Improving Service Level through Component Inventory Management

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ABSTRACT

In every company, determining an optimal inventory level balances the desired service level with the costs of holding too much inventory. For the medical device industry, the stakes are high as risks in the supply chain of devices used by hospitals and operating rooms can have a devastating impact. In this capstone, we focus specifically on component inventory sourced from a variety of suppliers that are used for assembly and finished goods production by our sponsoring medical device company. Beyond the typical safety stock formula that incorporates only consumption and lead times and a target service level, we evaluate additional planning levers that impact supplier service level. We interviewed and surveyed suppliers regarding their forecasting, production planning, and internal inventory management practices, and incorporated both qualitative and quantitative elements into our analysis of the key focus areas for improving service levels with our sponsoring company's component suppliers. We discuss key actions that can be taken related to the sponsor's supplier planning portal in the areas of forecasting, frozen period planning, and supplier evaluations that will reduce component service level risk in future planning periods. These actions are likely applicable to any medical devices manufacturer who experiences similar inventory challenges within their component supply chain.

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1. INTRODUCTION

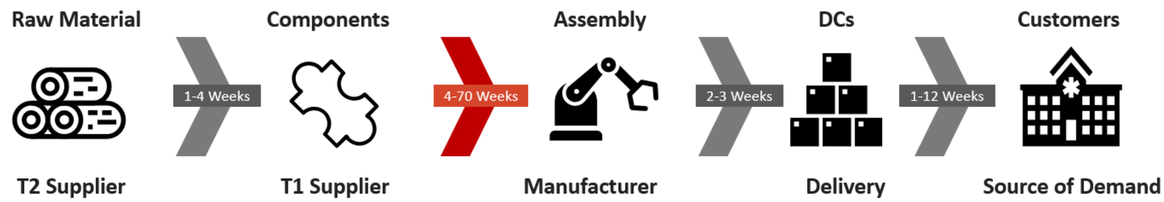
A medical device is defined as any instrument, apparatus, or machine used for medical purposes (World Heath Organization, 2022). The sponsoring company of this capstone is a manufacturer of primarily high-tech instruments used in hospitals in surgery or other operating procedures. The company is one of the largest in the world when measured by market share or revenue (over $5B globally). For medical devices, supply chain functions face unique inventory challenges as demand variability and volatility are often extremely high, while holding excess inventory can be extremely expensive (McKinsey, 2020).

The COVID-19 pandemic and resulting demand spikes for many medical products showed manufacturers how fragile their supply chains were and exposed many areas of risk many were unaware of. Unlike many other products, shortages in medical devices used in surgery or emergency rooms can directly impact patients' lives. Stakeholders across the medical device supply chain need to weigh the significance of stocking out of a potentially life-saving device against the high inventory carrying cost of complex and high-priced devices. In March 2020, Congress and the FDA recognized the criticality of keeping medical devices in stock by including in the CARES Act specific language, giving them increased authority to regulate the industry and protect patients from stockouts (FDA, 2020).

To avoid inventory risks and increase service levels, it is not enough for manufacturers to focus solely on increasing inventory or safety stock levels. Instead, it is critical to increase visibility across the supply chain and understand which other actions can be taken to reduce inventory (supply) risk. For our sponsoring company, existing demand variability and long manufacturing lead times make achieving their desired service level difficult. From an end-to-end supply chain perspective (raw material sourcing through finished good production and delivery to the end customer), the most significant contributor to total lead-time is outsourced (supplier) component inventory, which at the same time depends on other suppliers (as shown in Figure 1). This means that careful component inventory management is critical to achieve the desired service level for the sponsoring company to deliver finished products on-time and in-full to their finished-goods customers.

Figure 1

Typical E2E lead times for sponsoring company



While a blanket increase in stock levels may reduce inventory risk, often other policies can bring greater improvements to service level and delivery performance (van Kampen et al., 2010). For this reason, our recommendations are not limited only to inventory builds. Instead, our goal is to help the sponsoring company answer the following key question regarding their component part supply chain:

- What are the key drivers behind component inventory service levels, and what actions can the sponsor company take to improve service levels with its suppliers (reducing the risk of stockouts)?

Our hypothesis was that certain supplier characteristics (e.g., average capacity utilization or forecasting approach) coupled with component features (e.g., manufacturing complexity, material type) create service level risks to varying degrees, and therefore certain components will require action to address this risk (e.g., a reset of safety stock levels, or a change of inventory policies).

To address this question and test our hypothesis, we (1) gathered data from suppliers via supplier interviews and surveys, (2) gathered component demand and historical service level data from the sponsoring company, (3) converted supplier characteristics into variables for further analysis, and (4) built correlation matrix, regression, cluster and qualitative analysis to understand relationships between features and the risk of stockout to segment the components based on their characteristics and risk. From this analysis, we provided the sponsoring company with targeted insights and recommendations that allow them to better understand the risk within their component inventory supply chain and achieve a desired (higher) service level for their finished goods customers.

In the following chapters we discuss our review of the relevant literature focused primarily on inventory management in the global medical devices supply chain, then we describe the methodology that led us to our results and final recommendations for our sponsoring company. Lastly, we discuss some additional findings we uncovered beyond the scope of the initial research question and highlight areas for further exploration by the sponsoring company.

2. LITERATURE REVIEW

Inventory management for medical devices is particularly challenging for several reasons – demand variability, product cost, and impact of a stock-out are all extremely high while increasing supply chain costs apply constant pressure to maintain a minimum amount of inventory. To help the sponsoring company understand the key drivers behind their component service level, we focused our research on leading inventory management practices in the medical devices industry, including the following concepts which we discuss in the subsequent section:

- Managing Inventory in Multi-echelon Supply Chains
- Inventory Policies
- Service Level
- Inventory/ Stock-Keeping-Unit (SKU) Segmentation

2.1. Managing Inventory in Multi-echelon Supply Chains

Many medical device companies have a multi-echelon supply chain, meaning that a single finished good requires components manufactured by various suppliers (Gomes, 2022). This complexity does not end there because these suppliers usually have a multi-echelon supply chain themselves, which means that they depend on multiple supplier operations and varying lead times (Clark & Scarf, 2004). In reviewing the product flows with the sponsoring company, we learned that their supply chain is extremely complex in the sense that most finished goods not only sourced components from many suppliers but most finished goods used a significant number of these components in each assembly, meaning tens of suppliers were often directly involved in the supply chain for a given single finished good product. To help them manage the complexity, the sponsoring company had moved the majority of its component inventory management to a vendor-managed-inventory (VMI) model, which we describe in the next section.

2.2. Inventory Policies

Along with many other industries, medical devices have tried to innovate different methodologies to reduce supply risk and stock-outs. One of the factors responsible for shortages is the delay in generating the replenishment order. The decision on when and how much to order is driven by the inventory level, the lead time of the components, the transportation time, and the storage capacity of the supplier and customer (Bragg, 2012). Since there is more than one party responsible for this information, companies have developed different types of contractual relationships with their suppliers – these contracts vary in determining who is responsible for the size of the order, delivery time, and stock levels. In the literature there are primarily two inventory contract types that differ primarily on who manages the inventory level and reorder points: (1) Standard Inventory Management Practice and (2) Vendor Managed Inventory (supplier).

- Standard Inventory Management Practice: In this approach, the client is responsible for generating a standard Purchase Order for the supplier to fulfill a replenishment. The time required by the supplier to deliver the order will depend on the agreements with the client on lead times, quantity range, and frozen planning windows if applicable (Vandeput, 2020).
- Vendor Managed Inventory (VMI): In contrast, in a VMI model the supplier or vendor is responsible for managing the inventory levels at the client's facility. The client shares information with the supplier to help them achieve optimal inventory levels, such as inventory level in their warehouses, the weekly demand, forecast, and maximum capacity. The ownership of the inventory at the clients' facility can be the supplier's (cosigner) or the client's but is often vendor owned until it is consumed (Vandeput, 2020).

Since most of the inventory of components for the sponsoring company is managed through VMI, we continued our research by understanding service level drivers in the context of a VMI replenishment model.

2.3. Service Level

In general, the selection of the right inventory level and optimal replenishment order depends on different factors such as (1) how costly is a stock out, (2) how much capacity does the supplier have, (3) how seasonal the product is, and (4) how expensive is the overstock (Caplice & Ponce, 2021). Both industry and academia utilize various approaches with varying degrees of complexity to manage inventory and balance cost and risk. Standard practices exist for deciding how much to order at a time (e.g., economic order quantity, "EOQ"), how to calculate the inventory quantity threshold that should trigger an order for more inventory (re-order point, "S"), the amount of buffer stock to hold beyond expected typical consumption to hedge against the risk of disruptions, delays, or unplanned adverse events (safety stock, "SS"), and the probability of non-stockout (Cycle Service Level) (Caplice & Ponce, 2021).

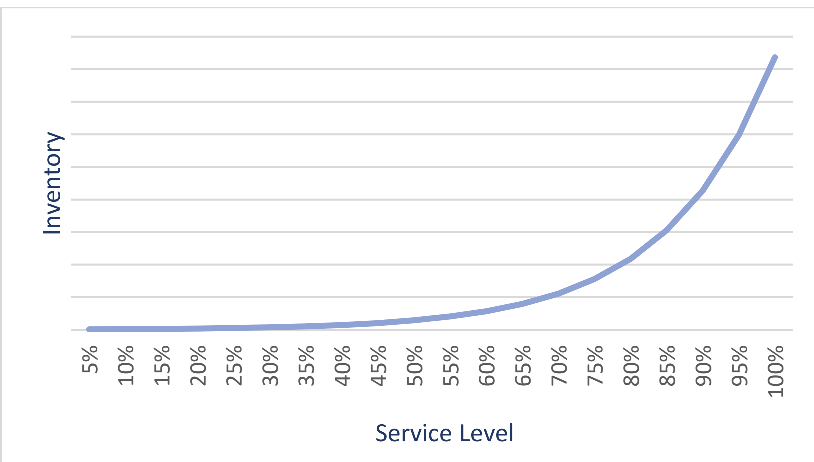
In our capstone, the most critical KPI is the component supplier's service level. In this case, the sponsoring company has a different definition of service level (in a VMI model) than the traditional approach. Instead of measuring the percentage of non-stock-outs over the total orders, they measure the percent of weeks from which a component is without stockouts or risk of stockout ("risk of stockout" is defined as stock below one week of inventory). In discussing with our sponsor company, key inputs related to their management of service level that we define here are the following:

- **Average Weekly Demand (AWD)**: Average of the weekly demand projected for the following weeks
- **Inventory on hand (IOH):** The level of inventory that is physically in their facility (VMI model)
- **Inventory Replenishment Level (IRL):** Target level of inventory at the facility (aligns with the AWD)
- **Safety Stock (SS)** = Safety Factor (K) * Standard Deviation of Demand over Lead Time ($K\sigma_{DL}$)
- **Service Level / Cycle Service Level:** This is often defined as the probability that there will not be a stockout during a replenishment cycle (Caplice & Ponce, 2021). For this capstone, we used a weekly indicator calculated by dividing the Inventory on Hand by the Average Weekly Demand for each component, which allowed us to view the number of weekly instances where there was an inventory risk or service level reduction.

To increase the desired service level (and reduce stock-outs), a non-linear increase in inventory is generally required, as evidenced in Figure 2. e*.g., moving from an 85 to 87% service level requires a much smaller increase in inventory than moving from 95 to 97%.* Because many of the sponsoring company's component suppliers already have a high service level (above 90%), the investment required to increase their performance by a blanket safety-stock increase would be too costly. Instead, they were looking for data-driven approaches and insight into additional variables that could be addressed to increase supplier service level performance.

Figure 2

Relationship between desired service level and inventory



2.4. Inventory/Stock-Keeping-Unit (SKU) Segmentation

To understand which variables (beyond lead-time) were primarily driving the service level performance of suppliers, we identified the most relevant suppliers based on their revenue contribution so our recommendations could provide the highest benefit. In addition, to understand the behavior across different components, we hypothesized that clustering algorithms may provide some insights into supplier or product characteristics that drive a higher or lower performance.

In our research, the most common approach to segment components or products we identified was using the Pareto rule: i.e., 20% of a group generates 80% of the impact (Pyzdek & Keller, 2012). This segmentation can be done based on different criteria. In selecting our most critical suppliers, we focused the Pareto rule on revenue, which allowed us to segment the components necessary for manufacturing the finished goods with the highest revenue. After segmenting suppliers and components, we researched common leading clustering techniques to begin to extract insights that could help us understand if different segments had different service level drivers.

Two popular techniques we reviewed, K-means and K-modes, make it possible to do segmentation via cluster analysis to study components and identify the variables that drive their behaviors. This tendency of grouping similar components and defining characteristics as a group helps us understand what key drivers are responsible for certain outcomes in service level. This segmentation can be done by quantitative or qualitative analysis (Bonthu, 2021)

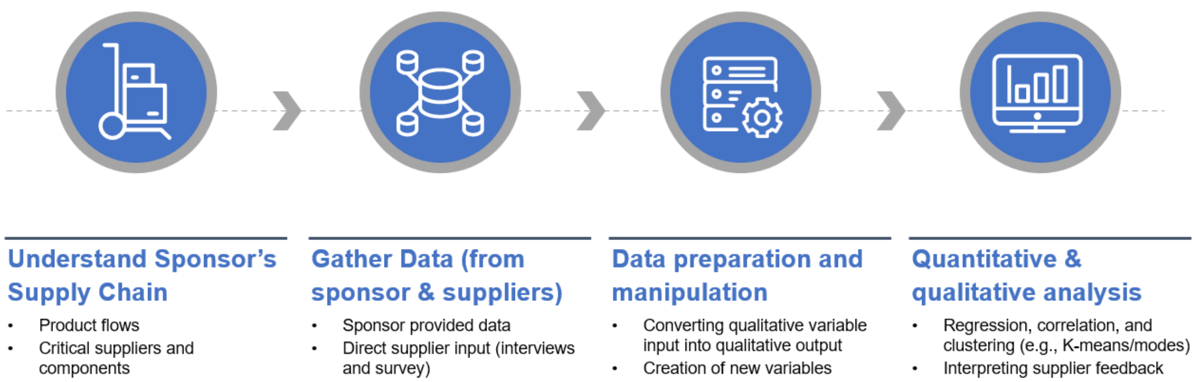
Now that we reviewed key concepts and terminology, leading inventory practices, and various industry-leading practices to understand service level drivers (such as K-modes), we will discuss our approach to gather and analyze the data collected throughout this project in the following section. While many of these techniques had been used previously in the context of inventory management and/or the medical devices supply chain, applying them to understand the relationship between quantitative and qualitative variables with supplier service level performance (in our approach) appeared to be novel.

3. DATA AND METHODOLOGY

The high-level approach of our methodology is summarized in **Figure *3***. In the initial stages, we focused our efforts on understanding the complexity behind the sponsoring company's supply chain and determined where to focus the data-gathering efforts. Once we received our initial datasets, we determined that direct supplier input would also be required to gain a holistic understanding of the variables that affect the service level since they were the primary source of information. We designed a series of interviews and supplier surveys to collect it. Once we received all the responses, we converted a portion of the qualitative data into a quantitative format to begin our analysis and eventually provide our recommendations. We discuss each of these four steps in more detail in the following sections:

Figure 3

Methodology Diagram



3.1. Understand Sponsoring Company's Supply Chain

A supplier produces either one component or a group of components with similar characteristics. Since the sponsoring company often operates on a VMI (Vendor-Managed-Inventory) model, the suppliers store their inventory at the sponsoring company's facilities, and the transfer of ownership (plus associated payment) only occurs on consumption. Because of this setup, suppliers (vendors) generally are not required to hold additional safety stock at their own facilities, although in some cases they still do. During the first stages of the project, we worked with the sponsoring company to map out the various supply chain flows used for its key component suppliers. This exercise revealed the complexity involved – many of the suppliers had their own network of tier 1 and tier 2 suppliers. Coupled with raw material lead times their total lead times to supply to the sponsor often exceeded 6-months. Also, a combination of shipment methods was used across various stages in the process, implying varying levels of lead-time variability across each component flow.

Because of the complexity of the sponsoring company's component supply chain, we worked with them to narrow our scope to a group of "top" suppliers responsible for roughly 80 percent of finished goods revenue (following the Pareto principle) shown in Table 1 with redacted supplier names. Due to clear differences we noticed in the supply chain flows, we categorized the suppliers into the following groups:

- **Packaging** – generally short lead times, lowest manufacturing complexity
- **Plastic (components)** – generally short lead times, medium manufacturing complexity
- **Metal (components)** – generally medium lead time, higher manufacturing complexity
- **Electronics (e.g., chips)** – generally longest lead times, highest manufacturing complexity

Table 1

In-scope components list (non-exhaustive)

CATEGORY	CONTRACT	SUPPLIER	SCOPE
ELECTRONICS	Standard PO	A	1 COMPONENT CABLE
PLASTICS	VMI	B	2 COMPONENTS
PLASTIC/METAL	VMI	C	2 COMPONENTS
METAL	VMI	C	12 COMPONENTS
PLASTICS	VMI	D	10 COMPONENTS
ELECTRONICS	VMI	E	10 COMPONENTS
ELECTRONICS	VMI	F	5 COMPONENTS
METAL	VMI	G	6-9 COMPONENTS
PLASTICS	VMI	H	10 COMPONENTS
METAL	VMI	I	5 COMPONENTS
METAL	VMI	I	10 COMPONENTS
METAL	VMI	J	2 COMPONENTS
TTMETAL	VMI	J	6 COMPONENTS
METAL	VMI	K	ALL COMPONENTS
PACKAGING	Standard PO	L	ALL COMPONENTS
PACKAGING	VMI	M	ALL COMPONENTS
PACKAGING	VMI	N	ALL COMPONENTS

After finalizing the scope of components and supply chain flows, we identified the data needed for each supplier and in-scope component that would help us understand the relation to service level, which we discuss in the following section.

3.2. Data Collection

Throughout the project, the company provided us with key data elements summarized in Table 2. These files were mostly a combination of extractions from source systems and manually maintained Excel files. We first focused on gathering data on historical inventory levels, demand, and actuals (shipments). Next, we determined which data could be used to indicate service level and associated supplier performance to meet their delivery requirements and maintain an appropriate level of safety stock (i.e., preventing stock-outs).

Table 2

Data sources

Data Type	Description	Time Horizon
Demand	Actual demand	Monthly
SKU-List	In-scope components and their classification	N/A
Forecasts	Future period forecasts	Monthly
Diagram	Lead times and component flows for top suppliers	N/A
Variable list	Sponsor's predicted/potential variables impacting safety stock	N/A
Service Level-A	Service level issues as a proxy for component supplier performance	Weekly
Service Level-B	Past stock-outs or instances of stock below safety levels	Weekly

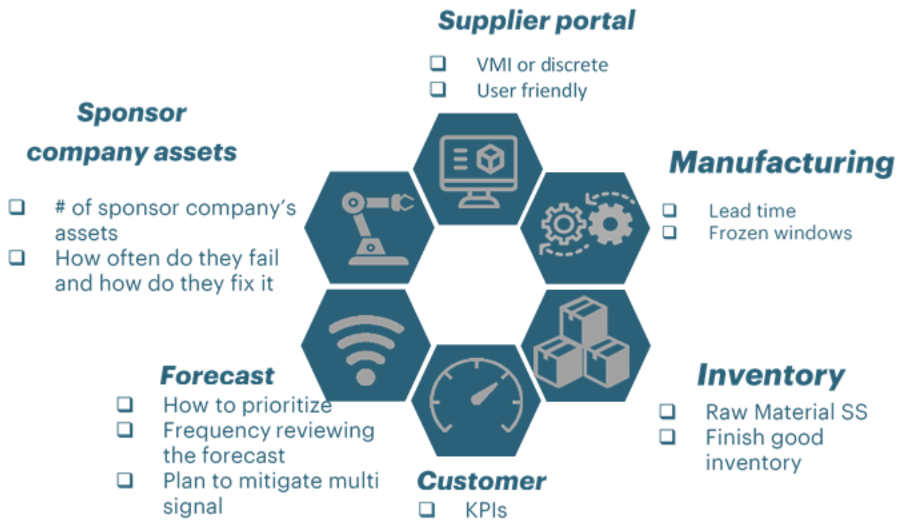
To measure service level historically, the sponsoring company had a manually maintained data file (referred to in Table 2 as "Service Level-B" file), which measured service level on a weekly basis via the ratio of inventory on hand and the average weekly demand (0 ratio with non-zero demand would indicate stock out).

After reviewing all the data from the sponsor company, we determined that the best approach to building a list of all potential variables impacting supplier performance was to gather additional information directly from those suppliers. The sponsoring company initially suggested a six-category structure to help us focus on areas they believed could be important, as shown in *Figure 4.*

1. Supplier portal: system that suppliers use to view upcoming demand requirements for the sponsoring company, which includes minimums (safety stock) as well as future period forecasts
2. Manufacturing: general information regarding their lead times and frozen windows (if any) involved in their manufacturing processes
3. Inventory: refers to general inventory policies and on-side safety stock of suppliers
4. Customer: which KPIs does this supplier value internally?
5. Forecast: does the supplier "trust" the forecast in the supplier portal, e.g., or do they produce based on historical shipments alone?
6. Sponsor company assets: in some cases, the sponsoring company owns manufacturing assets located in the suppliers' facilities – in some cases this leads to maintenance or other production risks and thus the sponsoring company suggested to include it as a category

Figure 4

Preliminary variable categories



Drawing on established relationships between suppliers and the sponsoring company, we interviewed a group of 5 suppliers selected based on their different types of component materials (representing different types of supply chains). Based on those responses, we designed a survey to send to the remaining top suppliers to gather data across the full scope of components, allowing us to improve the list of variables that may impact service level. In attendance at these interviews were generally 1-2 planners responsible for supplying components to the sponsoring company – to encourage the supplier to speak freely, the sponsoring company did not attend the interviews. As the purpose of the interviews was to gather insights into the causes or potential causes of service level risk, we built upon our initial framework shown in Figure 4 and grouped questions into seven categories (see Table 3), adjusting the focus of each interview to suit a supplier's insights and nuances of their specific components or past inventory and production challenges.

Table 3

Supplier Interview Questions Overview

Sec	Category	Example
1	Managing production signals	e.g., what is the process following when you see a conflict and need to prioritize one component over another?
2	Usage of the sponsoring company's supplier portal	e.g., how often do you alter production based on the future forecasts in the portals?
3	Measuring customer service	e.g., what is the top KPI used internally to measure performance?
4	Supplier supply chain and manufacturing operations	e.g., what is your target machine utilization for in-scope components?
5	Supplier inventory policies	e.g., what is your typical raw material safety stock level?
6	Inventory metrics	e.g., how do you track performance to safety stock or service level targets?
7	Asset management	e.g., do you have any assets owned by the sponsoring company in your own production line, and how has that impacted your performance?

Based on these initial supplier interviews, we adjusted some of the questions and built an email/web-based survey designed to gather data and capture similar responses to 26 questions focused on the same seven categories. We used a combination of multiple-choice and scalar response options to prepare the responses for potential analysis. Table 4 provides an overview of the 26 questions and their anticipated insights.

Table 4

Supplier survey questions overview

Questions	Topic	Comments/Insights
1, 2	Supplier information	Supplier names anonymized before providing data back to sponsoring company
3	Usage of supplier portal	Determining the relationship if any between using the portal and supplier performance
4	Supplier inventory policies	Determining the relationship if any between VMI vs. discrete PO policies and supplier performance
5, 6, 7, 8	Usage of supplier portal	Determining relationship if any between inputs used to plan production and supplier performance
9	Managing production signals	Determining relationship if any on process to manage signal conflicts and supplier performance
10	Inventory policies	Determining relationship if any between standard average lead time and supplier performance
11	Supplier supply chain and manufacturing operations	Determining relationship if any between target machine utilization and supplier performance
12	Supplier supply chain and manufacturing operations	Determining relationship if any between staffing capacity and supplier performance
13	Inventory metrics	Determining relationship if any between choice of internal inventory KPIs and supplier performance
14	Measuring customer service	Determining if internal assessment of performance matches external
15	Supplier inventory policies	Determining if holding on-site safety stock increases supplier performance
16	Supplier inventory policies	Determining if raw material lead times impact supplier performance
17, 18	Supplier inventory policies	Determining if frozen windows impact supplier performance
19, 20	Asset management	Determining if the sponsoring company-owned assets at supplier locations impact performance
21	Supplier supply chain and manufacturing operations	Determining if specific supplier processes impact performance
22	Usage of supplier portal	Determining if supplier's usage of new product introductions data impacts performance
23, 24	Usage of supplier portal	Determining if payment issues have any impact on performance
25, 26	Supplier information	Open text questions to inform us of any potential missed topics or variables and provide open supplier insights

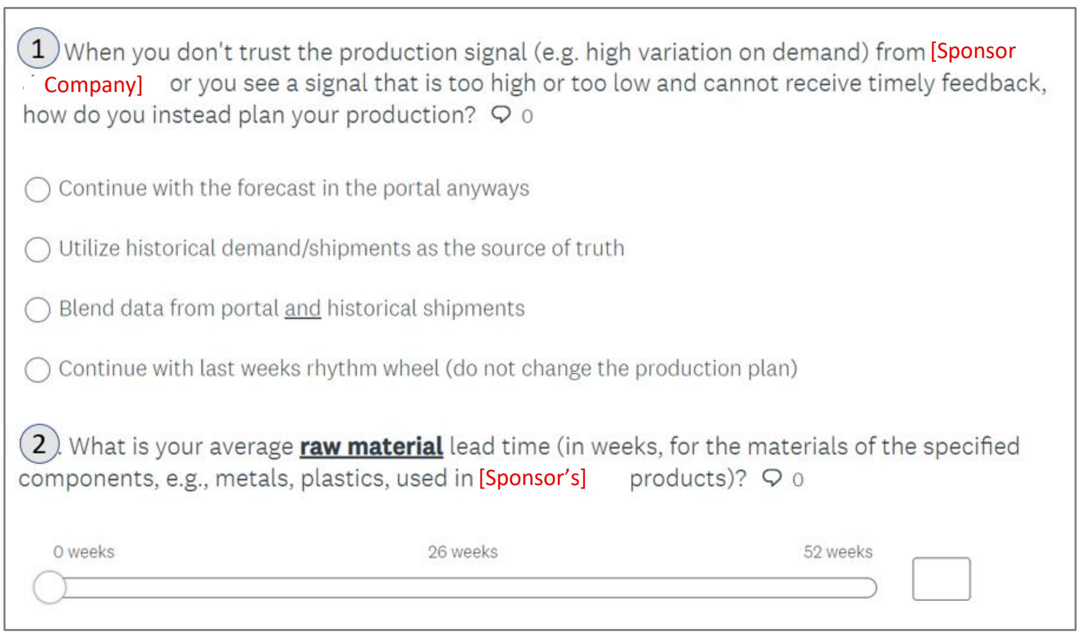
From the data collected directly from the sponsor along with the survey data we finalized our collection of both numeric and qualitative variables, and then processed, consolidated, and prepared the data for our analysis as detailed in the next section.

3.3. Data Preparation and Manipulation

After gathering the required data, we consolidated it and updated the format for processing, starting with supplier survey data. Since the supplier survey questions were a mix of categorical and numeric responses, we converted the qualitative responses to binary values. Figure 5 gives an example of (1) qualitative data from the survey that required a binary conversion and (2) numeric data from the survey (the complete survey can be found in the appendix of this document).

Figure 5

Survey questions example, in which the first question requires a binary transformation



1 When you don't trust the production signal (e.g. high variation on demand) from [Sponsor Company] or you see a signal that is too high or too low and cannot receive timely feedback, how do you instead plan your production? 0

- Continue with the forecast in the portal anyways
- Utilize historical demand/shipments as the source of truth
- Blend data from portal and historical shipments
- Continue with last weeks rhythm wheel (do not change the production plan)

2 What is your average **raw material** lead time (in weeks, for the materials of the specified components, e.g., metals, plastics, used in [Sponsor's] products)? 0

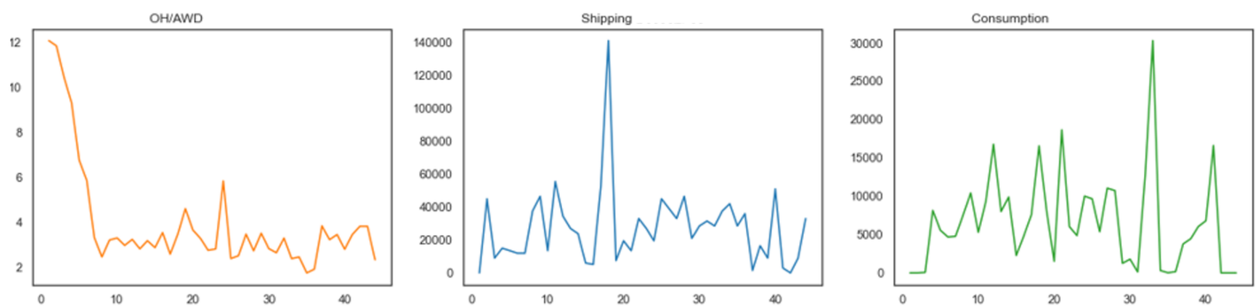
0 weeks 26 weeks 52 weeks

Next, to prepare the data we decided to normalize the survey-data variables and cleaned up various other data issues such as null values in the cases where the answer was not mandatory. We then cleaned the historical service level, component demand, and forecast data. In consolidating the data, some mismatches were found: (1) some information was not available in all three places, so we decided to drop the component information entirely, (2) the primary key that we were using to match between files (component ID) had differences between the various files, so we created a dictionary that connected the IDs between the different documents. To better understand our next steps, we started by visualizing the data to identify any immediately visible patterns.

Figure 6 is a visual representation of one component of the AWD/OH ratio, supplier shipments, and consumption for finished goods production. In the image we noticed a high variability between the weeks, which was evidence of the complexity in the sponsor's supply chain and the challenges for the component suppliers.

Figure 6

Graph of Service Level (OH/AWD), Shipping and Consumption



To consolidate this time series information with the survey data, we created four new types of variables: (1) Mean of Service Level (OH/AWD), (2) Sum of Shipping, (3) Sum of Consumption, and (4) Count of Service Level (which in turn includes four variables, one for each range of values).

- <u>Mean of Service Level (OH/AWD):</u>
  The average of the division of OH by AWD for the weeks that data was available

- <u>Sum of Shipping</u>:
  Sum of all the shipments of the first 40 weeks of 2021 (used to understand the dimensions of the suppliers by the total volume that they shipped during the year)

- <u>Sum of Consumption</u>:
  Sum of the first 40 weeks of 2021 of the sponsor company's consumption of the components (used for finished goods manufacturing and assembly)

- Count of Service Level:

  To allow the model to interpret the historical service level some processing was required from the data received from the sponsoring company. The service level data was maintained in a weekly time-series format consisting of the inventory on hand at the sponsoring company (in a VMI model), divided by the average weekly demand. As a rule, at least four times the average weekly demand (AWD) was desired to be kept in on-hand inventory (IOH). Thus, instances where the ratio was dramatically lower than 4, e.g., 1 indicated a potential shortage or approaching stock-out in components if replenishment was not performed before all remaining inventory was consumed in production.

  Assuming there was demand for the component, a ratio of 0 in any week in which there was planned consumption (production) would indicate a risk in service (delaying finished goods production). To quantify this risk for the analysis and allow for additional modeling, we quantified (counted and summed) the instances where the service dropped to 0 as supplier service level risks, and cases when it came very close to 0 as near service level risks – therefore the four new variables used to measure this were:

  (1) Count of weeks with Service Level (OH/AWD) = 0

  (2) Count of weeks with Service Level (OH/AWD) between 0 and 1

  (3) Count of weeks with Service Level (OH/AWD) between 1 and 4

  (4) Count of weeks with Service Level (OH/AWD) higher than 4

  After preparing the service level data we now had a baseline with which to begin our quantitative analysis detailed below.

3.4. Quantitative Analysis

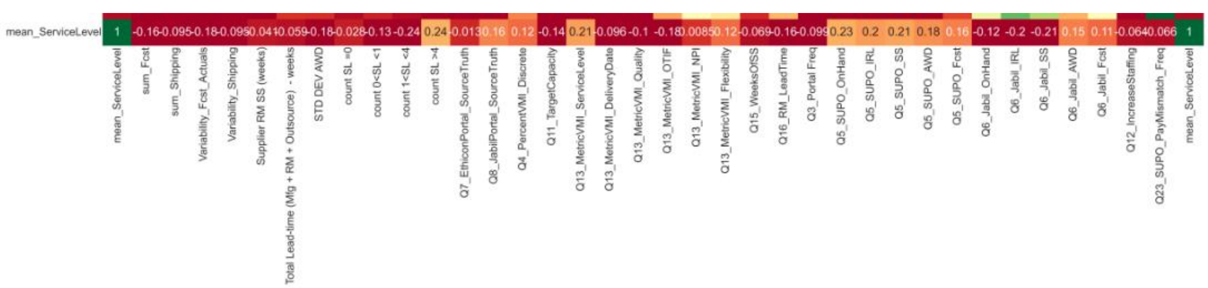
We tried various strategies to get a better understanding of the relationship between the variables and segments of components and suppliers. We began with regression and correlation techniques to identify those relationships, then performed segmentation techniques such as K-means and K-modes to identify any service level patterns between various components or suppliers.

First, we ran a Lasso-regression with all the numerical and non-binary categorical variables collected from the supplier responses in the survey, so it would be possible to predict the service level based on the relationship with the other variables. We used Lasso Regression because it can automatically convert the qualitative variables into binary and drop (or reduce the coefficient of) the variables that are highly correlated with each other and not add value to the analysis. There were no clear relationships between the variables that were able to help us predict the service level through Lasso regression – the R^2 from the validation data was near 0, which meant that it did not provide any actionable information.

The next step was to understand the correlation between the mean of Service Level and the other variables created from the data collected. Since there were variables that were not numerical, and the binary conversion that we did was losing some information by creating one variable for each [possible value -1], we converted the answers from text scalable questions (for example the answer: *'More than once per week (including daily),' 'About once per week,' 'Less than once per week,' 'N/A - not using the portal'*) into numerical values based on our experience and knowledge about how each answer should be weighted over the others. This gave us the correlation shown in Figure 7, which unfortunately showed no variables that had a strong correlation (>.7) with the Service Level variables.

Figure 7

Correlation between Mean of Service Level and other variables



After reviewing the existing models and referencing our literature review, we determined that segmentation might allow us to further identify patterns in the service level variable. Based on the literature review, we chose a clustering model (such as K-means or K-modes) might allow us to understand the relationship between the quantitative and qualitative variables collected from the data sources mentioned in Table 4 and the supplier interviews, with the supplier service level performance documented by the sponsoring company in 2021 (Sharma, 2019).

In ‘K-means’ (an algorithm that groups data into unique groups), the approach calculates the distances of the data points from the centroid and iterating until the optimal distance is found. In this approach, the number of clusters needs to be provided first as an input; thus, business and operations intuition gained through studies and work experience is sometimes needed to find the optimal number of clusters. Often, statistical analysis software that includes K-means clustering includes data on the silhouette scores across the cluster, allowing for an understanding of how well the data fits into the clusters and assisting in picking an optimal number of clusters for the dataset (Sharma, 2019). When working with categorical data in addition to numeric data, K-modes is usually used instead, which measures similarities between the values (segmentation through modes) (Bonthu, 2021).

Figure 8

K-mode cluster: the relationship between Suppliers and component volume

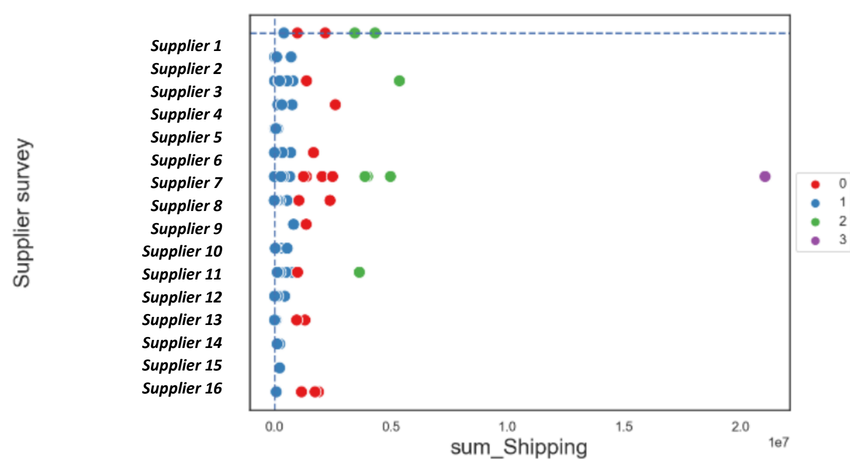
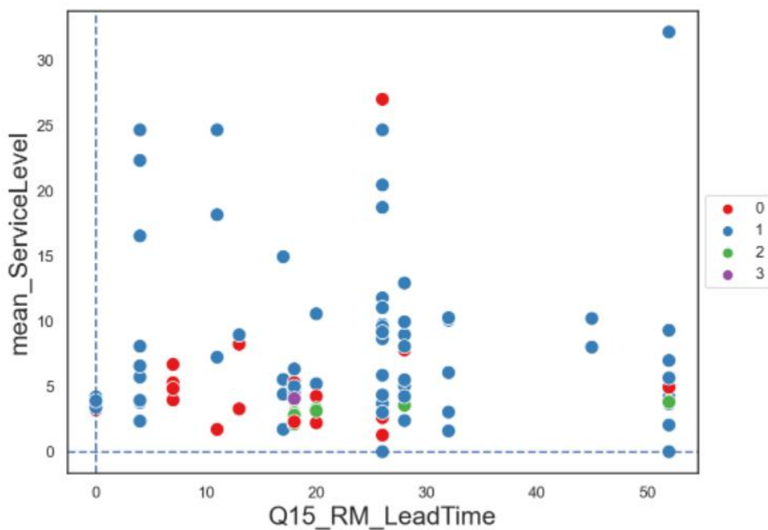


Figure 8 represents the result of one iteration of a K-modes clustering. In this case we are clustering by supplier and sum of shipments and have four different clusters represented by the colors purple, green, red, and blue. The figure shows that one variable that has a significant weight on the segmentation was the volume represented by the variable Sum of Shipping, since it is possible to draw vertical lines on the graph that divide the clusters almost perfectly.

Some clusters, such as service level over raw material lead time, did not show any actionable relationship (as shown in Figure 9). In this graph we took the mean of Service Level versus question 15 in the survey regarding supplier Raw Material Lead Time. As can be seen in Figure 9, there is no line that can be drawn to segment the clusters.

Figure 9

K-mode cluster, the relationship between Service Level and Lead time



In addition to Raw Material (RM) Lead Time, we created K-modes plots for several other variables that we hypothesized might have a direct relationship with service level: (1) supplier target capacity, (2) supplier manufacturing lead time, (3) component material type, (4) average weeks of additional safety stock held at supplier locations, (5) supplier portal usage, and others. While it may in part be due to the finite amount of direct supplier input received, none of the K-modes plots provided clear enough clusters to lead us to actionable recommendations for the sponsoring company. Because of this, we turned our attention back to the supplier survey and focused on analyzing their qualitative responses at a more granular level.

3.5. Qualitative Analysis

From the 26 responses that we received from the supplier's survey (93% response rate), 74% of suppliers indicated total lead times beyond 12 weeks (raw material procurement plus manufacturing), yet documents provided by the sponsoring company to the supplier recommended the supplier not use the future period forecasts (>12-week horizon) and instead only use short-term and long-term average weekly demand (0-12 week horizon). For this reason, suppliers that require visibility beyond 12-weeks were essentially producing without any insight into future periods and thus based to make assumptions about those period that either (1) demand would continue as it was or (2) demand variability might increase. In addition, we reviewed the agreed frozen production windows with the sponsoring company and noticed that many were set by default to a 2-week period but rarely reflected the needs of the suppliers (this confirmed by the supplier survey). To better understand this contrast between current agreements and true supplier requirements and its impact on service level, we began a deep dive of the supplier survey responses to understand which actions each supplier was taking and how they were responding to these challenges. In the next chapter, we discuss the results of the search for relationships among service level and the other variables, as well as our insights from the supplier survey data that translated into our final recommendation for the sponsoring company.

4. RESULTS AND ANALYSIS

In our initial results we analyzed the correlation between service level and the other variables collected from the sponsoring company and the supplier survey. Because the correlation matrix displayed no values above 0.7 (for additional variables against the historical service level), we focused more on specific examples of historical service level risk from the data provided by the sponsoring company and weighed more heavily the direct supplier input into our recommendations for service level improvements. Thus, our results are organized into the following sections which we discuss in turn:

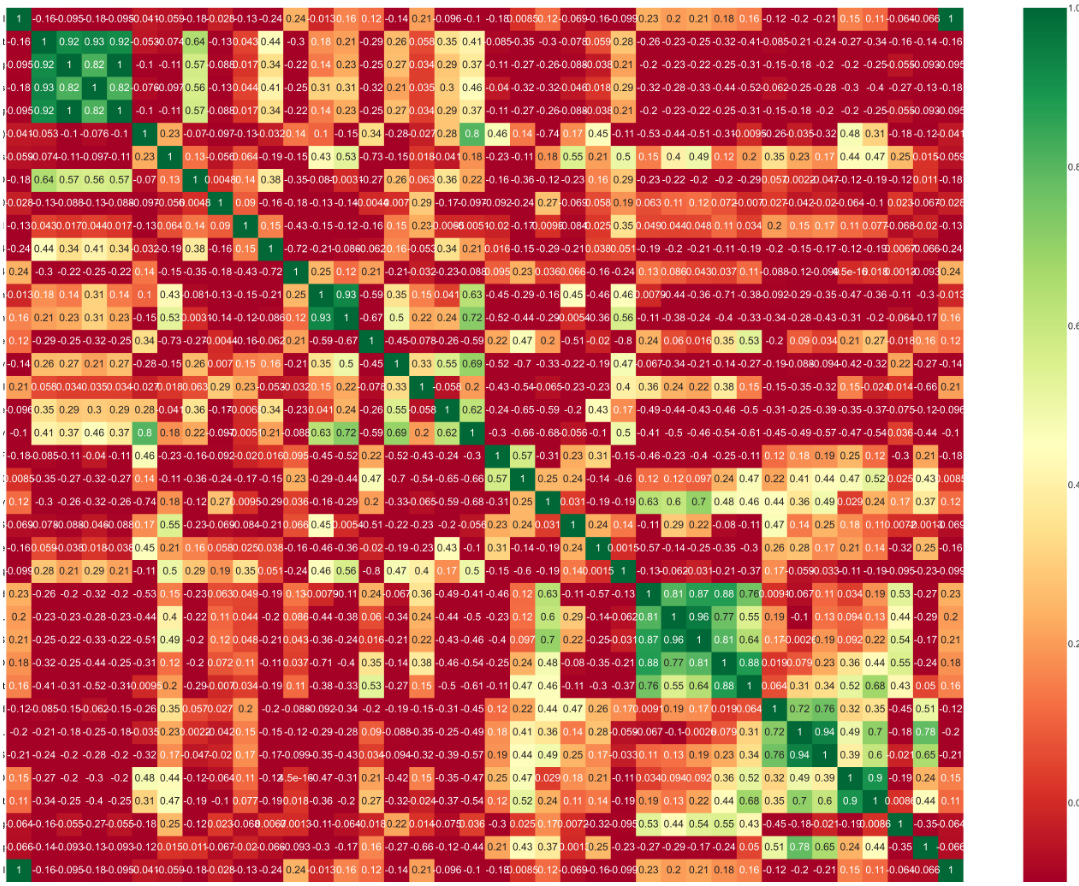
- Relationships between Variables
- Supplier Perception of Forecast Accuracy
- Realistic Frozen Windows
- Supplier Service Level Performance Metrics

4.1. Relationship between Variables

After concluding the supplier survey and importing the additional sponsoring company data, we analyzed the correlations between the behavior of the suppliers and their historical service levels (by using the mean of Service Level). Figure 10 represents the scale of the correlation matrix. While the variables have been truncated from the image, the key finding was the amount of red color displayed in the matrix, which indicated no medium to high correlations with any of the service level variables.

Figure 10

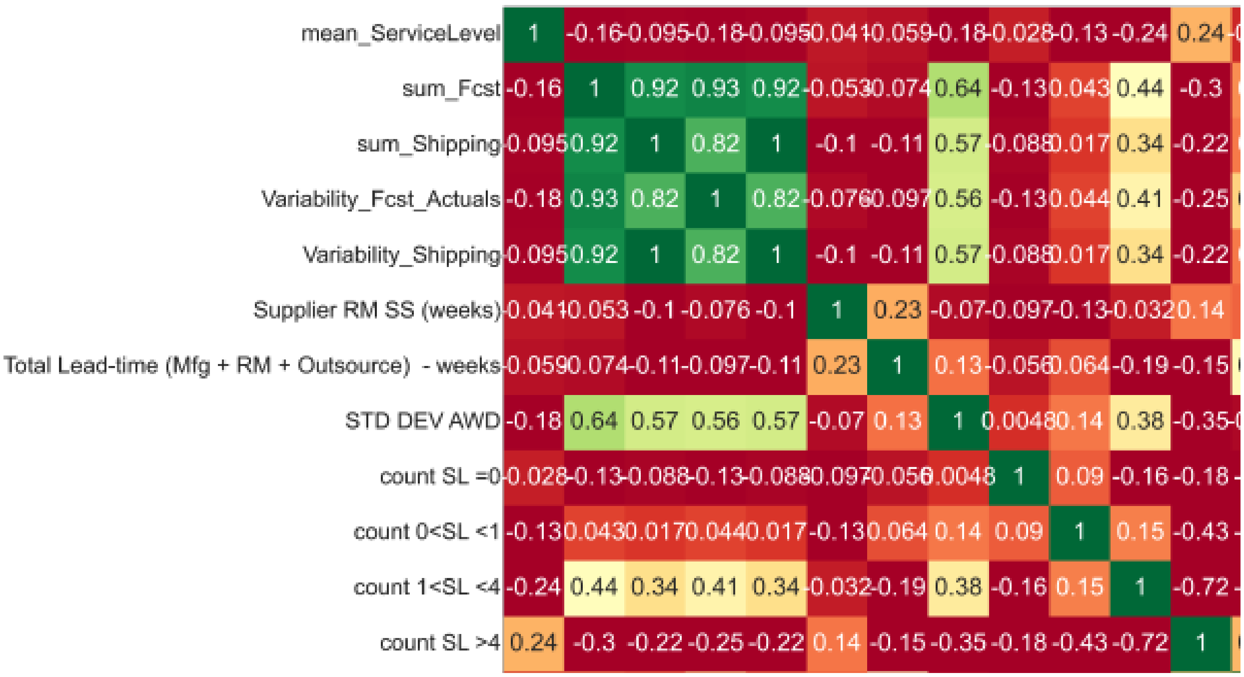
Correlation Matrix between survey questions and quantitative variables from sponsor company



Zooming to the top left corner of the matrix, as shown in Figure 11, we can see an example of the correlations between the quantitative data and the survey responses representing supplier behavior. Certain variables that were expected to be extremely highly correlated indeed were (e.g., forecasts and supplier shipments). However, the key relationship is those in the rows of “count SL = 0” or “count SL <1,” which indicate a stock-out (risks) or near stock-out (potential service level risks). In the full matrix we did not find a correlation above 0.5 with any of the other variables with these 2 KPIs, meaning that we needed to look at the data more qualitatively and dig deeper into specific supplier survey insights.

Figure 11

Zoom-in of the top left corner of the correlation matrix



In the next section we turn our attention to results from the analysis of the data gathered directly from suppliers in the interviews and survey.

4.2. Supplier Perception of Forecast Accuracy

At the end of the supplier survey, an optional free text field question inquired what one change that the sponsoring company could implement that would help suppliers improve their service levels. Of the 23 responses in this question, 15 included a reference to increased forecast accuracy or increased visibility into future demand. Upon reviewing internal training documents provided by the sponsoring company to their suppliers, we noticed the wording *"Do not use the component forecast to plan your production."* Instead, it suggested that suppliers use short-term and long-term average weekly demand, which went 3 and 12 weeks into the future, respectively. Coupled with the perception that the forecast already was inaccurate, this direction not to use the portal forecast validated the feedback received in the open response question. From the supplier survey, we added together the supplier's raw material lead time and manufacturing lead time, and found that, for 74% of the suppliers surveyed, lead times exceeded (in some case more than doubled or tripled) the 12-week period of visibility that the portal was providing them with average weekly demand data. Beyond those 12 weeks, if suppliers were not able to use forecast data, they would be left to make their own assumptions about demand variability and forced to choose between building in excess capacity with the goal of maintaining a very high service level, or assuming stable demand and de-prioritizing service level in cases of demand spikes to focus on delivering with a lower cost. This tradeoff was confirmed by the supplier survey responses, as we can see in Figure 12, which displays their attempts to balance service and costs due to suppliers' perceived lack of available accurate forecasts to plan production beyond the 12-week period.

Figure 12

Example of suppliers with different priorities

E.g., Supplier A – Real Data
Prioritizes Service Level

Majority of Volume Via	VMI
Avg. RM + MFG Lead Time (excl. transit)	**27 weeks**
Target Capacity	**75%**
Additional SS Held @ Supplier Location	**10 weeks[2]**
Ranking of Flexibility in KPIs	**4 of 6**

E.g., Supplier B – Real Data
Prioritizes Cost

Majority of Volume Via	VMI
Avg. RM + MFG Lead Time (excl. transit)	**30 weeks**
Target Capacity	**97%**
Additional SS Held @ Supplier Location	**0 weeks[2]**
Ranking of Flexibility in KPIs	**6 of 6**

Compiling real data from the survey, it is easy to see this behavior in the responses received. For one supplier, referred to as "Supplier A" here (names masked to sponsoring company and readers), target capacity is below average (75%), and 10 weeks of additional safety stock beyond that already stored at the sponsoring company. In a VMI model inventory is not always kept on-hand at the supplier in addition to the customer, adding costs but providing a buffer against any unexpected increases in demand or interruptions to manufacturing or supply. For "Supplier B," excess available capacity is almost 0, and they chose not to hold additional stock beyond the existing VMI-safety stock at the sponsoring company, keeping their inventory holding costs as low as possible.

While this supplier may have been able to maintain a high service level in the historical 2021 data, operating with so little room for error implies a risk of future stock outs. In addition, in the question of "most critical KPIs" from the supplier perspective, Supplier B ranked "flexibility [to meet demand spikes]" as the lowest priority (6 of 6 KPIs). While the lack of trust in the future period forecast is the largest pain point for suppliers of all types, for the sponsoring company, some suppliers based on their material type (e.g., plastics, metals, electronics) or manufacturing complexity will inevitably have very different end to end lead times that in part are sometimes out of their control. By ensuring that the forecast is accurate and updating the messaging to suppliers to inspire confidence in the forecast, suppliers will not be forced to make tradeoffs that do not align with the sponsoring company's goals and risk future period service level interruptions in cases of high demand variability.

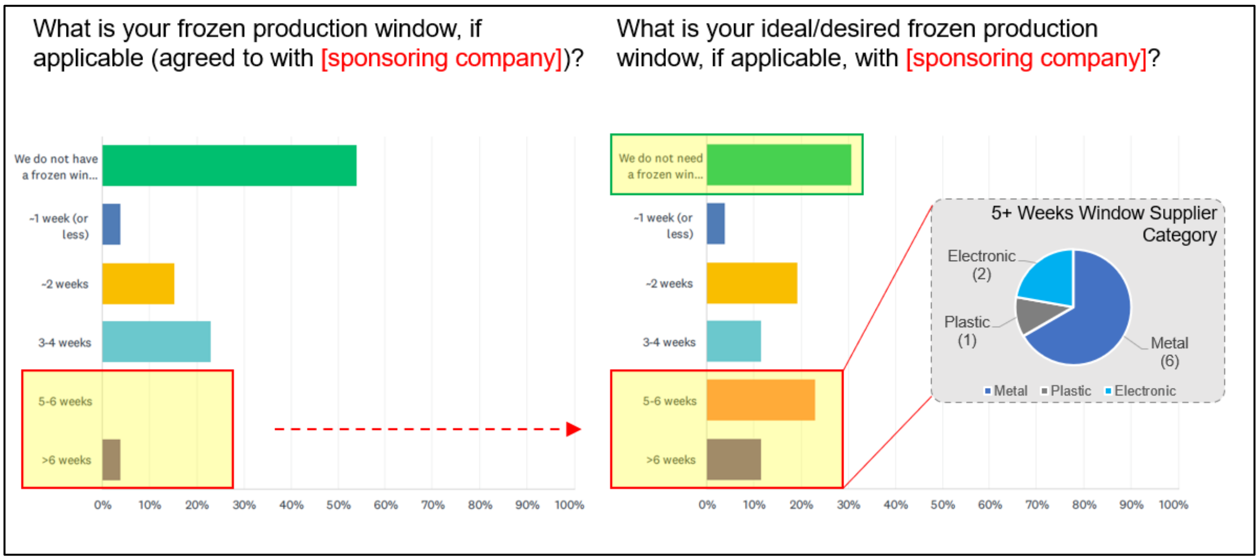
Because of these differences on complexities and priorities, and the fact that some suppliers and components are more critical to the sponsoring company than others, not all suppliers should be evaluated the same way (and some may be "allowed" or even encouraged to prioritize cost over service in the right circumstances). Currently, the sponsoring company freezes requirements to most suppliers 2 weeks out (also known as a 2-week frozen period) and evaluates all suppliers in a similar way across the same service level review process. To realistically plan production based on the distinct characteristics of each key supplier, we recommended establishing supplier-specific frozen windows and segmenting suppliers for their evaluation metrics to make sure the right KPIs are prioritized for both parties. This approach will allow for alignment between the suppliers and the sponsoring company on which priorities (e.g., high service level or low cost) should be at the top of the list, in case it is not always service level. In the next section, we explain the significance of establishing realistic frozen windows in more detail.

4.3. Realistic Frozen Windows

In the supplier survey, responses to one of the survey questions indicated a significant increase from currently implemented to *desired* frozen planning windows (see Figure 13).

Figure 13

Assessing current vs. desired supplier frozen planning window



To understand why this is critical to improving service level, we discussed the implications of this survey question result with our sponsoring company. We determined that if a supplier needs 5-6+ week frozen planning periods from the sponsoring company but is only given 2 weeks as a default, blanket approach, there is inherently a planning disconnect between the two companies that has the potential to have a risk in service level (a stock out) if demand spikes or an issue reduces supply within the short-term planning horizon (or gap between the default and actual/required frozen planning period). In addition, research has shown in multiple cases that implementing appropriate frozen periods helps lessen the impacts of inaccurate forecasts (or perceived inaccurate forecasts) and subsequent bullwhip effect (Lian et al., 2006). After the forecasting challenges, establishing realistic frozen windows was the second most mentioned topic in the open-ended response question. For many suppliers, COVID-19 has caused delays in shipping and sourcing of raw materials that make having real frozen windows even more crucial.

Unsurprisingly, of the suppliers that indicated the need for an increased window, the majority were metal or electronics suppliers, that generally require longer lead times in sourcing raw material as well as additional manufacturing complexity (compared to packaging or plastics suppliers). By implementing realistic frozen windows and incorporating them into their planning system, the sponsoring company may need to raise safety stock in some cases where there is a perception (driven by the new frozen period) of increased lead time. However, the risk of stock out will likely outweigh any increases holding costs in these cases.

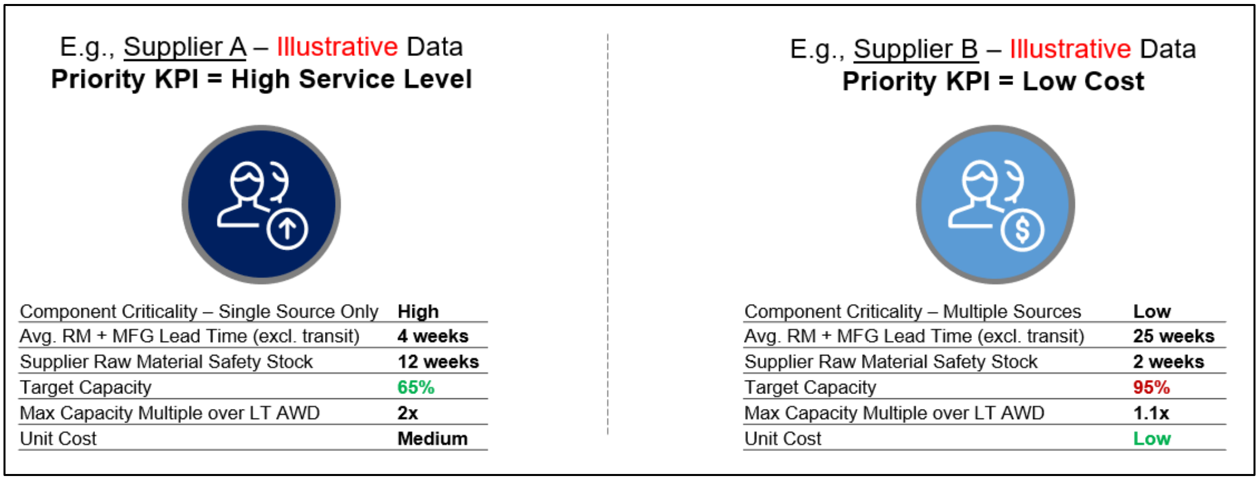
Another benefit of establishing and implementing real frozen periods with suppliers is the ability to measure their performance effectively. For example, a complex semi-conductor manufacturer and a producer of plastic tubes shouldn't be measured by their ability to maintain a perfect service level through a demand spike in the short-term average weekly demand (forward 3-week period). Suppliers need to be segmented based on their capability and component criticality to effectively be measured and incentivized to increase service level – thus our next section details our recommendation to establish regularly-reviewed, transparent, segmented, supplier-performance metrics.

4.4. Supplier Service Level Performance Metrics

With limited long-term visibility due to the forecasting challenges, the suppliers we interviewed discussed making trade-offs between cash, cost, and service level. Segmenting suppliers (and components if necessary), then setting and communicating performance targets accordingly will help align service level goals and reduce costs across the supply chain. Without revealing any specific supplier data, the illustrative example in Figure 14 shows how suppliers make these trade-offs (risking service level in the case of “Supplier B”) without transparent, aligned, and appropriately segmented performance metrics between them and the sponsoring company.

Figure 14

Illustrative example of service level tradeoffs from lack of aligned performance metrics



In this example, “Supplier A” built in extra capacity and invested in raw material to be able to meet spikes in demand and maintain service through supply issues, whereas “Supplier B” may not have the ability to tie up cash in additional raw materials beyond a bare minimum and drives cost savings through a high-capacity utilization. This tradeoff of putting cost and cash above service may be acceptable for the sponsoring company if the components are dual sourced and not so critical for finished goods production. However, for critical components, the sponsoring company should establish service level and capacity targets that prioritize service level instead. After determining which KPIs are most important based on segment, these transparent and supplier-specific goals can be measured on a regular basis (i.e., quarterly, or monthly where possible) to ensure incentives are aligned appropriately and service level trade-offs due to previously discussed challenges (i.e., forecast trust/accuracy, lack of frozen windows) do not need to be made. Beyond the recommendations related to service level, in our analysis we uncovered several other insights relevant to supply chain improvements for the sponsoring company, which we discuss in the next chapter.

5. DISCUSSION

In addition to the main research question of component service level, throughout our analysis we noticed other findings in the data that we provided to the sponsoring company as areas worth further investigation by supply chain teams, including the following:

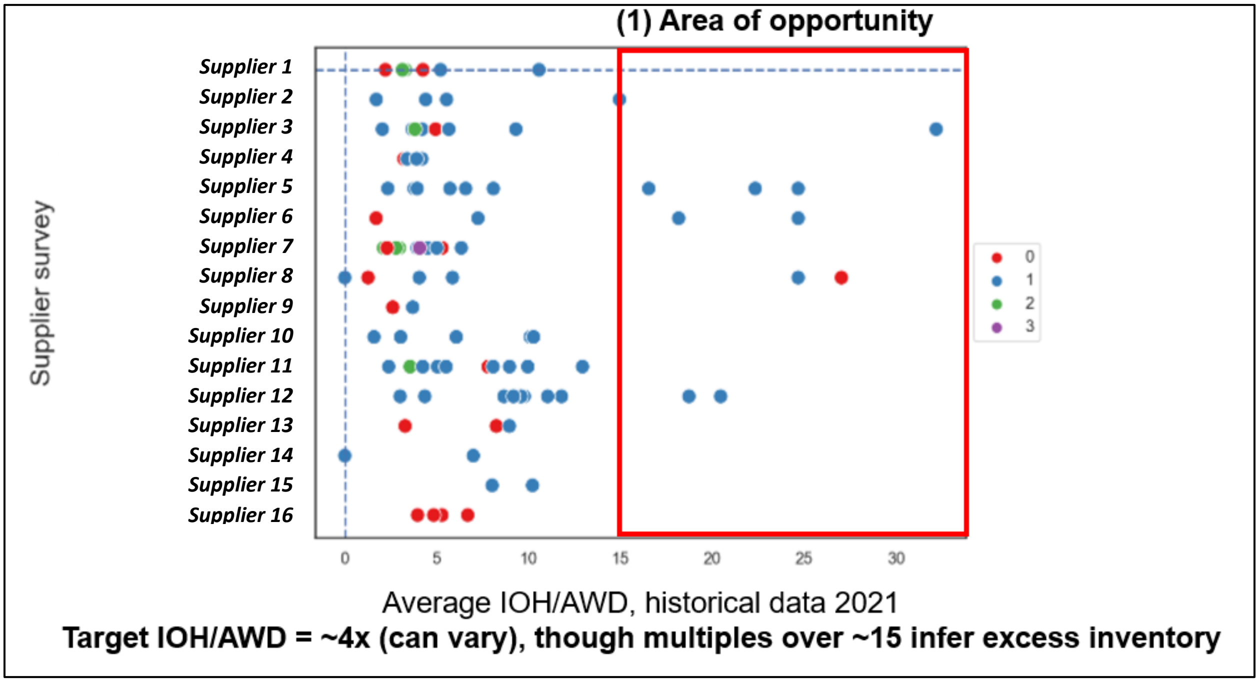
- Inventory Reduction Opportunity
- Additional Trends and Considerations for Segmentation
- Additional Risk Areas for Further Evaluation

5.1. Inventory Reduction Opportunity

While in the process of building K-modes clusters to assess service level related metrics, we plotted (at the component level) the average inventory on hand (IOH) over average weekly demand (AWD) for the intersection of suppliers that both responded to the survey, and for whom we had available data on hand from the sponsoring company as seen in Figure 15. Our intention was to identify suppliers that risked service level interruptions by averaging between 0 and 1 ratio (or close to 1, meaning that they had on hand, only about 1 week of stock based on average demand levels). We were surprised to see across 5 suppliers several components with ratios well above target (averaging over 15 IOH/AWD). In a VMI model, these ratios add significant cost to the sponsoring company since the inventory sitting in their locations is automatically purchased after a 90-day period per contract. The components and the associated 5 suppliers represented in the red box in Figure 15 should be reviewed carefully by planning teams to determine why there were and likely still are holding so much additional inventory for these components, and how (if not intentional) this can be mitigated in future periods.

Figure 15

Identified area of inventory reduction opportunity

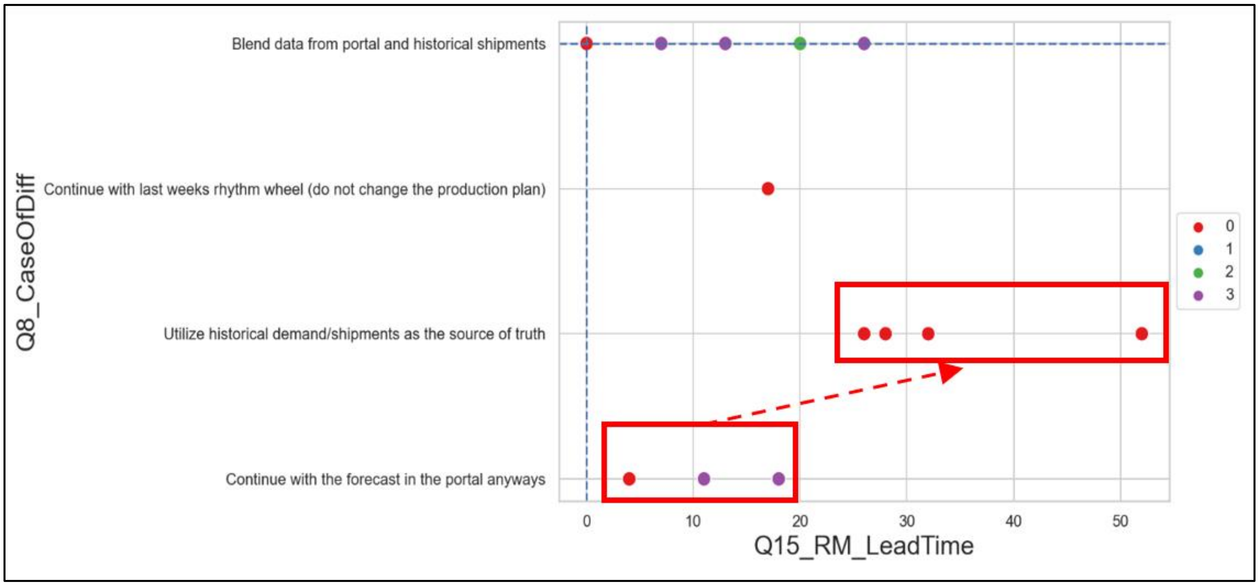


5.2. Additional Trends and Considerations for Segmentation

As part of the supplier survey, suppliers were asked to provide their average lead times for raw material, and in a separate question inform us how they would react to a spike in demand communicated through the sponsoring company's supplier portal as shown in Figure 16. By plotting these two variables during a clustering analysis, we noticed a clear division in behavior. As the raw material lead time of suppliers increased, the less likely they were to use the forward-looking data in the supplier portal, and the more likely they were to turn to the historical shipments to continue to plan their upcoming shipments. To mitigate this behavior, planners should be proactive about communicating to suppliers with longer lead times in cases where the demand spike is understood to be "real" and turning to historical shipments would lead to an unplanned supply interruption.

Figure 16

Supplier reaction in case of demand spikes - which data they turn to based on raw material lead times



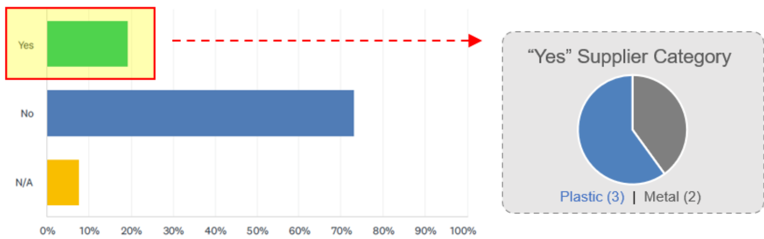
5.3. Additional Risk Areas for Further Evaluation

At the request of the sponsoring company, we included a survey question which had sponsoring company assets (production machines) located physically at the supplier manufacturing locations. We asked suppliers whether issues with those assets had ever becomes so serious that those assets themselves caused service level risks to the sponsoring company. As seen in Figure 17, five suppliers indicated this had happened, a significant percentage in our opinion. While a root cause analysis of these specific incidents is outside the scope of this capstone, we recommend that the sponsoring company perform one to prevent these machines from causing interruptions in the future (causes may include lack of preventative maintenance, training, machine ageing, etc).

Figure 17

Sponsoring company assets in supplier manufacturing facilities

[If you have [sponsoring company] machines in your facilities….] have you had any issue with these assets serious enough to lead to a service level reduction in the last ~year (e.g., breakdowns, unexpected maintenance)?



ANSWER CHOICES	RESPONSES	
Yes	19.23%	5
No	73.08%	19
N/A	7.69%	2
TOTAL		26

With our results and recommendations complete, we conclude in the next section by highlighting the impact of taking appropriate actions to improve the component supply chain in all the aforementioned areas.

6. CONCLUSION

At the beginning of this project, we sought to help the sponsoring company answer the following question regarding their component supply chain:

- What are the key drivers behind component inventory service levels and what actions can the sponsor company take to improve service level (reducing the risk of stockouts)?

A key challenge of studying service level is that in "normal" conditions, maintaining a near perfect service is often easy. For a supplier, a perfect world would be one in which demand never changes, lead times are short and non-variable, and the future is always known. Of course, unexpected events occur across all those dimensions, and thus the supplier response to those challenges is the key to understand the drivers of service level in real world conditions. This is the reason we initially decided to survey the suppliers of the sponsoring company directly and blend their response data with the qualitative sources such as demand and service level metrics maintained by the sponsoring company. Many of the trends we uncovered through our review of the data, were confirmed, or mentioned directly by the suppliers in the last question of the survey themselves (a question on open feedback for what actions could be taken to improve their service level in sales to the sponsoring company).

6.1. Recommendations

These themes led us to the recommendations discussed around various changes to be made to key areas that drive service level performance for the supplier most severely, including:

- **Trust in the Forecast:** Giving suppliers the ability to trust in and plan based on medium-long term forecasts
- **Realistic Frozen Windows:** Implementing realistic frozen periods based on direct supplier input
- **Supplier Performance Metrics:** Aligning on transparent supplier performance metrics based on the sponsoring company's segmentation of suppliers based on component criticality

6.1.1. Trust in the Forecast

To give suppliers confidence in the forecast data the first step is to ensure there is a high degree of confidence in the forecast from the sponsoring company as well. Efforts should be made first to review the forecast accuracy specifically at the component level. For unique situations such as dual sourcing a component across two suppliers, processes should be put in place at the sponsoring company to ensure that the forecast is as accurate for finished-goods requirement as it is for the associated semi-finished product (components). Once the accuracy between the finished goods and components forecasts is confirmed, MAPE data should be collected and then shared directly with suppliers for their component portfolio to inspire confidence in the forecast. In the supplier portal training materials, supplier guidance should then be updated allowing suppliers to plan with a specified degree of confidence in future-period forecast data (vs. the current guidance), and any known or pending issues with component forecast data should be communicated with an associated action plan to correct them.

6.1.2. Realistic Frozen Windows

In situations where the forecast may not be accurate or unexpected demand spikes occur, realistic frozen periods become critical to service level. While it may be a significant upfront effort for the sponsoring company to review the required frozen windows across all its top suppliers, it is essential for accurate planning. Due to COVID-19 and current global supply chain challenges, many suppliers have seen lead times for materials and parts increase and thus may not be able to respond as quickly as they were pre-pandemic, meaning any currently established frozen periods that exist may no longer be accurate. While establishing increased frozen windows will result in some cases of increased safety stock, a semi-regular review with supplier (perhaps quarterly) of frozen windows will ensure that there is visibility into the true flexibility of suppliers and will reduce service level risks by providing the sponsoring company with the ability to act immediately if fluctuations in demand require shipments changes within the window. Of course, some efforts will need to be made to ensure suppliers are providing accurate and minimal frozen periods, though with open and honest communications both parties will benefit from the process.

6.1.3. Supplier Performance Metrics

Lastly, not all components are equally critical for the sponsoring company's manufacturing process, and thus supplier performance metrics need to be established based on a segmented approach – i.e., for some components a near-perfect service level may be required whereas others that may be dual-sourced or less critical, a service level in the mid-90s (%) could be acceptable. From interviewing suppliers and analyzing results in the survey, we observed a wide range of value placed on service level and a wide range of ability (based on supplier size, access to cash) to address improving it. Therefore, the sponsoring company should evaluate suppliers differently based on their components and what the sponsoring company needs to prioritize For example, in less critical, high-volume components, quality and cost should be considered top priorities, and these priorities should be communicated directly to the supplier on a regular (again perhaps quarterly) basis. For sole-sourced, critical components, the sponsor should ensure that service level is prioritized by reviewing in detail with the supplier their ability to respond to unexpected (hypothetical) events. Specifically, the sponsoring company should ensure these suppliers are maintaining the ability to support a high service level by (1) reviewing their capacity utilization to ensure there is an appropriate amount of excess built-in, (2) confirming they have an appropriate amount of raw material inventory available to support demand variability (and financially supporting them in specific cases of small suppliers with limited cash reserves), and (3) reviewing their ability to support in situations of sudden demand increases from both a staffing and machining perspective, especially in cases of new product introductions (that often create unexpected or previously unobserved demand patterns).

In a hypothetical (best-case) scenario, a component supplier has perfect visibility into the forward looking 1–2-year forecast of the customer, allowing them to plan long term machining, staffing, and production needs appropriately. They might have also agreed on realistic short-term frozen period to maintain production efficiencies and utilize a healthy capacity. In addition, with alignment on a target service level and clear priorities on where to trade flexibility for cost, supply chain resilience and component price is optimized throughout the supply chain. On the other hand (in the worst-case scenario), fluctuations in long term demand and the bullwhip effect make planning difficult for the supplier in both the long and short term, and they struggle to maintain enough inventory while constantly planning reactively instead of proactively, with limited clarity on their specific goals, inevitably achieving a less than perfect service level.

6.2. Future Research

For future research opportunities, we recommend an additional research project focused on building a simulation model that helps to understand and predict the service level of suppliers based on the different types of supplier characteristics and variables discussed in this capstone (e.g., raw material lead-time, target capacity, etc.). To complete this project, we recommend addressing the current limitations that we have seen in our analysis which include (1) the maintenance of more robust historical service level data and metrics that detail the different reasons why a supplier had a stock out or near-stockout in the past and (2) to expand the supplier survey to a larger group of suppliers to get an increased statistical sample for a model to be trained appropriately.

For the sponsoring company, we are confident that further action in the areas discussed above, as well as the further research opportunities, will allow them to make significant service level improvements in their component inventory supply chain for their complex, global portfolio of life-saving devices.

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APPENDIX

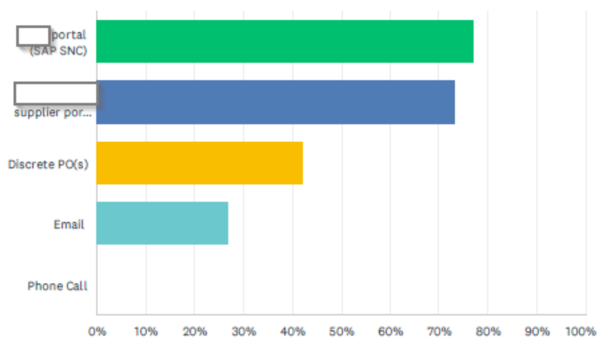
Survey sent to the suppliers

Q1 Please enter company name and group of components (only seen by MIT students and researchers, data will be anonymized before being provided back to

Answered: 26 Skipped: 0

Q2 What are you using currently to receive orders?

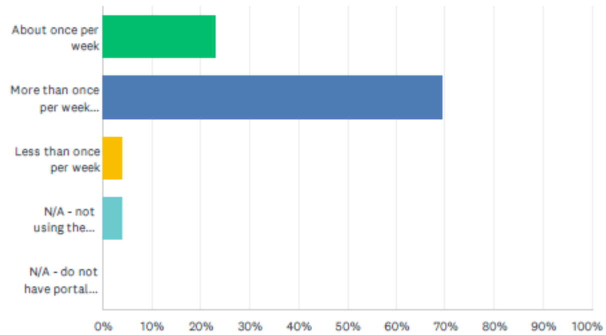
Answered: 26 Skipped: 0



ANSWER CHOICES	RESPONSES	
portal (SAP SNC)	76.92%	20
supplier portal (aka	73.08%	19
Discrete PO(s)	42.31%	11
Email	26.92%	7
Phone Call	0.00%	0
Total Respondents: 26		

Q3 How often do you view the data in the [ ] and [ ] portals?

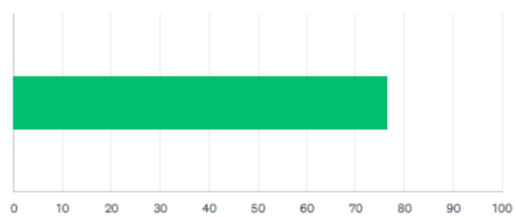
Answered: 26 Skipped: 0



ANSWER CHOICES	RESPONSES	
About once per week	23.08%	6
More than once per week (including daily)	69.23%	18
Less than once per week	3.85%	1
N/A - not using the portal	3.85%	1
N/A - do not have portal access	0.00%	0
TOTAL		26

Q4 What portion of your component orders operate on VMI vs discrete POs (for [ ] components)?

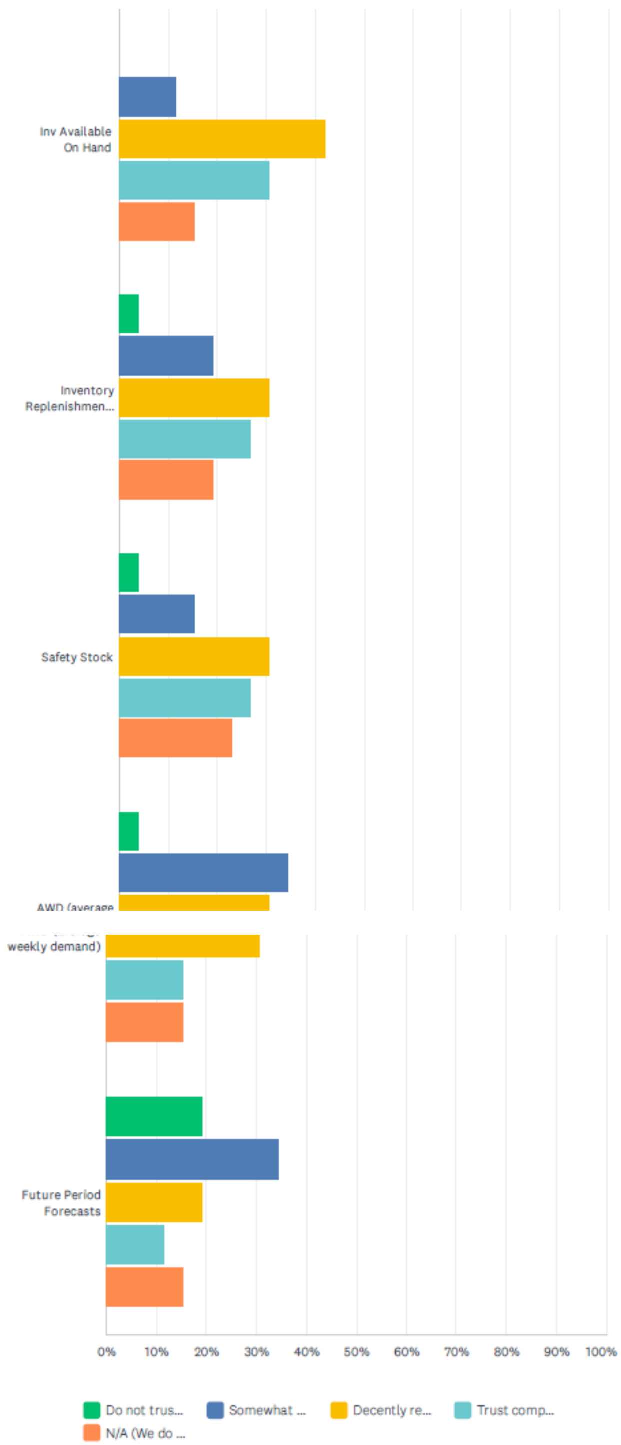
Answered: 26 Skipped: 0



ANSWER CHOICES	AVERAGE NUMBER	TOTAL NUMBER	RESPONSES
	77	2,066	27
Total Respondents: 26			

Q5 In using the portal, which elements presented in the portal do you use to plan production, and which elements of the portal do you trust?

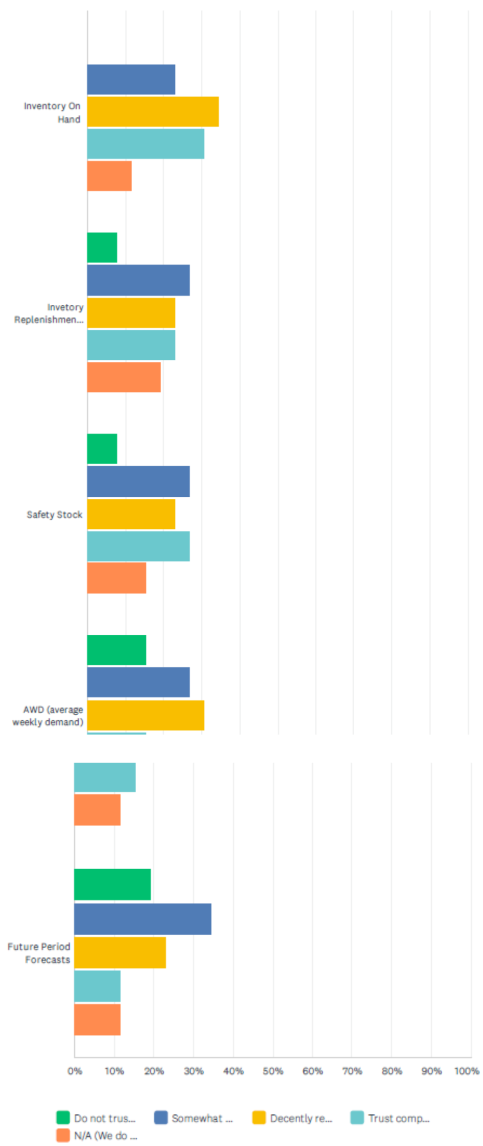
Answered: 26 Skipped: 0



	DO NOT TRUST OR FIND RELIABLE ENOUGH TO USE TO PLAN PRODUCTION	SOMEWHAT RELIABLE, USED SOMEWHAT TO PLAN PRODUCTION	DECENTLY RELIABLE, USED OFTEN TO PLAN PRODUCTION	TRUST COMPLETELY, ALWAYS USED TO PLAN PRODUCTION	N/A (WE DO NOT USE OR HAVE ACCESS TO THIS PORTAL)	TOTAL
Inv Available On Hand	0.00% 0	11.54% 3	42.31% 11	30.77% 8	15.38% 4	26
Inventory Replenishment Leve (IRL) QTY	3.85% 1	19.23% 5	30.77% 8	26.92% 7	19.23% 5	26
Safety Stock	3.85% 1	15.38% 4	30.77% 8	26.92% 7	23.08% 6	26
AWD (average weekly demand)	3.85% 1	34.62% 9	30.77% 8	15.38% 4	15.38% 4	26
Future Period Forecasts	19.23% 5	34.62% 9	19.23% 5	11.54% 3	15.38% 4	26

Q6 In using the portal, which elements presented in the portal do you use to plan production, and which elements of the portal do you trust?

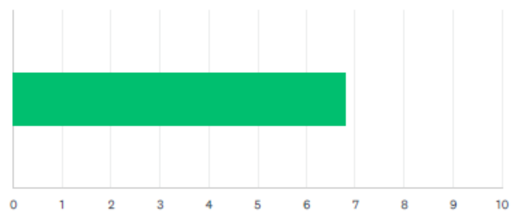
Answered: 26 Skipped: 0



	DO NOT TRUST OR FIND RELIABLE ENOUGH TO USE TO PLAN PRODUCTION	SOMEWHAT RELIABLE, USED SOMEWHAT TO PLAN PRODUCTION	DECENTLY RELIABLE, USED OFTEN TO PLAN PRODUCTION	TRUST COMPLETELY, ALWAYS USED TO PLAN PRODUCTION	N/A (WE DO NOT USE OR HAVE ACCESS TO THIS PORTAL)	TOTAL
Inventory On Hand	0.00% 0	23.08% 6	34.62% 9	30.77% 8	11.54% 3	26
Invetory Replenishment Level (IRL) QTY	7.69% 2	26.92% 7	23.08% 6	23.08% 6	19.23% 5	26
Safety Stock	7.69% 2	26.92% 7	23.08% 6	26.92% 7	15.38% 4	26
AWD (average weekly demand)	15.38% 4	26.92% 7	30.77% 8	15.38% 4	11.54% 3	26
Future Period Forecasts	19.23% 5	34.62% 9	23.08% 6	11.54% 3	11.54% 3	26

Q7 On a scale of 1-10, in general, how much does the data in the portal directly drive your production as the single source of truth vs. other sources of information? Please skip this question if you do not use the portal.

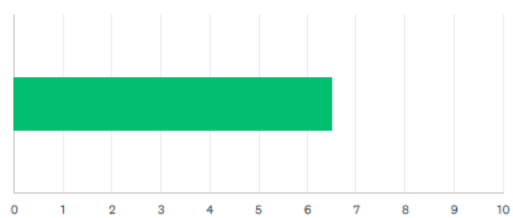
Answered: 19 Skipped: 7



ANSWER CHOICES	AVERAGE NUMBER	TOTAL NUMBER	RESPONSES
	7	136	20
Total Respondents: 19			

Q8 On a scale of 1-10, in general, how much does the data in the portal directly drive your production as the single source of truth vs. other sources of information? Please skip this question if you do not use the portal.

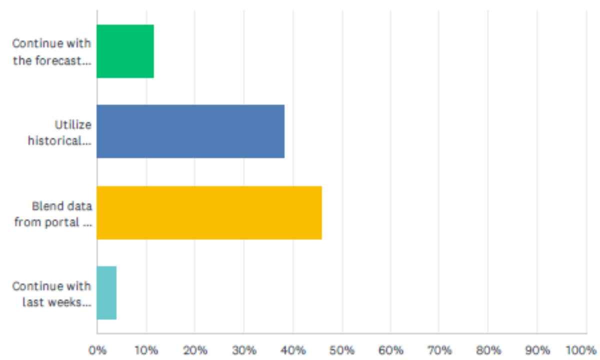
Answered: 21 Skipped: 5



ANSWER CHOICES	AVERAGE NUMBER	TOTAL NUMBER	RESPONSES
	7	143	22
Total Respondents: 21			

Q9 When you don't trust the production signal (e.g. high variation on demand) from [ ] portals, or you see a signal that is too high or too low and cannot receive timely feedback, how do you instead plan your production?

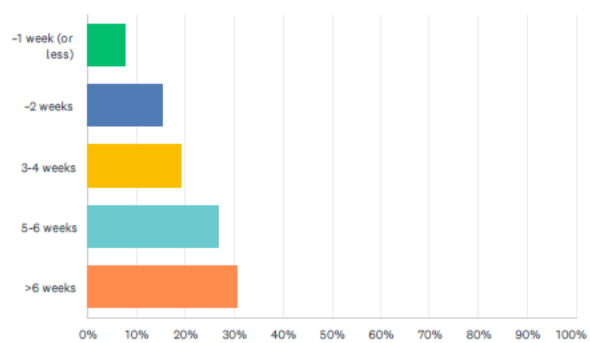
Answered: 26 Skipped: 0



ANSWER CHOICES	RESPONSES	
Continue with the forecast in the portal anyways	11.54%	3
Utilize historical demand/shipments as the source of truth	38.46%	10
Blend data from portal and historical shipments	46.15%	12
Continue with last weeks rhythm wheel (do not change the production plan)	3.85%	1
TOTAL		26

Q10 What is your end-to-end manufacturing average lead time for producing these specific [ ] components (assuming raw material is already on hand and available, including any manufacturing activities such as outsourced production)?

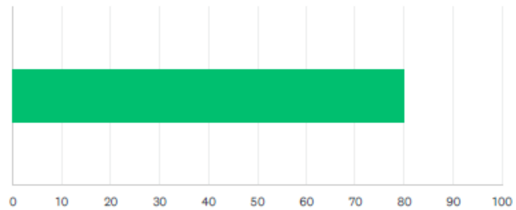
Answered: 26 Skipped: 0



ANSWER CHOICES	RESPONSES	
~1 week (or less)	7.69%	2
~2 weeks	15.38%	4
3-4 weeks	19.23%	5
5-6 weeks	26.92%	7
>6 weeks	30.77%	8
TOTAL		26

Q11 What is your target (ideal) installed capacity utilization % (overall estimate for [ ] products)?

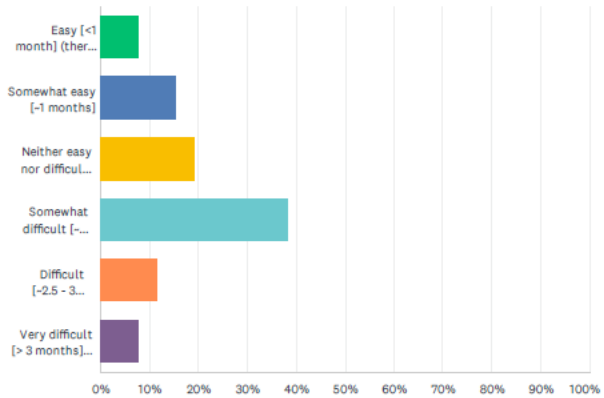
Answered: 26 Skipped: 0



ANSWER CHOICES	AVERAGE NUMBER	TOTAL NUMBER	RESPONSES
	80	2,163	27
Total Respondents: 26			

Q12 How challenging is it to increase your available staffing capacity to support production if/when needed (excluding challenges stemming from COVID-19)?

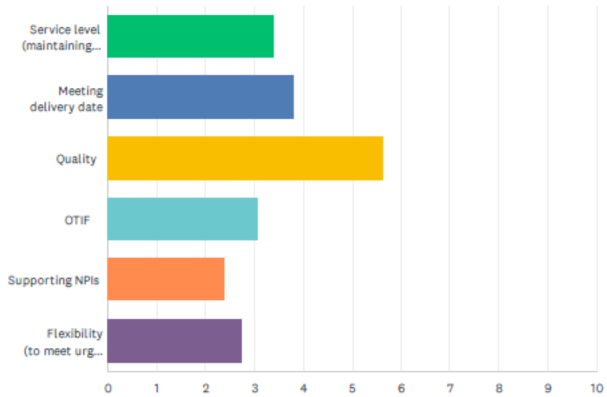
Answered: 26 Skipped: 0



ANSWER CHOICES	RESPONSES	
Easy [<1 month] (there is enough supply of capable and interested candidates)	7.69%	2
Somewhat easy [~1 months]	15.38%	4
Neither easy nor difficult [~1.5 - 2 months]	19.23%	5
Somewhat difficult [~2 - 2.5 months]	38.46%	10
Difficult [~2.5 - 3 months]	11.54%	3
Very difficult [> 3 months] (there is not enough supply of capable and interested candidates)	7.69%	2
TOTAL		26

Q13 Please rank from 1-6 your most critical metrics internally used when measuring your performance for VMI?

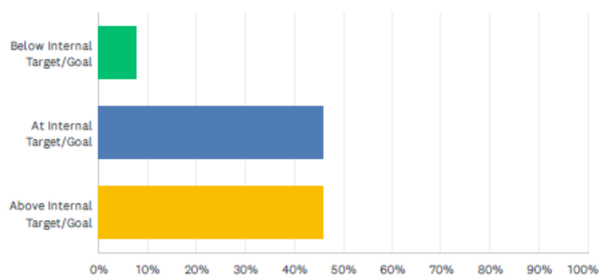
Answered: 26   Skipped: 0



	1	2	3	4	5	6	TOTAL	SCORE
Service level (maintaining or improving target service level)	0.00% 0	26.92% 7	26.92% 7	15.38% 4	19.23% 5	11.54% 3	26	3.38
Meeting delivery date	0.00% 0	38.46% 10	26.92% 7	23.08% 6	0.00% 0	11.54% 3	26	3.81
Quality	88.46% 23	3.85% 1	0.00% 0	0.00% 0	3.85% 1	3.85% 1	26	5.62
OTIF	0.00% 0	19.23% 5	19.23% 5	23.08% 6	26.92% 7	11.54% 3	26	3.08
Supporting NPIs	3.85% 1	3.85% 1	15.38% 4	23.08% 6	11.54% 3	42.31% 11	26	2.38
Flexibility (to meet urgent requests or spikes in demand)	7.69% 2	7.69% 2	11.54% 3	15.38% 4	38.46% 10	19.23% 5	26	2.73

Q14 On average, based on the criteria in the previous question, how do you consider your overall performance as a supplier in 2021? Please exclude KPIs reductions caused primarily by COVID-19.

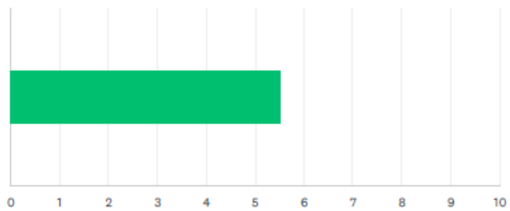
Answered: 26   Skipped: 0



ANSWER CHOICES	RESPONSES	
Below Internal Target/Goal	7.69%	2
At Internal Target/Goal	46.15%	12
Above Internal Target/Goal	46.15%	12
TOTAL		26

Q15 Excluding VMI inventory at locations, how many weeks (if any) of additional safety stock of components do you hold at your own location(s)?

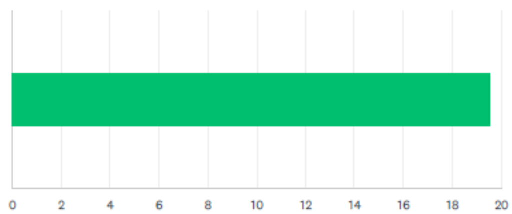
Answered: 26   Skipped: 0



ANSWER CHOICES	AVERAGE NUMBER	TOTAL NUMBER	RESPONSES
	6	149	27
Total Respondents: 26			

Q16 What is your average raw material lead time (in weeks, for the materials of the specified components, e.g., metals, plastics, used in products)?

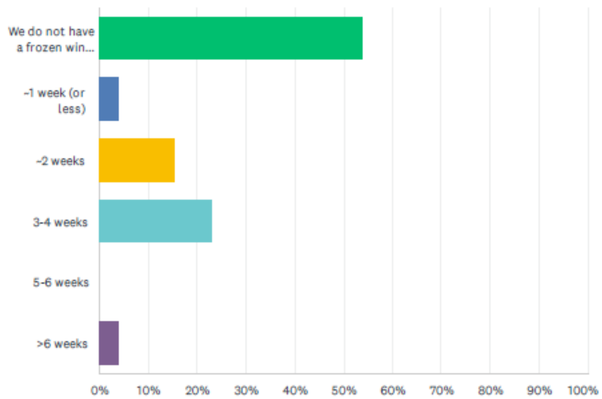
Answered: 26   Skipped: 0



ANSWER CHOICES	AVERAGE NUMBER	TOTAL NUMBER	RESPONSES
	20	528	27
Total Respondents: 26			

Q17 What is your frozen production window, if applicable (agreed to with)?

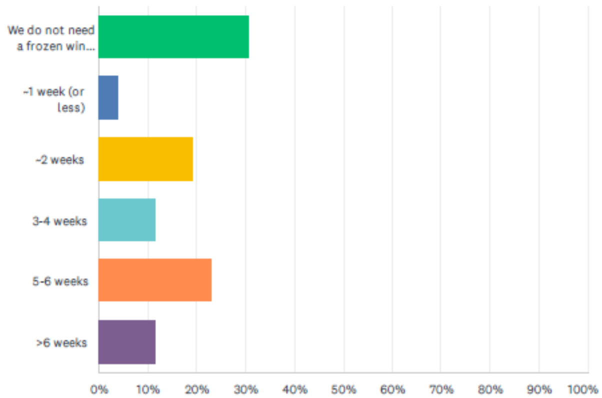
Answered: 26 Skipped: 0



ANSWER CHOICES	RESPONSES	
We do not have a frozen window in place with Ethicon/Jabil	53.85%	14
~1 week (or less)	3.85%	1
~2 weeks	15.38%	4
3-4 weeks	23.08%	6
5-6 weeks	0.00%	0
>6 weeks	3.85%	1
TOTAL		26

Q18 What is your ideal/desired frozen production window, if applicable, with ?

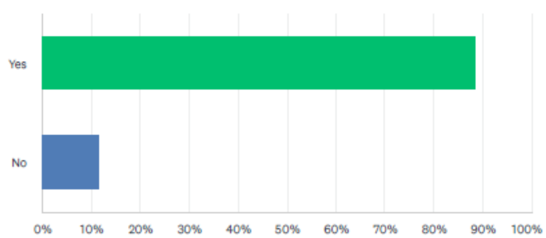
Answered: 26 Skipped: 0



ANSWER CHOICES	RESPONSES	
We do not need a frozen window	30.77%	8
~1 week (or less)	3.85%	1
~2 weeks	19.23%	5
3-4 weeks	11.54%	3
5-6 weeks	23.08%	6
>6 weeks	11.54%	3
TOTAL		26

Q19 Do you have any -owned assets in your production facilities?

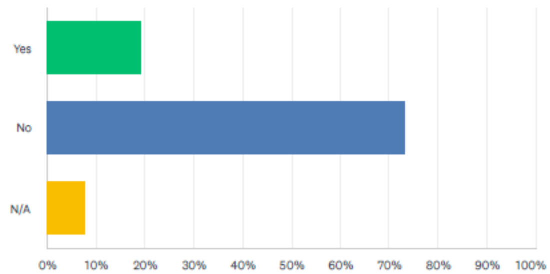
Answered: 26 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	88.46%	23
No	11.54%	3
TOTAL		26

Q20 If "yes" -- have you had any issue with these assets serious enough to lead to a service level reduction in the last ~year (e.g., breakdowns, unexpected maintenance)?

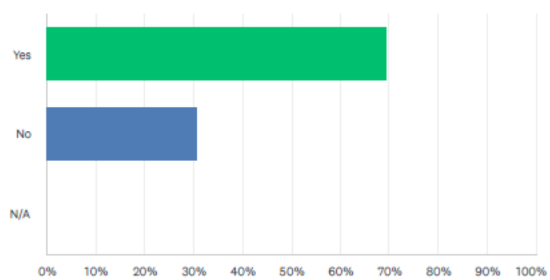
Answered: 26 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	19.23%	5
No	73.08%	19
N/A	7.69%	2
TOTAL		26

Q21 For components supplied to [ ] do the majority (>50%) of these components run on the same machine, work-center, or production process (i.e., is the same machine, work-center, or production process involved in manufacturing more than half of the supplied components, either by SKU count or volume)?

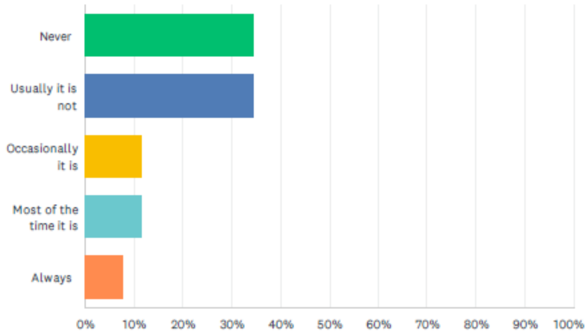
Answered: 26 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	69.23%	18
No	30.77%	8
N/A	0.00%	0
TOTAL		26

Q22 For communications on component life cycle (phase in & phase out) and/or new product introduction signals, is the supplier portal ( ), your main source of this information?

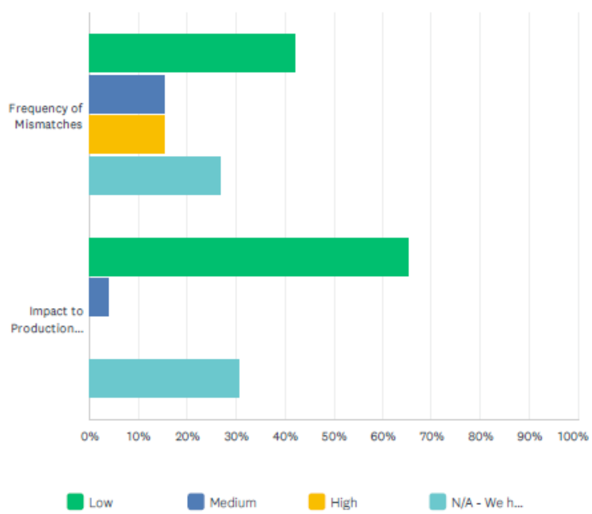
Answered: 26 Skipped: 0



ANSWER CHOICES	RESPONSES	
Never	34.62%	9
Usually it is not	34.62%	9
Occasionally it is	11.54%	3
Most of the time it is	11.54%	3
Always	7.69%	2
TOTAL		26

Q23 In the Supplier Portal, do payment mismatches you may have experienced have any impact on your production planning process?

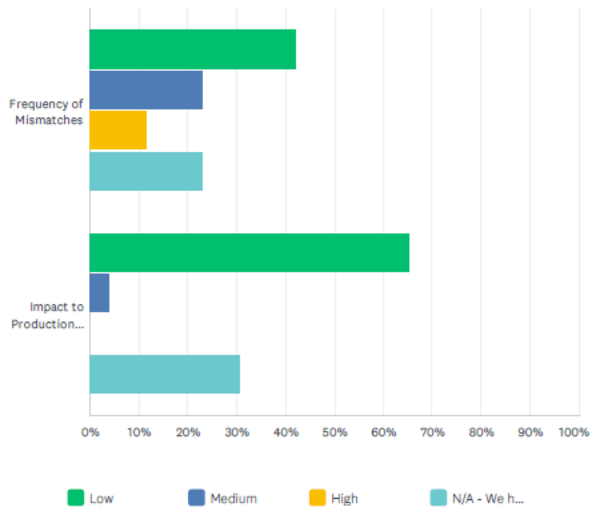
Answered: 26 Skipped: 0



	LOW	MEDIUM	HIGH	N/A - WE HAVE NOT EXPERIENCED THIS	TOTAL
Frequency of Mismatches	42.31% 11	15.38% 4	15.38% 4	26.92% 7	26
Impact to Production Planning	65.38% 17	3.85% 1	0.00% 0	30.77% 8	26

Q24 In the Supplier Portal, do payment mismatches you may have experienced have any impact on your production planning process?

Answered: 26 Skipped: 0



	LOW	MEDIUM	HIGH	N/A - WE HAVE NOT EXPERIENCED THIS	TOTAL
Frequency of Mismatches	42.31% 11	23.08% 6	11.54% 3	23.08% 6	26
Impact to Production Planning	65.38% 17	3.85% 1	0.00% 0	30.77% 8	26

Q25 What is the number one change that could make to help you as a supplier increase your service level or decrease component lead times (e.g., better forecast accuracy, implementing a frozen window, greater visibility, better communication, etc...)?

Answered: 23 Skipped: 3