing process and material of each SKU.

Supplier A chooses the make-to-order supply chain to mitigate the financial risks. That means, it starts the production only upon receiving the orders. The difference between the non-VMI and VMI SKUs is that VMI SKUs has an annual volume commitment and Supplier A receives a monthly report from DeCo instead of random ordering. Taking advantage of economy of scale, Supplier A schedules SKU’s manufacturing based on the historical data and their experience, leveraging its capacity, resources, and inventory cost.

4.1.3 Product Life Cycle and Manufacturing System in Supplier A

Two characteristics of the instruments SKU life cycle are defined, as Figure 2. The instrument’s life cycle is short and its demand is never stop. The supplier told us that all the SKU it manufactured might be ordered by clients, even though those SKUs have been replaced by its new generation. We call those old version SKU, or non-mass production SKU as retired SKU.
There are three phases of each SKU's life cycle, from being designed as new products to being replaced and stopped mass manufacturing, as Figure 2 shows.

Figure 2 – Products life cycle and manufacturing cell

We connected the life cycle and manufacturing working cell to explain the operation process. The manufacturing working cell means the dedicated clusters of machines or manufacturing processes in supplier's factory.

**New Development Phase:** All the samples of new development products before mass production are manufactured in the Pilot Cell. The machines in the pilot cell has capability to manufacture all the instruments.

**Processing Phase:** All the new products and replenishment products are mass manufactured in Production Cell, which accounts for the majority resource of the factory.
Retired Phase: All the retired SKUs, as well as low volume SKUs used production cell for manufacturing. The difference between the products in processing phase and retired phase is the scheduling order. The product in processing phase can be scheduled as the priority to be manufactured.

Apart from the pilot cell and production cell, customized production cell is used for customized products manufacturing to provide value added services or to meet clients’ specific requirements. The machines in this cell are manually operated by experienced engineers.

External Contract Manufacturing Operations

Over the years, Supplier A has developed an effective manufacturing process for the replenishment products. But for the new development products, Supplier A meets challenges hence the process needs to be optimized. In general, the manufacturer spends 80% in replenished products and 10% time and resource in new product development. The other 10% in the customized requirements. Here we mainly discuss the manufacturing process of the replenished and new development production.

Replenishment Production

There are 80% DeCo’s activities are replenishment products manufacturing. We split and draw its manufacture process as Figure 3 to help us understand how it works and how long the lead time of each process. This process is used for both instrument and implant manufacturing. For each instrument and implant, they are assembled by components. Each component has its unique manufacturing process. Assembling works are manually do till all components have been produced.
For each process, we observed:

**Order Entry:** For VMI products, DeCo shared Master Production Scheduling (MPS) system report with Supplier A, a lively database of DeCo’s weekly planning. Supplier A produces the latest weekly order reports and learns about the future potential orders by the plan. It makes decision whether produces additional volume to avoid urgent requests. Based on Supplier A’s experience, the accuracy is high in first two months of DeCo’s MPS report. For non-VMI products, Supplier A arranges manufacturing schedule until the order entry.

It takes one day to one week for scheduling each component in Supplier A’s Enterprise Resource Planning (ERP) system.
Manufacture scheduling: The majority time of the scheduling process spends on the capacity management. More than 70% of lead time wasted in the queue. All manufacturing behavior follow the stick schedule table.

Material Purchasing: The raw materials of implant and instruments shared almost the same suppliers’ resource. There is 90% raw materials can be ordered and delivered within one week and the remaining 10% need be ordered six months before. Ten percent of the raw materials are stocked in Supplier A’s warehouse, which can be used right away. The lead time of others stocked in raw material supplier’s warehouse takes average one week.

Set up: Each component has its unique machine setup process and average setup lead time is 8 hours. There is no mix setup for different components. We learnt from Supplier A that it can shorten the setup time from eight hours to three hours if the next component has the similar manufacturing process and set-up tooling is same.

The sequence of operation is strictly follow DeCo’s approved process. Even there is new technology and new machine designed for efficiency, the components must follow the approved process unless DeCo approves the new one.

Production: The manufacturing process can be finished within 10 minutes.

Assembling: Both the implant and instrument SKUs can be assembled until all their components produced.

Packaging, Releasing and Shipping: These three processes take 1 day to 5 days in total.

In summary, the long lead time wasted in three process. Each instrument or implant SKU wastes time in the queue of being manufactured, of being set up, and of waiting for other
components to be assembled together. Implant productions have one to three components and instruments have average 10 components.

**New Product Development**

Ten percent DeCo’s manufacturing activities are delegated for new development products, which account for 10% its revenue as well.

Manufacturing process starts from receiving the new design introduction, or proposal. Supplier A’s engineers cannot do sample manufacturing until DeCo approves the design proposal. Figure 4 presents the process started from new design to full production.

![Figure 4- Manufacture process in new development products](image)

We observed DeCo is not involved early in the process to help suppliers’ engineers to develop design, and to identify the problem in the mechanical way. The communication issue delayed the new product launch time. Here is an example shows the current problem in new development products manufacture. In May of 2014, DeCo needed 80,000 pieces of new product G in August. DeCo shifted design to Supplier A but did not engage supplier’s designers and engineers to work on the sample manufacturing. Supplier A’s engineers did pre-production review, which involving the specification check, functionality check, raw material specification, order review and testing sample. But it took Supplier A’s another six months to revise the sample back and forth since the design flaw and quality problems.
Another challenge is the limited resource of machines and personnel. Eighty percent of engineer resource has already been spent on new product development and launch a product. Therefore, resource is limited for other manufacturing process or any optimization projects.

4.2 DeCo’s Internal Structure and Communication Channel Analysis

The aim of drawing the organization structure of procurement team at DeCo is to understand how DeCo’s teams work with suppliers and how internal team cooperate together. We can optimize the current process and mitigate the risks.

First of all, we draw an organization chart of Procurement department to help us to know how many roles facing to suppliers at DeCo. There are three functions, planning & system, engineering & technology, and Purchasing, are coexisted in Procurement team.

Planning & System Team: this team works on the forecasting, supply planning and ordering. They worked with suppliers and DeCo’s marketing & sales team together to learn about the demands.

Engineering & Technology: this team mainly focus on the technical supports to the purchasing people and external supplier. They work on quality control and new products development as well.

Purchasing: this team mainly purchase the raw materials and outsourced instruments, as well as do supplier management.

The Figure 5 is the current procurement team structure.
Figure 5– DeCo’s Procurement team organization chart

Though interviews, we learnt DeCo’s planner used ERP system to manage the daily operations. For VMI products, DeCo additionally uses the Master Production Scheduling (MPS) system, which concentrates planning on the parts or products that have the great influence on company profits or which dominate the entire production process by taking critical resources. The DeCo’s instruments have been grouped by VMI and non-VMI products code. Figure 6 shows the current internal information flow.
The current VMI goods account for 50% of total products and are viewed by week. We found challenges and long lead time factors in these two different order management practices.

**Discrete PO:** there is no contract using for managing the goods delivery time. It is hard to regulate the lead time. Supplier A aligns the lead time with DeCo’s supplier manager by each order based on both schedule leverage. Another challenge is hard to capture the lead time due to the manual operation. We observed that some planner or purchaser copied the previous order with similar items in system to shorten order creation time. However, the lead time was calculated by the previous order creation date, instead of the real order date.

**VMI Ordering:** DeCo delivers the annual blanket Purchase Order to order VMI goods due to its frequent request and high volume. In current case, all the VMI codes are defined by DeCo’s
planners. DeCo's planner defined the top 10% volume SKUs as VMI goods based on historical data. DeCo's planner uses MPS system to manage the schedule.

Aiming to understand how they communicate with their suppliers, we also studied DeCo's supplier facing team project. Prior to 2013, the traditional communication structure was inefficient. Each supplier talked to different DeCo's role, within three function team mentioned above. There was no co-ordination, no relationship structure, nor strategy development with each other. The situation was similar as the unorganized structure, which before the Supplier Face Team Project showed in Figure 7. Yet, both sides were expected by the other to be all-round experts and enable to solve the problems. Therefore, the expertise on both sides was underutilized since the information was translated along the chain from expert to non-expert to non-expert to expert. Those inefficient behavior and contact wasted time. After the project, DeCo procurement team redesigned a four-team people supplier facing team for each group of suppliers.

![Before the Supplier Face Team Project](image1)

![After the Supplier Face Team Project](image2)

**Figure 7: Supplier face team project**
Each supplier facing team comprise four roles. They are supplier manager, planner, and engineer and quality controller from technical operation team. When suppliers meets problem, they approach their delegated supplier managers and connect specific people in their supplier facing team. Based on internal feedbacks, this project lead to a structured and better managed communication and relationship through supplier managers and multi-functional teams who may operate across geographies and/or be global. Lots of know how within the teams enable both teams to work strategically on joint projects to generate added value.

We analyzed and drew the picture of the instrument supply chain working flow, supplier manufacturing process, product lifecycle, and DeCo’s internal communication channel. These efforts aim to find the gaps in the operation and to work out solutions to achieve instrument supply chain agility in the medical device industry.

4.3 Agility Attribute Evaluation

We qualitatively and quantitatively analyzed the current characteristics of the instrument supply chain to identify reasons why DeCo has no capability to respond to the demand quickly. In this section, we evaluated eight key agility attributes in order to find the gaps and problems to be optimized in the next chapter, Recommendations and Conclusion. The agility attribute include distribution channel management, forecasting, supplier manufacturing flexibility, supply chain visibility, product lifecycle management inventory, level of service, and lead time. The order of those attributes follows the four steps of the instrument supply chain.

4.3.1 Distribution Channel Management
Through the data analysis, we observed the demand for instrument replenishment has four main characteristics:

- Small-volume demand
- Orders uncertainty
- No Communications between Distributors
- Invisible Inventory Management by Distributors’ side

**Small-volume demand**

To explore the demand distribution, we looked at data for 12 months of actual demand of the entire instrument base, as Table 3 presents. In total, more than 81% monthly demand of SKU are smaller than 10 units. Generally, we observed a declining number of SKUs as demand decreases, as Figure 8 shows.

**Table 2 - The entire instruments base monthly demand**

<table>
<thead>
<tr>
<th>Monthly Demand</th>
<th>SKUs</th>
<th>Share %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5</td>
<td>6,608</td>
<td>73%</td>
</tr>
<tr>
<td>5-10</td>
<td>722</td>
<td>8%</td>
</tr>
<tr>
<td>10-20</td>
<td>699</td>
<td>8%</td>
</tr>
<tr>
<td>20-50</td>
<td>582</td>
<td>6%</td>
</tr>
<tr>
<td>50-100</td>
<td>224</td>
<td>2%</td>
</tr>
<tr>
<td>100-200</td>
<td>194</td>
<td>2%</td>
</tr>
<tr>
<td>200-500</td>
<td>46</td>
<td>1%</td>
</tr>
<tr>
<td>500-1000</td>
<td>18</td>
<td>0%</td>
</tr>
<tr>
<td>1000-2000</td>
<td>4</td>
<td>0%</td>
</tr>
</tbody>
</table>
We found, as Table 2 showed, Supplier B follows the same demand distribution that 60% of the instruments procured from Supplier B have less than 5 units in monthly demand. Almost 80% instruments procured by Supplier B have a demand smaller than 20 unit a month. For further discussion, we identified slow moving instrument as having less than 5 units in demand per month, and fast moving for instruments between 5-100 units in monthly demand.

Table 3 – Monthly demand delivered to Supplier B

<table>
<thead>
<tr>
<th>Monthly Demand</th>
<th>SKUs –Supplier B</th>
<th>Share of Total SKUs</th>
<th>VMI Order</th>
<th>VMI Share of Total SKUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-200</td>
<td>35</td>
<td>5%</td>
<td>2</td>
<td>6%</td>
</tr>
<tr>
<td>50-100</td>
<td>24</td>
<td>4%</td>
<td>10</td>
<td>42%</td>
</tr>
<tr>
<td>20-50</td>
<td>93</td>
<td>14%</td>
<td>56</td>
<td>60%</td>
</tr>
<tr>
<td>10-20</td>
<td>74</td>
<td>11%</td>
<td>66</td>
<td>89%</td>
</tr>
<tr>
<td>5-10</td>
<td>52</td>
<td>8%</td>
<td>40</td>
<td>77%</td>
</tr>
<tr>
<td>0-5</td>
<td>400</td>
<td>59%</td>
<td>311</td>
<td>78%</td>
</tr>
<tr>
<td>Total</td>
<td>678</td>
<td>100%</td>
<td>485</td>
<td>72%</td>
</tr>
</tbody>
</table>

We also looked at the type of orders for the instruments to find a pattern. As shown in Table 3, seventy-two percent of Supplier B’s instruments are under a VMI order. For slow moving SKUs, it accounts for 78% of the total Supplier B’s Instruments are under VMI order.
condition. That means the VMI conditions are not enforced. The share of instruments under VMI order is smaller for the faster moving products, the opposite of what is expected due to the purpose of VMI — outsourcing the order process for the frequently ordered instruments to the supplier to simplify the planner’s job.

**Distributors Ordering Uncertainty**

We looked at the distributors’ ordering pattern to extrapolate what the orders look like, due to the lack of purchase order data from DeCo to suppliers. We examined instruments procured from two designated suppliers and found that orders from distributors do not follow a predictable pattern but rather flow in a volatile manner.

One reason for the volatility is DeCo’s practices of blocking orders for financial reasons. This practice was applied in Q4 (Oct.-Dec.) of 2013 and 2014. Figures 9 shows the disruption to the order flow caused due to that practice in the extremely high volume of orders in January 2014. The “No order” policy happened also in June of 2014.

![Ordering Pattern from Distributor A](image)
![Ordering Pattern from Distributor B](image)

**Figure 9 — Ordering pattern from distributors**
By comparing ordering patterns from distribution A and B, we can assumed the orders from distributors to DeCo were based on forecast or other drivers, such as a quota, or a sudden freeze on orders, etc.

**Communications between Distributors**

By interviewing the demand manager, we learned that DeCo’s 36 distributors have no communication channel with each other. Moreover, DeCo has no database and communication platform to help distributors share their information, such as inventory on hand. For example, Hospital A orders a small-volume order with two SKUONE and requests a short lead time of distributor A. Distributor A asks for DeCo’s sales team when it needs an urgent replenishment due to having no stock in its warehouse. Then, DeCo helps distributor A to check the inventory of other distributors by phone or email. Once DeCo finds the SKUONE, it asks distributor B to deliver it to A. At the same time, DeCo delivers the SKUONE order to the supplier with its minimum quantity guarantee. By doing this case study, we found that the current information barrier hurts the flexibility of moving instruments between distributors.

**Inventory Management by Distributors Side**

Distributors have implant inventory but no instrument stock in their warehouse, as the DeCo’s demand manager said. All current inventory of instrument is managed by DeCo’s distribution centers. As mentioned above, we found the current inventory management of distributors is invisible. The data and information of inventory level, and inventory drivers such as Economic order quantity (EOQ) and Safety stocks cannot be tracked.
4.3.2 Forecast

When we interviewed Supplier A, the interviewer gave DeCo’s forecasting planner a positive feedback. The percentage of forecasting accuracy scoring at 3.5 and above is higher than other clients, at a zero to five score scale. DeCo did best forecasting and the inaccuracy is normal in medical device industry. Therefore, a better forecasting will help DeCo to be more competitive if DeCo can solve the current problems.

The forecasting drivers are historical data and distributors’ budget plans. Yet, we have no visible database can track the historical data and the current operation increase the data error.

First, we have no visible database or tools can be tracked. There is no historical data of new instrument products, which accounts for almost 50% of the budget, as Table 4. The base instrument products are easier to forecast but no enough history.

<table>
<thead>
<tr>
<th>2015 Instruments Budget</th>
<th>Spend</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broken Repair</td>
<td>$8M</td>
<td>15%</td>
</tr>
<tr>
<td>NPI</td>
<td>$25.2M</td>
<td>47%</td>
</tr>
<tr>
<td>Full Set Orders</td>
<td>$10M</td>
<td>19%</td>
</tr>
<tr>
<td>Unforeseen Direct Expense</td>
<td>$0.5M</td>
<td>1%</td>
</tr>
<tr>
<td>Conversion</td>
<td>$10M</td>
<td>19%</td>
</tr>
<tr>
<td>Total</td>
<td>$53.7M</td>
<td>100%</td>
</tr>
</tbody>
</table>

For legacy instruments, which is 77% of total SKUs number, it is hard to predict. High demand variability cannot be avoid since the unpredictable demands while there are over 12,000 SKUs at DeCo.

Second, the current operations by distributors increases the difficulty to manage the data collection due to instrument kits storage by either hospital or distributor. Large hospitals that frequently use instrument kits can keep them, while other small hospitals must return kits back
after finishing usage. For those instrument kits managed by distributors, they need to use labor to check the instrument states. For the kits left in hospital, distributors have no database and system to track those instant requirements. When studying the data, we observed the Mean Absolute Percentage Error (MAPE) over 100% in many of the SKUs, which stand deviation is 132% and mean is 60%, see Figure 10 shows. We assume that double calculate or mistakes due to manual error enhances the inaccuracy.

![MAPE result of SKU forecasting](image)

**Figure 10 – MAPE result of SKU forecasting**

4.3.3 Supplier Manufacturing Flexibility

The lead time in manufacturing process accounts for 70% and above of the total consumed time. There are four key reasons leading to current situation.

First, the majority waiting time is spent for components’ scheduling and setting up for each components. One instrument has average 10 components. For each operation, it takes 8 hours for single part set-up and 10 minutes for production finish. Meanwhile, all those 10 components cannot be lined up due to the capacity, which means they have to wait to be
manufactured till they have be scheduled. Another situation is very small replenishment volume for old version of SKU can be ordered. All of these increase the capacity scheduling difficulty. The 70% of instrument’s lead time is in queue, as Figure 3 shows.

For small batches or sampling products, Supplier A makes those products and moves to other ones, instead of waiting for the quality assessment. Supplier A mentioned it is too costly to wait and the products have 60% acceptance rate. Supplier B takes the risk to re-setup and re-reproduce them.

Second, the set up binding is not allowed in machine. One component has one setup process and we cannot mix the machine and process. The manufacture process cannot be changed unless the SCR is accepted by DeCo, even though the better technology can lead to efficiency. The only way to make it more efficient is to find other components which has the same process to line them up, which means knowing the production constraints can shorten the setup time.

4.3.4 Inventory

We studied the history data comes from Supplier B. Total inventory value in DeCo warehouse is $250M, which the extrapolation of data from partial inventory data and anecdotally validated in interviews, six times the annual business budget at $40M. This number does not include the inventory in the distributors’ warehouses. Studying those data, we found 65% of the supplier’s SKUs have more than a year worth of inventory, see Figure 11 shows.
When we break down the Weeks of Supply (WOS) view by type of order, we observe that through all the week of supply ranges, the VMI and distinct PO ratio is similar, suggesting that even when an instrument is under VMI, the inventory WOS can rise well above the lead time period, corroboration of an insight from several DeCo employees who indicated that VMI instruments are not managed per order.
This is true not only for week of supply analysis, but also for dollar value of the inventory. We looked at inventory of instruments from a selected Supplier and found that the inventory value of VMI instruments is almost equal to that of instruments under discrete PO.

Table 5 - Value and number of SKUs by two PO types

<table>
<thead>
<tr>
<th>Contract Type</th>
<th>Nov’14</th>
<th>Dec’14</th>
<th>Feb’15</th>
<th>Number of SKUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discrete PO</td>
<td>$17,000,000</td>
<td>$16,600,000</td>
<td>$18,222,292</td>
<td>192</td>
</tr>
<tr>
<td>Vendor Managed</td>
<td>$14,000,000</td>
<td>$14,000,000</td>
<td>$10,063,009</td>
<td>485</td>
</tr>
<tr>
<td>Grand Total</td>
<td>$31,000,000</td>
<td>$30,600,000</td>
<td>$28,285,301</td>
<td>677</td>
</tr>
</tbody>
</table>

For this study, we identified slow moving instrument as having less than 5 units in demand per month, fast moving for instruments between 5-100 units in monthly demand, and very fast for instruments with above 100 units in monthly demand.

When we break down the WOS view by demand frequency, such as slow moving, fast moving. We noticed that the vast majority of the instruments with over 120 weeks of supply are slow movers, as Figure 13 shows, suggesting that DeCo either bought unnecessary units to meet Minimum Order Quantities requirements from suppliers or failed to change inventory (i.e. safety stock) targets when demand changed due to launch of a new series.

Figure 13 - Weeks of supply by SKU demand

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Besides the challenge between the minimum order quantity and inventory, another constrain is the number of the backorders, leading to lagged response to the distributors.

### Table 6 – Backorders by SKU group

<table>
<thead>
<tr>
<th>SKU Group</th>
<th>Total</th>
<th>Months with Back ordered</th>
<th>SKUs with Back ordered</th>
<th>Share of back orders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Fast</td>
<td>261</td>
<td>179</td>
<td>91</td>
<td>35%</td>
</tr>
<tr>
<td>Fast</td>
<td>1,483</td>
<td>940</td>
<td>504</td>
<td>34%</td>
</tr>
<tr>
<td>Slow</td>
<td>3,143</td>
<td>1,384</td>
<td>611</td>
<td>19%</td>
</tr>
<tr>
<td>None in 9 months</td>
<td>3,894</td>
<td>853</td>
<td>329</td>
<td>8%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>8,781</td>
<td>8,781</td>
<td>1,535</td>
<td>17%</td>
</tr>
</tbody>
</table>

From the data analysis in Table 6, 17% of total SKUs were backordered in 2014. Average 35% of SKUs with demand above 5 units/month (fast/very fast movers) were backordered in 2014.

#### 4.3.5 Supply Chain Visibility

As introduced above, there is no visibility on inventory at distributors, on report of forecasting, nor on supplier’s production constraints.

It is also hard to measure DeCo’s agility performance without the control over its VMI orders, or without the receipt of order to capture lead time.

#### 4.3.6 Level of Service

Level of service to distributors is target is 96%, but the actual LOS is currently at 90%, as the interview result from DeCo internal.

DeCo keeps high target of LOS regardless the destination the orders, such as hospitals and distributors.

#### 4.3.7 Product Lifecycle Management
When product moves from base product status to legacy status with the inception of new series, its demand falls as is its criticality in the marketing effort. The change in demand drives the inventory level down and the ordering strategy should be revisited, such as reevaluating the district PO or VMI strategy. From the interviews with DeCo’s personnel, there is no process in place to treat instruments in different stages of their lifecycle differently.

4.3.8 Lead-Time

Lead time numbers are spread out almost uniformly from 20 days to 180, and then with lower occurrences, from 200 to 690 days, as Figure 14 presents.

The reason for the wide distribution of lead times is that in many cases. For example, planners would maintain an open PO from which they keep order instruments. This causes a difficulty in determining the real lead time because lead time is measured from the time the order was opened to the time it was received at DeCo, and if no new PO was opened but rather an existing one was used, the lead time cannot be determined.

![Lead Time Distribution](image)

**Figure 14 – Lead time distribution**
Demand and Lead Time correlation

After excluding all orders with a lead time greater than 300 days, assuming these are part of the ‘open PO’ group, and plotting lead time against demand (units/month), No relationship found between demand and lead time, seen as Figure 15 and 16.

As mentioned above, most instruments have demand of less than five a month. The lead time for these between 20 to 300 days.

![Graph](image)

**Figure 15 – Demand and lead time correlation**

When we plot WOS against demand, we observe that the slow movers WOS ranges from 12 weeks to 165, while the fast movers (>10 units per month) usually do not exceed 70 weeks of supply in inventory – still a very high number considering the over 12 weeks of lead time.
4.4 DeCo’s Supply Chain for implant

During the interviews process in was mentioned multiple times that the implant supply chain is more efficient. For example, the average lead time of implant is controlled within 12 weeks. We studied the implant supply chain and compared it to the instruments’. We continued to study how many process can be transferable to increase instrument supply chain agility.

Within the interviews, we looked at the current implant supply chain process, which is regarded as a marginal profit driver, which saved cost and decreased the lead time. We compared the implant and instrument supply chain in Figure 17.
Figure 17 – Current implant and instrument supply chain

The feedback of the implant supply chain is more positive than that of instrument supply chain. Implant provide high service level. Based on the comparison between both of them, we realized there are mainly five differences.

**Implant supply chain has less variable demand:** Compared with the 3000 SKUs in implants, the instruments have over 12,000 SKUs, including the new product and old product. All the new, processing, and retired SKUs of instrument might be ordered. None of those old products can be ignored even though the requests represent a very small percentage per year. The implant kits are delivered to hospitals directly based on the smoothing demands.

**Implant supply chain has more accurate forecasting:** Implant planning is accurate based on historical data. Instrument historical demand raw data is not replicable. The requests are delivered to DeCo when the original instruments are broken or unusable. In addition, it is hard to forecast at beginning and end of instrument SKU life cycle.
Implant supply chain has less complicated manufacturer’s portfolio: Majority of the implants are produced by DeCo in house, that is to say the process and quality can be controlled. At the same time, more than 75 suppliers working for instruments. Therefore, DeCo can manage the resource based on products’ lifecycle and manufacturing process.

Implant supply chain has lower inventory and shorter lead time: The distributors store and track the implants with real data, yet, they do not keep instruments inventory. Distributors have no visibility to keep safety stock. Distributors have no inventory of DeCo’s instruments. They store implants only. Implant suppliers are easier to be managed due to high order volume and less supplier pools. However, Instrument suppliers are difficult to be managed due to the uncertain orders and small volumes. The suppliers need 12 – 16 weeks for manufacturing.

The main reason is they lack in the capacity for manufacturing by instrument suppliers and 80% instruments are unique and hard to do standard ones. Therefore, suppliers postpone the manufacturing and result in a long lead time.

Implant supply chain has better Supply Chain Visibility: All the data can be tracked by DeCo. Apart from the above attributes, Implant supply chain wins more attention by DeCo since implants selling drive the revenue. All the instruments are provided for free when the distributors order them.

Therefore, implant supply chain is easier to be managed and tracked with its characteristics: smooth demands, accurate forecasting and ordering, centralized suppliers, in-house manufacturing, and traceable inventory kept by DeCo and its distributors.
4.5 Conclusions from Data analysis and interviews – What hinders agility?

We realized the current characteristics of the instrument supply chain: high demand variation, inaccurate forecasting, and decentralized contract manufacturer, long lead time on manufacturing process, high inventory cost, invisible distributor stocks, and rigorous regulation.

Briefly, we summarize the key observations of the analysis process that we see as obstacles to agility: information barriers, operational inflexibilities, and general supply chain misalignments.

4.5.1 Information barriers

Forecast inaccuracy:

The reasons for inaccuracy are as follows:

- Short lifecycle of independent SKU and endless long-tail requirement for retired SKUs.
- 77% of instruments are replenished based on wear and tear and lost instruments which makes it hard to predict.
- New products’ budget accounts for 50% of total instrument budget.

Invisibility and untraceable data: There is no visibility to real demand from end-users but only demand from distributors is captured.

4.5.2 Channel Alignment

Distribution Channel management: First, There is no visibility to distributors’ inventory. Distributors order based on annual budget, not necessarily based on demand – because there is no visibility to distributors inventory, and there is no way to make sure no replenishment of
instruments are not for high safety stocks levels. And there is no utilization of instruments from the different distributors. Second, there is no communication between distributors.

4.5.3 Operational Flexibility

**Supplier Flexibility:** First, The lead time in manufacturing process accounts for 70% and above at the consumed time. The majority waiting time is spent for scheduling and setting up for each components. The set up binding is not allowed in machine. Second, The MOQ is uncertain, adding the difficulty to leverage the backorder and safety stock, as well as the service level and cost.

**Unmanaged Planning and VMI Orders:**

There are five key constrains listed below:

- **Small-volume demand:** Almost 60% of the instruments procured have less than 5 units in monthly demand.

- **Distributors Ordering Uncertainty**

- **Invisible Inventory Management by Distributors side**

- **VMI conditions not enforced.**

- **No process to move Instruments under VMI back to Distinct PO once an instrument demand falls.**

**High level of inventory:** drivers for the excess of inventory are inaccurate forecast, minimum order quantity required by suppliers, lack of transshipment between distributors, lack of visibility across the supply chain, and long lead time.
We also learned from the implant supply chain that efficient distributor management, complicated manufacturer’s portfolio cut down, and inventory management could improve instruments supply chain agility.
5 Recommendations and Conclusion

Based on the interview we conducted, and the data we collected, we recommend the following steps to improve responsiveness while keeping low inventory levels. In general, our recommendations are aimed to constitute a more efficient information and material pipelines between suppliers, DeCo, and distributors. Removing information barriers would lead to reduced lead time, less inventory, and as a result would lead to a better forecasting and responsiveness. Side effect would be improved relationships with suppliers.

Our recommendations are broken up here by the areas of the supply chain which they address: distribution channel, Supply channel, and DeCo’s practices.

5.1 Distribution Channel Strategies

5.1.1 Build a Database of Inventory at Distributors

As discussed above, instruments are given to distributors at no charge, against an annual quota, to facilitate the sales of implants. Once shipped, an instrument is written off the books of DeCo, and is not being tracked for usage. The result is that DeCo doesn’t have visibility to the distributors’ inventory levels and therefore can’t evaluate their inventory management practices. We recommend that DeCo build a database of inventory at the distributors’ warehouse. This will help DeCo monitor instruments, advice distributors on inventory management strategies, and facilitate the implementation of the recommendations that will be discussed later in this chapter.
DeCo can extend access to the database to distributors. Key members of the supply chain, distributors can use this data to share real time demand and inventory information. DeCo could use it to make an informed decisions about ordering and forecast.

Noting that has already been existed for implants, we recommend to extend, if possible, the existing system to instruments as well.

5.1.2 Coordinated Replenishment Between Distributors

We strongly recommend that DeCo, or any company seeking agility, consider viewing distributors’ warehouses as distribution centers of the same network, and use this network to facilitate a rapid flow of goods through the supply chain. Therefore, we recommend that DeCo utilize instruments as needed between distributors.

Moving instruments between distributors as a second source of replenishment would serve two goals. First, this will be an additional source of supply when a demand in distributor A proves to be higher than expected and distributor B has the instrument in his shelf. In this case, distributor B can provide the product much faster than a supplier would. Second, by opening replenishment channel through distributors, DeCo could avoid emergency orders to be sent to suppliers and plan future orders better, making our following recommendation easier to achieve.

The current practices allow for the purchasing of instruments to fulfil a certain order from distributor without considering the availability of these instruments at other distributors’ warehouse. Currently, DeCo would purchase 30 units (to meet minimum order quantities) of an instrument to fulfil an order of one unit to a distributors while this instrument is available in high quantities at another distributors’ warehouse.
Transhipments is a tactical solution to achieve agility and is a common practice in multi-location inventory systems that involves monitored movement of stock between locations at the same echelon level of the supply chain. We can find examples of such mobility in 60 cases examined by Tagaras (1999), where introducing transhipments reduced the total safety stock, reduced the total cost, and increased the fill rate in each of the 60 cases. Tarages also shows that the benefits of inventory movement between warehouses are substantial and increase with each location added to the network.

Forming an information sharing platform by building the database from the previous recommendation and establishing communication channels between distributors, or conversely between DeCo and the distributors, will facilitate that material sharing.

5.1.3 Slow moving instruments managed from and by DeCo

We recommend that all slow movers, mainly legacy instruments, be managed at DeCo’s Distribution Center. No legacy instruments should be held at the distributors’ warehouses. We do not see a justification for keeping these slow moving instruments at 36 independent warehouses. We envision the process to be as follows:

- A demand for a certain slow moving instrument is transmitted from a hospital to a distributor.
- The order would be then directed to DeCo
- DeCo would send it directly to the hospital.
- After using the instrument, the hospital would return it, sanitized, to DeCo.

Pooling inventory into one warehouse would have the following effects:

- Reduced total inventory as a result of the consolidation of 36 safety stocks into one.
• Reduced lead time to customers as the chance that such instruments would need to be ordered from supplier is low when servicing from only one warehouse. Backorders would be reduced as well.

5.2 Suppliers Strategies

DeCo lost knowledge and expertise when they outsourced instruments. In addition, we observed lack of communication between DeCo to their suppliers beyond forecasts and orders (information barrier). Our recommendations aim to leverage on the expertise the suppliers gained during the past years in manufacturing these instruments and suggest number of ways, through understanding the constraints and opportunities of the instruments’ production, to reduce lead time, increase responsiveness, and reduce costs.

5.2.1 Order instruments in products family

DeCo should work with suppliers to establish families of instruments. The objective is to minimize setup time for instruments within the groups. DeCo then should work with suppliers to reduce or eliminate the minimum order quantity requirement. Minimum Order Quantity (MOQ) should be applied at the group level, not at the SKU level. For example, a family of three instruments with each MOQ of 30 units, could be ordered together with a total of 30 units, not 90 per the current terms. This was corroborated during the interviews we conducted with executives of a medium sized supplier. It will be the responsibility of the supplier to send lists of families as they already build families in their production plan in order to reduce setup times.
Products would be considered a families if they are made from the same materials, follow the same production cells, and share similar machine setup. The objective of organizing products in families is to minimize setup times.

The benefit is reduced minimum order quantities, lower inventory due to not ordering in undesired quantities, reduced working capital, and improved forecast accuracy.

5.2.2 Dedicated Production Cells at the Suppliers’ floor

DeCo should work with suppliers that have an important share of their volume with DeCo (Anecdotally, at least 20%) on allocating a production cell at their production floor. Allocation of production cell to DeCo, which can include Joint Reconstruction division, as well as Spine and Head, would provide DeCo with the flexibility of in-house manufacturing, decrease lead time by 50%, and reduce cost per unit by 15%. As noted in the analysis section, most of the lead time is waiting in queue, and the main reason for the long lead time is capacity constraints and competition on capacity with other suppliers’ customers. Dedicated capacity would enable DeCo to prioritize orders and control manufacturing similar to in-house production.

The way to achieve allocation of capacity is by order instruments in uniform volume and commit for a minimum order volume per months to guarantee such allocation is justified. To institute a dedicated production cell at a manufacturer we recommend implementing two approaches:

Smooth flow of orders: Currently, DeCo’s order pattern is unpredictable and changes greatly from month to month which makes it hard for suppliers to plan production. DeCo should work on smoothen orders to suppliers. Implementing smooth ordering policy, regardless on capacity allocation, would allow suppliers, having predictable volume flow from
DeCo, to plan for DeCo’s work while keeping setup time to minimum and therefore reducing cost per unit and lead time.

**Commitment for a certain volume of orders by Dollar amounts:** This commitment would be around 50% to 60% of the currently average monthly order volume.

We confirmed the feasibility of this recommendation in interviews we conducted with a supplier’s executives who also validated the benefits expected by estimating that the lead time would drop from 8-12 weeks to 4-6 weeks and that the cost per unit would be discounted by 15%.

### 5.3 DeCo’s Practices

#### 5.3.1 SKU Proliferation

Major problems associated with product proliferation include higher production, inventory, and holding costs, and increased susceptibility to stockouts. An effective product proliferation reduction program needs to be based on several principles: resisting the temptation of introducing a completely new instruments set with the inception of a new implant series; placing limits on product choice; and implementing effective strategies for product end of life.

This can be achieved in number of ways, for example, DeCo can incentivize instruments designers by the number of existing instruments used in a new series set – the fewer new instruments introduced into the system, the bigger the incentive would be.

DeCo can also launch and effort to rationalize existing SKUs in order to reduce the current number of instruments under the active portfolio. Instruments that are removed during this process from the portfolio, could be offered to distributors and hospitals at a cost.
5.3.2 Better Management of VMI

As mentioned in the previous sections, VMI conditions are not being met as suppliers deliver instruments outside of the minimum or maximum thresholds, sometime to meet their own financial targets. We believe that DeCo would benefit from enforcing the agreed upon inventory levels. Total inventory value will get reduced as well as the corresponding expenses.

5.4 Limitation and Future Research

The recommendations listed above contain limitations and constraints we encountered. Future research for DeCo or companies facing similar situations will meet the similar limitation.

Data Availability and Reliability: First, a major limitation of any empirical approach is the availability of accurate and reliable data. DeCo currently has 3,000 implant SKUs and more than 12,000 instrument SKUs. The number of instruments is constantly increasing due to the new products and existed products upgrade. The upgrades is driven by market needs. How to get accurate and timely information from hundreds and thousands lines of data is challenging to DeCo, and all the medical device manufacturers. During this project, we found the mismatching data of the same SKU from different data resource. Moreover, some data is proved wrong by DeCo due to the operational error. The data is hard to link together and some of data has the contradictions.

Second, the data should be related to the analysis. We observed that DeCo used more than one ERP system to manage its supply chain. Therefore, we received more than ten different data tables but still missing key messages we need for analysis.
Dynamic Supplier Manufacturing Process: Our current study is based on the site inspection on Supplier A and the data of Supplier B. The behavior of the consequence may differ between DeCo’s suppliers, depending on their process and operational strategy. We suggest the future research can interview more suppliers.

Time Horizon Selection and Extension: In this project, we only studied the latest data and some of them only cover three quarters. The short period data cannot present the whole picture of the problems without sensitive analysis and comparison with other company in the medical device industry.

As described above, we cannot get enough data for longer time horizon due to the huge amount of data and different data resource. Another reason is we had constrains to approach all the division and team members. Therefore, the data collection is harder than internal requests. We could not get some data or received them after more than three months request due for some cases. Therefore, we suggest the future project can have the access to the system.
Appendices

Appendix A – DeCo internal interview name list and question list

Name list:

DeCo: Designer, Sourcing manager, Planner, Senior supply & planning analyst, Supervisor, external operation, Planning & purchasing, EO planner working with supplier, supplier relationship manager, Supply chain team, demand manager working with distributor.

Question list for internal DeCo people

- How your instrument supply chain works?
- What’s the organization chart in your supplier interface teams?
- What system DeCo uses to track their supply chain and how they manage orders?
- Is value stream mapping as necessary to define external supply chain capability?
- How you manage the suppliers? How many multifunctional team are involved?
- What’s the supply chain process of implants? How it work?
- What’s your strategy of implant and instrument supply chain?
- Comparing the implant supply chain and instrument one, which one is better and why?
- Could you please share the contract? Is lead time on the contract?
- Have you got the conflict with your suppliers? How you handle it?
- What’s the role of the FDA and governance on instrument supplier management?
Appendix B – Supplier interview name list and question list

Name list:

Supplier A: Chief Executive Officer, Vice President of engineering & sales

Objective:

- Understand the current manufacturing process and order process of DeCo Implants and Instruments.
- Understand what works and what doesn’t with instruments and implants.
- Understand how company SI works with DeCo.

Questions during the on-site visit:

Basic information

1) What is DECO share in the supplier's total capacity?

2) Is DECO has a dedicated line at the supplier production floor?

3) Are you outsourcing any step of the work to a secondary supplier? Is the supplier uses a third party for any step?

4) How frequently DECO contact with you?

Production line and order

5) Do you make to stock or make to order?

6) Are you start production once the order is submitted or do they wait and manage their capacity?

7) Are there expedited orders? Can DECO pay to have orders expedited?

8) What is the shortest time needed for production? How much time for the set up process and what’s the cost on that?
9) Do you segment products? Family, minimum quantity but if only one?

10) Does a smaller order lead to a shorter LT? How can lead times be reduced for low volume products (no, it takes longer time or more expensive cost?)

11) Any unified process for different SKUs?

12) Are materials industry standard or special?

13) Are materials always on hand to make product, or do materials need to be ordered when a PO from DECO comes in?

14) What are the nature of orders from DECO – spikey or smooth?

**Inventory**

15) Does the supplier keep the right inventory level for VMI?

16) How does the supplier manage VMI?

17) What is the working inventory?

18) Does DeCo share any risk with you?
References


David M. Gligor1, Mary C. Holcomb and Theodore P. Stank, (2013) A Multidisciplinary Approach to Supply Chain Agility: Conceptualization and Scale Development


