Supply Chain Under COVID-19: a Case Study of a Multinational Pharmaceutical Company in Indonesia

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ABSTRACT

The healthcare sector is pivotal during a pandemic. To cope with the pandemic, a robust and resilient pharmaceutical supply chain is of paramount importance. Global logistics mobility has become a pivotal factor to enable the cross-border materials supply to arrive at the pharmaceutical production base. The COVID-19 pandemic has severely limited logistics mobility due to lockdowns, and community quarantines. A case study was conducted in an export-oriented multinational pharmaceutical company in Indonesia to investigate the main causal and intermediate events that led to the disruption of the pharmaceutical supply chain following the COVID-19 pandemic. There are two purposes of the study: (1) to provide the framework for the relevant industry in assessing the risk of the materials supply based on the logistics mobility risk and the demand projection of products with significant volume contribution; (2) to propose risk mitigation framework for supply chain planning process under similar economic shock. The study showed that air freight frequency used by the company in Q2-Q3 2020 has increased by 36 % vs YoY 2019; Materials with the highest supply vulnerabilities originated from regions Europe and North America; Concurrent supply chain planning process, Product Category Convergence Matrix, and SKU Prioritization Matrix were used by the company to formulate the strategic and operational mitigation in reducing vulnerabilities.

Keywords: *COVID-19, Logistics Mobility, Pharmaceutical Supply Chain, Supply Vulnerability*

I. INTRODUCTION

The global impact of the 2019 coronavirus disease (COVID-19) has been well-reported. This outbreak was deemed a pandemic by the World Health Organization (WHO) on 11th March 2020. During the 1st wave in 2020, there have been cases confirmed in at least 216 countries, areas, or territories, according to data provided by WHO (WHO, 2020). The COVID-19 pandemic has caused unprecedented measures to be taken by many countries, such as travel restrictions and restrictions on social gatherings (De Vos, 2020).

The Healthcare sector plays a critical role in protecting citizens against health risks arising from epidemics. Citizens expect the government to provide response systems to handle emergencies adequately, thus a robust and resilient pharmaceutical supply chain that is free of disruption is of paramount importance. In a globalized market, pharmaceutical production in one country has involved a complex supply chain network of raw materials suppliers from many countries. Global logistics mobility has become a pivotal factor to enable the cross-border raw materials supply to arrive at the production base.

Chopra and Meindl introduced the three logistical drivers: facilities, inventory, and transportation; and the three cross-functional drivers: information, sourcing, and pricing. These drivers will determine the performance of any supply chain. They also emphasized that the main objective of any company's supply chain is to achieve the balance between responsiveness and efficiency that best supports the company's competitive strategy. A supply chain's performance in terms of responsiveness and efficiency is based on the interaction between the following logistical and cross-functional drivers of supply chain performance: facilities, inventory, transportation, information, sourcing, and pricing (Chopra and Meindl, 2016).

A case study is conducted in an export-oriented multinational pharmaceutical company with a production base in Indonesia to investigate the main causal and intermediate events that led to the disruption of the pharmaceutical supply chain following the COVID-19 pandemic. The company produced health supplements, consisting mainly of multivitamins for local supply in Indonesia and 30 export countries on five continents where during the pandemic, the company experienced a demand surge for this product category. While in the other hand, the company also experienced severe logistics mobility disruption for materials imported from overseas suppliers. Referring to the framework of logistical drivers and cross-functional drivers mentioned above, there is a gap in practical knowledge on how the COVID-19 pandemic has affected those drivers, and how to ensure the supply chain responsiveness for highly demanded products during unprecedented events. The main purpose of the study is: (1) to provide the framework for the pharmaceutical industry in assessing the risk of the materials supply based on the logistics mobility risk and the demand projection of products with significant volume contribution; (2) to propose risk mitigation framework for supply chain planning process under pandemic situation while considering the responsiveness and efficiency objective. This framework could be used in the future to prepare risk mitigation for a similar economic shock. Therefore, the study was conducted to answer the following research questions:

- What is the COVID-19 impact on logistics mobility?
- What is the COVID-19 impact on materials supply vulnerability?
- How does the company execute the supply chain planning best practices for risk mitigation?

II. METHODS

A. *Measuring the COVID-19 Impact on Logistics Mobility*

A retrospective, time trend analysis of the ocean and air freight volume globally from the internal secondary data source as well as the air freight volume from the case study was performed from February 2nd to May 12th, 2020. The secondary data was collected through surveys that were distributed via email as well as via phone call interviews with the freight forwarders contracted by the pharmaceutical company where the case study is conducted (the company).

B. *Measuring the COVID-19 Impact on Materials Supply Vulnerability*

To assess the risk of the COVID-19 pandemic to materials supply continuity in the pharmaceuticals supply chain, the case study has been conducted in an export-oriented multinational pharmaceutical company with a production base in Indonesia (the company).

To understand the forward-looking materials supply vulnerability, the next 12 months' demand projection data was retrieved from SAP Advanced Planning and Optimization (SAP APO). This projection was used as the basis to do finished goods (FG) inventory ABC analysis. In materials management, ABC analysis is an inventory categorization technique. ABC analysis classifies an inventory into three categories—"A items" with very strict control and accurate records, "B items" with less strictly controlled and good records, and "C items" with the simplest controls possible and minimal records. The ABC analysis provides a mechanism for identifying items that will have a significant impact on overall inventory cost (Vollmann *et al*., 2005), while also providing a mechanism for identifying different categories of stock that will require different management and controls.

There are no fixed thresholds for each class, and different proportions can be applied based on objectives and criteria. ABC Analysis is similar to the Pareto principle in that the 'A' items will typically account for a large proportion of the overall value, but a small percentage of the number of items (Lysons and Farrington, 2006).

Examples of ABC class are

- 'A' items – 20% of the items account for 70% of the annual consumption value of the items
- 'B' items – 30% of the items accounts for 25% of the annual consumption value of the items
- 'C' items – 50% of the items accounts for 5% of the annual consumption value of the items

Another recommended breakdown of ABC classes (Wild, 2002):

- "A" approximately 10% of items or 66.6% of the value
- "B" approximately 20% of items or 23.3% of the value
- "C" approximately 70% of items or 10.1% of the value

Since the case study was conducted in a pharmaceutical manufacturing company, the ABC analysis was slightly adjusted to consider not only the inventory value but also the annual production volume for each FG stock-keeping unit (SKU) based on the Pareto principle applied in the analysis.

The result of FG ABC analysis was then used for prioritization in doing Bill of Materials (BOM) explosion analysis. A BOM or product structure is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts, and the quantities of each needed to manufacture an end product. A BOM may be used for communication between manufacturing partners or confined to a single manufacturing plant. A bill of materials is often tied to a production order whose issuance may generate reservations for components in the bill of materials that are in stock and requisitions for components that are not in stock (Reid and

Sanders, 2009). FG that are categorized as “A” class items were analyzed further to understand the required material components or ingredients via SAP Enterprise Resource Planning Materials Management (SAP ERP MM).

The material supply vulnerability assessment was conducted for the required material components under the “A” class FG items. The evaluation criteria for the assessment were designed through focused group discussion with material planners and material buyers using the consensus-oriented decision-making (CODM) approach (Hartnett, 2011). There are five material supply vulnerability parameters were chosen based on CODM results to assess the risk:

- Ordering lead time
- Material shelf-life
- Minimum Order Quantity (MOQ) supply coverage
- Regulation status of the material
- Sourcing complexity of the material

To weigh the risk consequences of each material supply vulnerability parameter, Analytic Hierarchy Process (AHP) was used as the decision-making method. The goal was to measure material supply vulnerability, and the aforementioned parameters were gone through expert evaluation using Pairwise Comparison with the scale shown in table I below (Saaty, 2008).

TABLE I. FUNDAMENTAL SCALE FOR PAIRWISE COMPARISON

Intensity of Importance	Definition	Explanation
1	Equal importance	Two parameters contribute equally to the goal
3	Moderate/weak importance of one over another	Experience and judgment slightly favor one parameter over another
5	Essential or strong importance	Experience and judgment strongly favor one parameter over another
7	Demonstrated importance	One parameter is favored very strongly over another; its dominance is demonstrated in practice
9	Absolute importance	The evidence favoring one parameter over

Intensity of Importance	Definition	Explanation
		another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed between intensity.

Source: adapted from Saaty (2008)

TABLE II. RISK LEVEL SCALE (RLS)

Risk Level	Expected Vulnerability Score
Low	1.0 – 3.6
Medium	3.7 – 6.3
High	6.4 – 9.0

Source: Author

The vulnerability of the parameters was calculated by using Vulnerability Rating on the scale of 1, 3, 5, 7, and 9 the higher the more vulnerable to supply disruption risk. The risk level was evaluated against the vulnerability score in table II. Table III shows the evaluation criteria for the risk assessment.

A firm's vulnerability to a disruptive event can be viewed as a combination of the likelihood of disruption and its potential severity. To measure factors affecting vulnerability, a metric of "expected vulnerability" can be used and such a metric would be the product of probability and consequences (Sheffi, 2007).

Expected Vulnerability (*xV*) can be expressed mathematically as the sum of individual material supply vulnerability for each parameter (*v*), where *v* can be computed as the product of risk probability (*p*) and its risk consequences (*c*). This risk level computation can be expressed into mathematical conceptualization as follows:

$$xV = \sum pici \quad (1)$$

$$vi = pi.ci \quad (2)$$

$$xV = vLT + vSL + vMQ + vRS + vSC \quad (3)$$

*p*LT : Lead Time risk probability

*c*LT : Lead Time risk consequences

*p*SL : Shelf-Life risk probability

*c*SL : Shelf-Life risk consequences

*p*MQ : MOQ supply coverage risk probability

*c*MQ : MOQ supply coverage risk consequences

*p*RS : Regulation Status risk probability

*c*RS : Regulation Status risk consequences

*p*SC : Sourcing Complexity risk probability

*c*SC : Sourcing Complexity risk consequences

TABLE III. EVALUATION CRITERIA FOR MATERIAL SUPPLY VULNERABILITY ASSESSMENT

Parameter	**Vulnerability Rating**				
	1	**3**	**5**	**7**	**9**
Lead Time	≤ 30 days	31-45 days	46-75 days	76-120 days	>120 days
Shelf-life	60 months	48 months	36 months	24 months	12 months
MOQ Coverage	< 60 days	60 – 74 days	75 – 89 days	90 – 179 days	≥ 180 days
Regulation Status	Non-regulated	Do & Tell	Prior Notification (Tell & Do)	Prior Approval (Tell, Wait, Do)	New Registration
Sourcing Complexity	Dual sourced with different parent company	Single sourced, however with multiple manufacturing sites of the same supplier	Ongoing qualification of the second manufacturing site	Single sourced commodity with various potential suppliers	Single sourced non-commodity/specialty with limited potential suppliers

Source: Author

C. *Formulating Supply Chain Planning For Risk Mitigation*

Observational research was done from February until December 2020 in which the author was directly involved in the management activities within the company to devise operational, tactical, and strategic risk mitigation.

III. RESULTS

The containment measures in most countries in the world have caused a shock that has simultaneously affected demand and supply in freight forwarding activities. The imbalance between demand and supply has severely limited cross-border logistics mobility. This situation became very critical for pharmaceutical companies in Indonesia due to the fact that up to 90% of the active pharmaceutical ingredients (API) consumption is imported from overseas (INDEF, 2020).

A. *COVID-19 Pandemic Impact on Logistics Mobility*

Based on the information compiled from the email survey and phone interview between February 2nd – May 12th, 2020 with freight forwarders contracted by the company, a significant imbalance in freight demand and supply was observed since March 11th, 2020 when WHO announced COVID-19 as a global pandemic. Freight demand and capacity index by region of origin and destination was created to show the situation during those periods (table IV and table V). Port locations are divided into six regions: North America (NA), Latin America (LATAM), Europe (EUR), North Asia (N. Asia), South Asia (S. Asia), Middle East and Africa (MEA).

Based on the region classifications mentioned earlier, Indonesia is grouped under South Asia. From table V, we can infer that ocean freight demand with origin from EUR, LATAM, and destination to S. Asia has exceeded the capacity. While ocean freight originated from NA and N. Asia (incl. China) with destination to S. Asia has limited capacity due to generally higher demand. Only ocean freight demand originated from S. Asia and MEA that has normal capacity levels to serve the destination to S. Asia. Saturated ocean freight capacity for the destination to S. Asia from most of the ports of origin during this period, while the need to get API supply to Indonesia is even higher due to market demand spike for multivitamins driven by COVID-19 pandemic in Indonesia, has forced the company to opt for air freight mode for better logistics mobility.

TABLE IV. AIR MARKET DEMAND AND CAPACITY INDEX

REGION		**DESTINATION**					
		NA	LATAM	EUR	N. Asia	S. Asia	MEA
ORIGIN	NA						
	LATAM						
	EUR						
	N. Asia						
	S. Asia						
	MEA						

Source: Author

TABLE V. OCEAN MARKET DEMAND AND CAPACITY INDEX

REGION		**DESTINATION**					
		NA	LATAM	EUR	N. Asia	S. Asia	MEA
ORIGIN	NA	[Green]	[Yellow]	[Yellow]	[Yellow]	[Yellow]	[Yellow]
	LATAM	[Yellow]	[Green]	[Green]	[Green]	[Red]	[Yellow]
	EUR	[Red]	[Yellow]	[Green]	[Red]	[Red]	[Red]
	N. Asia	[Yellow]	[Green]	[Yellow]	[Green]	[Yellow]	[Green]
	S. Asia	[Green]	[Green]	[Yellow]	[Green]	[Green]	[Red]
	MEA	[Yellow]	[Green]	[Green]	[Green]	[Green]	[Green]

Source: Author

TABLE VI. CAPACITY INDEX LEGEND

Color Code	**Explanation**
[Red]	Demand has exceeded available capacity
[Yellow]	Demand is higher and/or capacity is limited
[Green]	Demand and capacity at normal levels

Source: Author

Table VII shows that during the same period Feb-May 2020, the air freight frequency used by the company has increased by 36 % vs year on year 2019. While the tonnage of the goods imported via air in Feb-May 2020 has significantly higher than 2019 YoY by 119%. For the freight originating from EUR, there were suddenly higher frequency and tonnage via air in Feb-May 2020, a contrast to 2019 YoY where air freight was non-existence. This is somehow correlated to the situation in most European countries where the start of lockdown measures was implemented around mid of March (DW, 2020). This situation not only affected the company, but in general, it affected the global air freight volume as shown in fig.1.

B. *COVID-19 Impact on Materials Supply Vulnerability*

There are 149 FG SKUs produced by the company both for local and export markets. Demand projections of those 149 FG SKUs for 12 months onwards were downloaded from SAP APO and further analyzed using ABC class analysis. Out of 149 SKUs, only 26 SKUs will contribute to 70% of annual production volume as shown in table VIII.

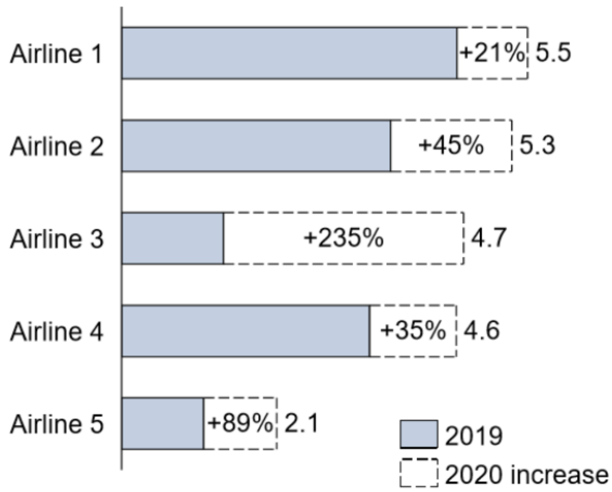


Fig.1. Air freight volume (thousand tons) of top 5 airlines on 15-21 April 2020 vs the same week of 2019 (*source: Seabury*)

TABLE VII. AIRFREIGHT VOLUME COMPARISON YEAR ON YEAR

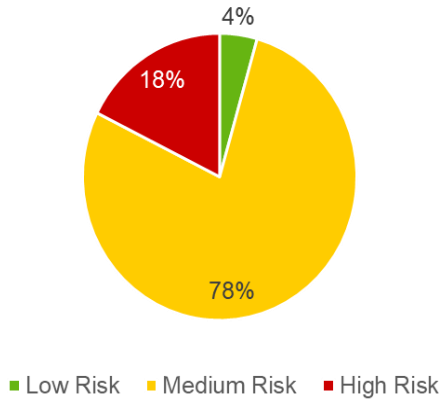
Origin	**Feb-May 2019**		**Feb-May 2020**	
	Frequency	Tonnage	Frequency	Tonnage
EUR	-	-	6	80.79
N. Asia	6	98.05	16	252.28
S. Asia	7	49.68	6	72.52
NA & LATAM	2	14.40	2	33.81
MEA	7	38.60	-	-
TOTAL	**22**	**200.73**	**30**	**439.40**

Source: Author

BOM explosion was done for 26 FG SKUs that are part of item class A. BOM analysis was downloaded from SAP ERP MM for those item class A SKUs. Based on the analysis, there are 68 raw material ingredients that are required to produce those 26 FG SKUs.

CODM approach was used during the FGD involving material planners and material buyers to assess the material supply vulnerability based on the evaluation criteria in table III, and then calculated the RLS based on equation (1). Out of 68 raw material ingredients, there are 18% categorized as high risk, 78% as medium risk, and only 4% as low risk (fig.2). To understand the relationship between logistics mobility discussed in the earlier section, boxplot analysis was used to show the distribution of risk level scale of each material based on the region of origin (fig.3).

Based on the boxplot analysis, we can infer that most of the materials with high RLS originated from regions EUR and NA, while for other regions only an outlier came from N. Asia. The results of the assessment show that the vulnerability of the raw materials for the A class items produced by the company is rather high for the ones imported from EUR and NA regions.



Source: Author

Fig.2. Proportion of risk level scale of 68 material ingredients

TABLE VIII. ABC CLASS ANALYSIS OF 12 MONTHS ROLLING FORECAST OF 149 SKUS

Item Class	**% Annual Volume**	**Count of SKU**	**% Total SKU**
A	70%	26	17%
B	21%	43	29%
C	9%	80	54%
TOTAL	100%	149	100%

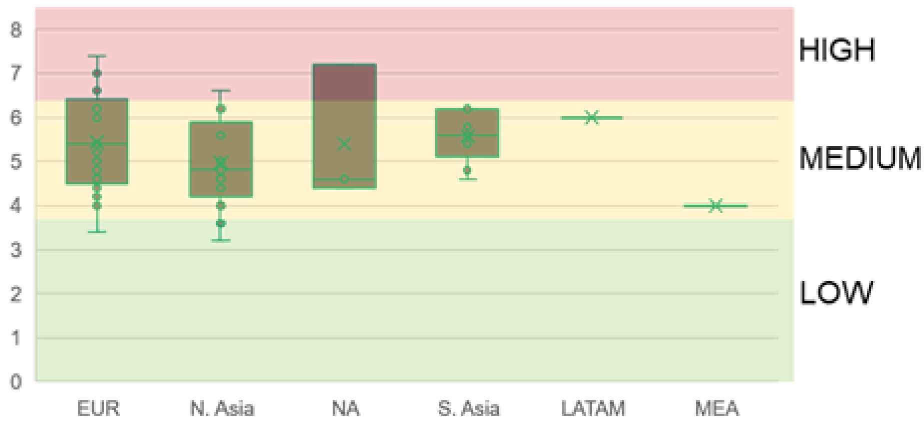
Source: Author

C. *Best Practices of Supply Chain Planning For Risk Mitigation*

The company is classified as a manufacturing company that produces pharmaceuticals and food supplements mainly for the market within Asia-Pacific countries. The pharmaceuticals and food supplements industry is well-known as a highly regulated industry, in which changes must be managed accordingly to ensure compliance with the regulation. To better understand the market dynamics and its linkage to manufacturing capabilities, the company categorized its products based on two main classifications: (1) Therapeutic Area; (2) Regulatory Perspective.

The classification is based on Therapeutic Area resulting in categories as below:

- Nutritional
- Cough & Cold
- Analgesics
- Digestive Health
- Medicated Skin Care
- Allergy
- Cardiovascular



Source: Author

Fig.3. Box Plot of risk level scale of 68 materials based on the region of origin

Based on a regulatory perspective, the products are classified into three categories:

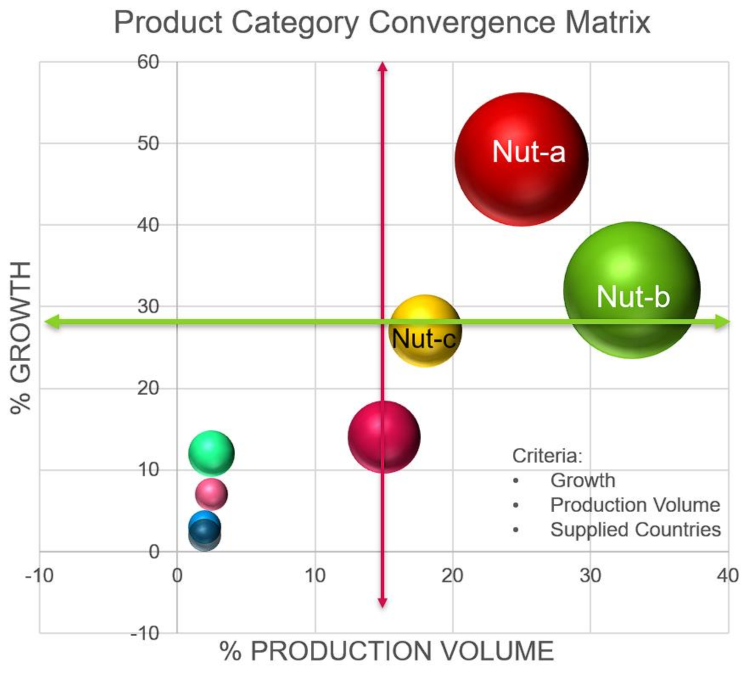
- Rx (by prescription only)
- Over-The-Counter (OTC) Drug
- OTC Supplements

The company evaluated the market dynamics during the COVID-19 pandemic based on actual demand data of each SKU according to the sales orders report for the 1st half of 2020. To understand the impact of the pandemic to demand growth, the sales orders of 2020 were compared to the same period of 2019. To understand the magnitude of supply impact, the company also identifies the number of countries supplied for each of the product categories. According to this data, three criteria were compared between product categories as shown in table IX. From the table it can be inferred that the Nutritional category had experienced the highest YoY growth, the highest 12 months rolling forecast production volume, as well as the most countries to be supplied. To create a more granular overview of the Nutritional category, three sub-categories were created: Nut-a (High vitamin C and D), Nut-b (High vitamin B-complex), and Nut-c (High vitamin C and high calcium). The product category convergence matrix (Fig.4) was used to identify the category that has the highest demand and supply magnitude during the pandemic period.

TABLE IX. PRODUCT CATEGORY MAPPING

Category	**YoY Growth**	**Volume Contribution**	**Number of Supplied Countries**
Nut-a	48%	25%	17
Nut-b	32%	33%	18
Nut-c	27%	18%	5
Cough & Cold	12%	2.5%	2
Analgesics	14%	15%	5
Others	<10%	6.5%	1

Source: Author



Source: Author

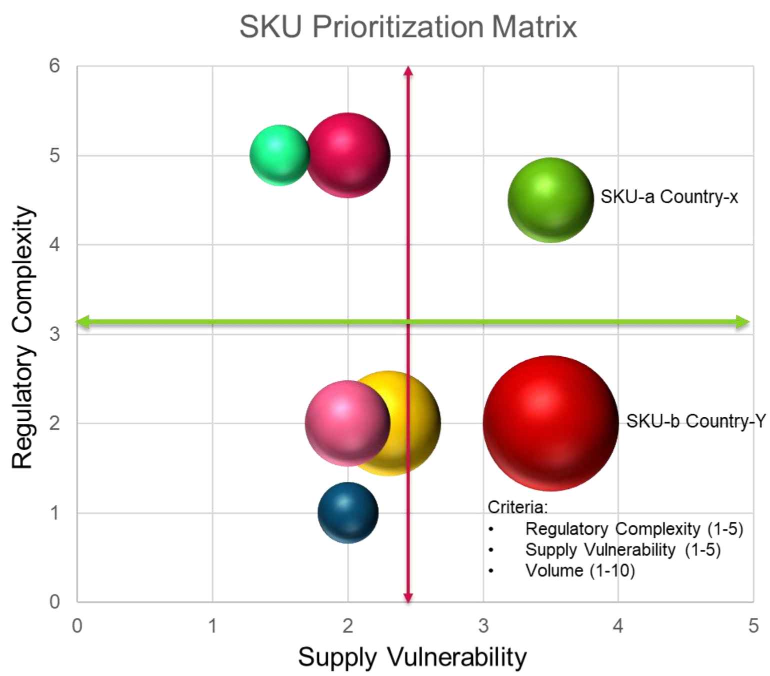
Fig.4. Product Category Convergence Matrix for the company products

Product Category Convergence Matrix (PCC Matrix) combined three criteria to be evaluated for strategic supply chain decisions and split the grouping into four quadrants. On the y-axis, it shows the % of demand growth, while on the x-axis it shows the % of production volume contribution. The bubble size represents the number of countries supplied, the more countries the bigger the bubble size. Based on the PCC Matrix, it can be inferred that all products under the Nutritional category are placed in the high growth and high production volume quadrant. The company used this matrix to decide the supply chain resources allocation and prioritization, where during the pandemic period products under the Nutritional category is the most sought by the market. With this fact, the supply chain resource allocation is prioritized toward Nutritional products. The supply chain resources are production facilities, inventory, transportation, information, sourcing, and pricing.

The company used the PCC matrix result to set up the supply chain operational mitigation plan. The main constraint in production facilities is capacity. With the fact that all nutritional products are placed in the high growth-high volume quadrant, the available capacity was prioritized for those products. However, another constraint arises in which the demand during the peak pandemic period exceeded the available capacity. There was a risk of low service level while the company had received growing pressure from local health authorities as well as some health authorities for export countries destinations due to the urgency of nutritional supply to boost up the immune system of the society. Risk pooling is widely used in supply chain management to reduce demand variability through diverse customer bases. With the fact found that Nut-a and Nut-b sub-categories contributed to almost 60% of the production volume, as well as supplied into many countries of destination, the company had decided to focus the production activities only on these two sub-categories on the short-term basis (up to 3 months horizon). The company coordinated with the affiliates at the countries of destination to do risk pooling by focusing the short-term demand only on a few specific product formulas and a few packaging formats to reduce production complexity and debottleneck the capacity. This supply chain operational mitigation enabled the company to absorb the vast majority of the short-term demand for the nutritional category while keeping the short-term service level at an acceptable rate. The material supplier also benefitted from a focused portfolio that gives more predictable materials, and component types to be prepared and forecasted in the short term.

In the mid-term (12 months horizon), the company set up supply chain tactical mitigation to minimize the risk of material supply disruption. PCC Matrix showed that the 12-month rolling demand forecast of Nut-a and Nut-b are the top two growth and volume contributor to the company. The actions from the operational mitigation had proven to be effective and provided the lessons learned platform for the tactical mitigation. The risk pooling had been elevated to the mid-term plan, and with this method, the portfolio between diverse customers in different countries had been focused only on a few SKUs. With a focused portfolio both on formula and packaging format, the degree of material and component commonality is increased. Based on material and component commonality analysis, the most common materials and components were included in the safety stock adjustment process based on materials supply vulnerability analysis. The company prolonged the materials ordering horizon based on the component commonalities to reduce supplier vulnerability through increased material forecast accuracy. In addition to the prolongation of the materials ordering horizon, the company also decided to rent an additional space of materials storage for highly vulnerable materials as aligned with the safety stock adjustment mentioned above.

To reduce material supply vulnerability beyond 12 months horizon, the company has put into a plan the structured evaluation on strategic sourcing of materials and strategic regulatory activities with regards to registration of alternative materials for high growth-high volume products. There were three criteria used by the company, those criteria are plotted into the SKU Prioritization Matrix (fig.5.) to decide the course of action for a specific product SKU in a specific country. Firstly, regulatory complexity was used as one of the criteria due to the different regulatory requirements in each country where the products are distributed. The higher the complexity, the higher the score on the y-axis. The second criterion is the supply vulnerability of the products based on the RLS as discussed on the Material Supply Vulnerability topic. The higher the vulnerability, the higher the score on the x-axis. The third criterion is the production volume of the respective SKU, the size of the bubble on the matrix represents the size of relative volume contribution.



Source: Author

Fig.5.Example of SKU Prioritization Matrix

The strategy for each product SKU will be different depending on the quadrant. For highly complex-highly vulnerable SKUs, the registration for alternative material sources will require a significant amount of lead time while the supply vulnerability is high. In this case, the strategy will be to increase inventory safety stock both on the finished goods level and materials level to minimize the risk of supply disruption. In the highly complex-less vulnerable quadrant, the strategy will be to increase the safety stock of material only, while the finished goods safety stock will remain the same.

In the less complex-highly vulnerable quadrant, the strategy will be to speed up the alternative material sourcing registration while in parallel getting the materials from the new source into the company's warehouse. Usually, the countries with the less complex regulatory system will use "Do & Tell" or "Tell & Do" change management which has a shorter lead time for registration.

IV. DISCUSSION

To the best of our knowledge based on a systematic literature review done in several studies (Chowdury *et al*., 2021); (Pujawan and Bah, 2021); (Shi *et al*., 2021), this is arguably the first study to understand the COVID-19 pandemic impact on logistics mobility and materials supply vulnerability which focused on export-oriented pharmaceutical manufacturing company based in Indonesia. The study also decodes the best practices of the pharmaceutical supply chain planning for risk mitigation. The company is both in a pivotal role to supply the multivitamins needs not only for Indonesia but for the export market, and at the same time also severely impacted by the constraints on logistics limitations and materials supply delays. A supply chain's performance in terms of responsiveness and efficiency is based on the interaction between the following logistical and cross-functional drivers of supply chain performance: facilities, inventory, transportation, information, sourcing, and pricing. On the facilities driver, the company did not change the location of the production site but focused on improving the efficiency to increase short-term capacity. The company did change the storage site, where the decision was not driven by the location but instead by the need of storing more materials that are highly vulnerable as aligned with its safety stock policy. On the inventory driver, the company did change its inventory policy by adding safety stock for the highly vulnerable materials. This decision was aimed to improve the responsiveness to the demand while managing the risk of materials supply due to logistics mobility disruption. However, interestingly the company also managed to minimize the impact on efficiency by increasing the degree of materials and component commonalities through agreement with the commercial partners to focus on a highly demanded portfolio based on a product formula and packaging format. With this, the company can minimize the additional storage space needed to store the highly vulnerable materials despite higher safety stock. On the transportation driver, the company did not have many choices in the short term but to use the air freight mode which is more costly than the sea freight to bring the materials from overseas. In this case, in the short term, the company decided to focus more on responsiveness and sacrifice efficiency. However, in the medium term, the company focused on the prolongation of the materials ordering horizon and adjusting the safety stock for highly vulnerable materials, with the aim to minimize air freight transportation needs thus improving efficiency. On the information driver, the company leveraged the information available from the logistics service providers to better understand the logistics mobility risk. The company also leveraged the information available from its materials supplier to understand the supply vulnerabilities. This information was then used as the basis to plot historical demand data both before and after the pandemic started, and regulatory nuances were also added into the context to aid the decision-making. On the sourcing driver, the company did not change the supply network on the materials supply side in the short and medium term. However, the company set the strategic direction of establishing multiple sourcing for highly vulnerable materials. On the pricing driver, the company decided not to adjust the price of the goods sold during the pandemic despite several cost parameters being affected, but the revenue was still growing mainly due to the significant demand surge for health supplement products.

V. MANAGERIAL IMPLICATIONS

A. *Materials Safety Stock*

Safety stock is a term used by logisticians to describe a level of extra stock that is maintained to mitigate the risk of stock-outs (shortfall in raw material or packaging) caused by uncertainties in supply and demand. Adequate safety stock levels permit business operations to proceed according to their plans (Monk and Wagner, 2009). Safety stock is held when uncertainty exists in demand, supply, or manufacturing yield, and serves as insurance against stock-outs.

The amount of safety stock that an organization chooses to keep on hand can dramatically affect its business. Too much safety stock can result in high holding costs of inventory. In addition, products that are stored for too long a time can spoil, expire, or break during the warehousing process. Too little safety stock can result in lost sales and, thus a higher rate of customer turnover. As a result, finding the right balance between too much and too little safety stock is essential.

The company may need to optimize the utilization of SAP APO to plot the demand projection which can be used for BOM explosion analysis and compare it with the 3 months historical moving average to find the most optimum balance of the quantity of the monthly materials needed for each component. The quantity of safety stock can be based on this monthly optimum balance, the higher the risk level scale of the materials, the longer safety stock coverage is needed. Table III can be used as the reference for the length of safety stock coverage, considering the lead time, MOQ coverage, and shelf-life. Materials with short shelf-life should be managed very carefully, too much safety stock could increase the risk of write-off due to expiration.

B. *Materials Sourcing Complexity*

Realizing the potential losses from supply risks, the company must consider incorporating risk management into its operations. Dual sourcing is a prevailing strategy for mitigating supply risk to ensure supply chain stability (Silbermayr and Minner, 2014). One approach to working with a dual supply strategy is to order products from two or multiple suppliers at the same time (Tomlin, 2006); (Yu *et al.*, 2009); (Ju *et al*., 2015). All suppliers provide similar-quality products for enterprises, but homogeneous products may have differences in terms of price, lead time, reliability, and other attributes (Hou *et al*., 2017). In the pharmaceutical industry, dual sourcing is rather complex since the effort needed will depend on the material type whether it is specialty or commodity, the regulation status of the material, and the lead time for getting approval from health authorities in different customer countries have variability. The priority should be to qualify dual sources for commoditized materials since this is the easiest option for the short-term considering the pandemic situation uncertainty. While qualifying a dual source for specialty materials could be costly and time-consuming, the most ideal solution will be to formulate the product using commoditized materials as much as possible.

C. *Materials Forecast Accuracy*

In the global competitive market, manufacturers require to forecast the optimum quantity of material inventory to reduce cost and maximize the efficiency of the supply chain. Companies aim to supply the required amount of material in right place and at right time with the right cost. If the material is not available according to the need, the supply chain may incur expensive repercussions and production downtime. In this regard, forecasting the optimum amount of raw material is of paramount importance for the company. The importance is now even more critical amid the global COVID-19 pandemic which adds more uncertainty.

Artificial neural networks (ANN) could be further researched by the company to develop the optimum model for generating accurate forecasts in the uncertain period driven by the global COVID-19 pandemic. ANN model can be developed to forecast the optimum quantity of material inventory in a fuzzy environment.

The function of the ANN model is to generalize unseen data depending on several factors. These factors are the appropriate selection of input-output parameters, the distribution of the input-output dataset, and the format of the presentation of the dataset to the neural network. Selected input parameters are the significant variables that affect the materials inventory of a manufacturing organization. An earlier study (Ali *et al*, 2011) was conducted in a pharmaceutical manufacturing company to develop an ANN model that considers product demand, lead-time, supplier reliability, holding cost, and materials cost as the input. The output parameter of the model is the amount of materials inventory. The model is illustrated in fig.6.

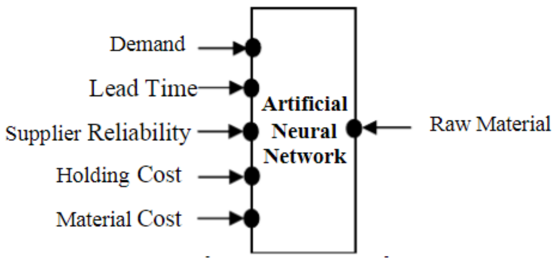


Fig.6. Schematic diagram of ANN developed in the earlier study (Ali et al, 2011)

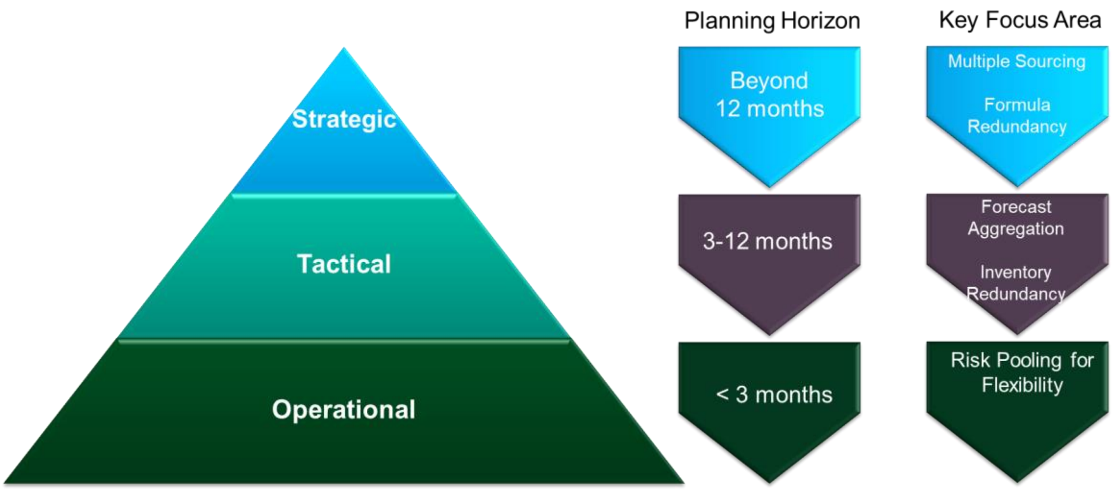
According to the study, the model is proven to be successful in terms of agreement with actual values for a pharmaceutical company. From comparative analysis with Fuzzy Inference Systems and Economic Order Quantity, the study concluded that the ANN model outperforms others in determining the optimal amount of raw material inventory more accurately.

D. *Supply Chain Planning Horizon for Risk Mitigation*

Supply chain planning is a pivotal part of Integrated Business Planning which is a common-sense process for aligning company plans and actions on monthly basis. The management team is required to review the projected demand generated from product and portfolio management, sales, and marketing activities over a planning horizon of typically 24 months or more.

Integrated Business Planning plays important role in balancing demand and supply, as well as monitoring the alignment of execution to the strategic plan. Monitoring how well the strategic plan is being executed involves reviewing strategic initiatives, action plans, and actual and projected results. As a result, by necessity, the planning horizon needs to be the longer term to provide visibility and transparency to current and anticipated action plans in support of the strategy.

The company divided the business planning horizon into three different length-group with different key focus areas for risk mitigation during the COVID-19 pandemic (fig.7.).



Source: Author

Fig.7. Business Planning Pyramid and its horizon

The planning horizon at the operational level is looking at a time frame of fewer than 3 months with a key focus area being risk pooling for flexibility. At the tactical level, the horizon is extended from 3 up to 12 months and mainly focuses on forecast aggregation and inventory redundancy. Beyond 12 months is classified as a strategic horizon in which the focus is mainly on multiple sourcing of vulnerable materials and product formulation redundancy.

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