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Design Lean Supply Chain for Post COVID-19

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Abstract: Because of e-commerce, consumers request the immediate delivery of goods as well as product variety. The COVID-19 pandemic caused a lockdown within and between countries from 2020. This escalated serious challenges already faced by global supply chains in terms of the bullwhip effect and excess inventory. Global supply chains require sustainability. With the development and rollout of COVID-19 vaccines, economic recovery is expected. However, the research on the economic recovery of supply chains is limited. This study applies sustainability, lean production, and supply chain management to propose a sustainable lean supply chain framework and practical tools that cover four business settings. This study also discusses the use of the framework during the repair, shock, and rebound periods of economic recovery as the COVID-19 pandemic retreats. The aim is that enterprises will be able to flexibly adjust the supply chain and proactively prepare during the period of economic recovery.

Keywords: Lean production; Global supply chain; Sustainability, Economic recovery

1. Introduction

The globalization of business has accelerated in the past decades (Choi and Lee, 2017). The uncertainty of lead times in logistics operations has a major influence on the performance of a global supply chain and the suppliers' reliability (Schmidt and Wilhelm, 2000). Despite the popularity and benefits of global supply chains, excess inventory is a growing problem (Croson and Donohue, 2005), which escalated in the beginning of 2020 because of the COVID-19 pandemic.

Excess inventory is caused by absorption costing when capitalist societies encourage managers to increase production levels in excess of expected demand (Roychowdhury, 2006). Sutherland and Bennet (2007) defined overproduction as the act of producing something earlier than necessary. However, volume fluctuations and decreases in profit lead to price fluctuations that can occur anywhere in the supply chain, which subsequently leads to demand distortion or the bullwhip effect (Lu et al., 2012). Therefore, excess inventory can be considered one of the phenomena that occur because of the bullwhip effect within the supply chain (Christopher, 2005).

Global supply chains are complex, constantly evolving, and face multiple uncertainties. The lockdown between countries during the COVID-19 pandemic created high uncertainty, thereby escalating the problems of the bullwhip effect and excess inventory buildup. Enterprises that have production sites in Asia and markets in America and Europe have suffered from global supply chain challenges during the pandemic and it is expected that the challenges will leak into the post-pandemic period.

Lean production is known as waste elimination during the manufacturing process and is also widely implemented in the manufacturing industry (Singh et al., 2017). Meanwhile, environmental protection has drawn people's attention during the pandemic (Abdul-Rashid et al., 2017). There is greater importance placed on sustainability in global supply chains than before (Pipatprapa et al., 2018). The objective of this study is to develop a framework that can efficiently minimize the waste of excess inventory throughout the supply chain using lean and sustainability approaches during the post-pandemic period. Enterprises can apply the framework to adjust their supply chain during the economic recovery.

2. Collecting data to build framework

2.1 Economic cycle

Economic cycle generally refers to the regular expansion and contraction of economic activities along the overall trend of economic development (Wasserman, 1984). It is the fluctuation of gross national output, gross income and employment, and the alternation or cyclical fluctuation of national income or overall economic activity expansion and contraction (Drautzburg, 2019). The economic cycle has four stages: Prosperity, recession, depression, and recovery (Nordhaus, 1975). Economic recovery is a post-recession stage during which the economy recovers and exceeds the peak employment and output reached before the recession. Common features of the recovery stage are super-high growth in real GDP, employment, corporate profit, and productivity indicators (Barbosa-Filho and Taylor, 2006). Consumer confidence is regarded as the turning point from contraction to expansion (Flaschel et al., 2008). The economic recovery stage consists of the three periods of repair, shock, and rebound (Burns, 1951). This study adopts these three periods of the recovery stage of the economic cycle and analyzes the global supply chain phenomenon of each period. To simplify the description, this study uses the term "economic recovery" as the recovery stage of the economic cycle.

2.2 The inventory issue of supply chain

The distortion of demand information implies that manufacturers who only observe the immediate order data may be misled by amplified demand patterns. This has serious cost implications. Because a considerable fraction of a retailer's assets is invested in inventory, retailers and stock market analysts focusing on retailers focus closely on inventory productivity. Retailers seek to continually improve their inventory management processes and systems to reduce inventory levels (Gaur et al., 2005). The strategies for reducing the inventory problem caused by the bullwhip effect require information sharing of inventory status data, coordination of orders across retailers, and the implementation of promotional activities for the manufacturer. Therefore, these operational issues can be alleviated using capacity allocation schemes (Cachon and Lariviere, 1999), staggered order batching (Cachon, 1999), everyday low pricing (Sogomonian and Tang, 1993), and improved demand forecasting techniques (Chen et al., 2000).

This reduction in the bullwhip effect is caused by the lockdown that when demand information is centralized each stage of the supply chain can use the actual customer demand data to estimate the average demand. If a single member of the supply chain can forecast and order for other members, the supply chain can implement centralized multi-echelon inventory control systems that are known to be better than independently operating site-based inventory controls (Clark, 1960). Vender managed inventory (VMI) is a technique wherein the inventory storage manager has the responsibility of rendering or supplying goods for optimizing the inventory held by the distributors or users of goods (Nordhaus, 1975). The VMI systems or continuous replenishment programs have become prominent in this context of multi-echelon inventory control systems.

2.3 Lean practice for the globalized business settings

There is a need for a good approach and comprehensive assessment for providing lean solutions to the problem of overproduction and its variability throughout the business settings of research and development (R&D), production, inventory, and service management. The following is the description of the popular business settings, which are R&D management, production management, logistics management, and service management. This study combines lean production and sustainability with four business settings to determine a supply chain solution that addresses the problem of excess inventory on a global scale during the economic recovery period after the COVID-19 pandemic. The four business settings are "Lean for R&D," "Lean for production," "Lean for logistics," and "Lean for service."

(a) Lean for R&D: R&D under the lean principles address the waste of overproduction through the following techniques or best practices: Reducing batch size, product standardization, modular product design, and concurrent engineering (Muafi & Kusumawati, 2021). Several benefits result, including fulfilling shipping schedules and balancing supply versus demand, decreasing stock levels, reusing common modules to produce intelligently, and responding to demand fluctuation, which accelerate feedback processing. Finally, the 4Rs need to be implemented as a product development principle in order to support sustainability from the very beginning.

(b) Lean for production: Production management under the lean principles address the waste of overproduction through the following techniques or best practices:

Continuous flow, level scheduling, JIT, Kanban, Takt time, VSM, group technology, small batch sizes, and renewable energy (Novitasari and Agustia, 2021).

(c) Lean for logistics: The lean logistics creation of a product flow applies information technology (IT) practices to create valuable processes in a smooth system, thus minimizing interruptions and inventories and reducing costs and downtimes. Logistics management in combination with IT under the lean principles address the waste of overproduction using the following techniques or best practices: Supply network, warehouse, and transportation (Medina et al., 2021).

(d) Lean for service: Lean in-service management is considered based on point-of-service lean contracting. In addition to contracting, the following best practices are considered under service thinking that drive lean within its bases: Discounting, customer reservations, and review returns policy and handling, which allow the convenient buying and selling of merchandise and reduce the amount of unsold merchandise (Orjuela et al., 2021). A pull contract also has a single wholesale price; however, the supplier bears the supply chain's inventory risk because only the supplier holds the inventory while the retailer replenishes it as required during the season. Firms can adopt a pull contract that has a single wholesale price; however, the supplier charges that wholesale price for both prebooked and at-once orders.

2.4 Sustainable approaches in the supply chain

Based on the 17 Sustainable Development Goals (SDGs) and 169 Sustainable Targets issued in 2015 (United Nations), countries around the world have begun to develop the SDGs into activities that suit their own national conditions and implement these activities one by one. Global supply chains utilize natural resources globally (Scarano, 2019). Supply chain management needs to align with the SDGs to support sustainability (Evans et al., 2017). Renewable energy is useful energy that is collected from renewable resources, including sunlight, wind, rain, tides, waves, and geothermal heat (Ellabban et al., 2014). There is focus on replacing fossil fuels, which create high pollution, with renewable energy sources in manufacturing industries (Lund, 2007). According to ISO 14000, the 4Rs are suggested to be included in product development policies to prevent pollution from the very beginning and thereby improve product efficiency throughout the product life cycle (Braungart and McDonough, 2002). The 4Rs

refer to (1) Reduce: reduce the use of unnecessary components that create less value but bring high environment pollution, (2) Reuse: use repeated manufacturing processes or standard components, (3) Recycle: use something again for a different purpose, and (4) Replace: apply an environmentally friendly approach or things.

3. Materials and methods

In order to better understand the cause and effect between business settings, DEMATEL is applied to analyze the relationship between the variables (business settings). In DEMATEL, variables are separated into four different quadrants that are categorized as cause or effect. The variables are obtained from the collected responses of experts in order to determine the actions applied to address the focus-problem in real world situations. In order to understand the influence of the four business settings, this study sends out questionnaires to senior managers and directors whose companies have manufacturing sites in Asia and major customers located in America and Europe. Senior managers and directors are defined as experts that suffer from logistic challenges during the pandemic. Post-pandemic supply chain recovery is a key focus of these experts. After receiving 15 responses, (1) the direct relation matrix is generated for four business settings. Five levels of influence are defined as: 0: No influence. 1: Low influence. 2: Medium influence. 3: High influence. 4: Very high influence. (2) The 4 × 4 average matrix is obtained by finding the average of all the responses provided for each relationship in the matrix. (3) Normalize the direct relation matrix. (4) Draw a cause-and-effect diagram: Let Di and Rj represent the sum of the ith row (causal influence) and the sum of the jth column (effect influence), respectively, of the total relation matrix T, where $i = j = k = 1, 2, 3 \ldots n$. D+K and D-K are put in a diagram to clearly present the relationship between business settings.

4. Results

This study sent questionnaires to senior managers and directors whose companies have manufacturing sites in Asia and major customers located in America and Europe. Eight electronic goods manufacturing companies from Taiwan were involved in the DEMATEL study, from which 15 responses were collected. The average of the 15 responses was used to generate the direct relation matrix. By adding the all data in the same row, we get the sum of the four rows. The maximum value of the four sums is 6.067.

the direct relation matrix is divided by 6.067 to get the normalized initial direct relation matrix as shown in Table 1.

Table 1 - Normalized Initial Direct Relation Matrix

	Logistics	Production	Service	RD
Logistics	0.000	0.374	0.286	0.341
Production	0.319	0.000	0.319	0.264
Service	0.363	0.341	0.000	0.264
R&D	0.297	0.253	0.308	0.000

Then we calculate the total relation matrix, D+R, D-R, and the average of D+R, we get the total cause and effect table as shown in Table 2.

Table 2 - Total Cause and Effect

	D	R	D+R	D-R
Logistics	14.7427	14.5355	29.2782	0.2072
Production	13.6907	14.4606	28.1513	-0.7699
Service	14.4608	13.773	28.2338	0.6878
R&D	13.1542	13.2793	26.4335	-0.1251
		Average	28.0242	0.0000

We draw the prominence-causal diagram as shown in Figure 1. Service and logistics are the cause factors with benefits. R&D is the effect factor with risk. Production is the effect factor with benefits. The strength (D+R) between R&D and logistics are weak. This diagram tells us the cause-and-effect relationship between the four business settings during economic recovery.

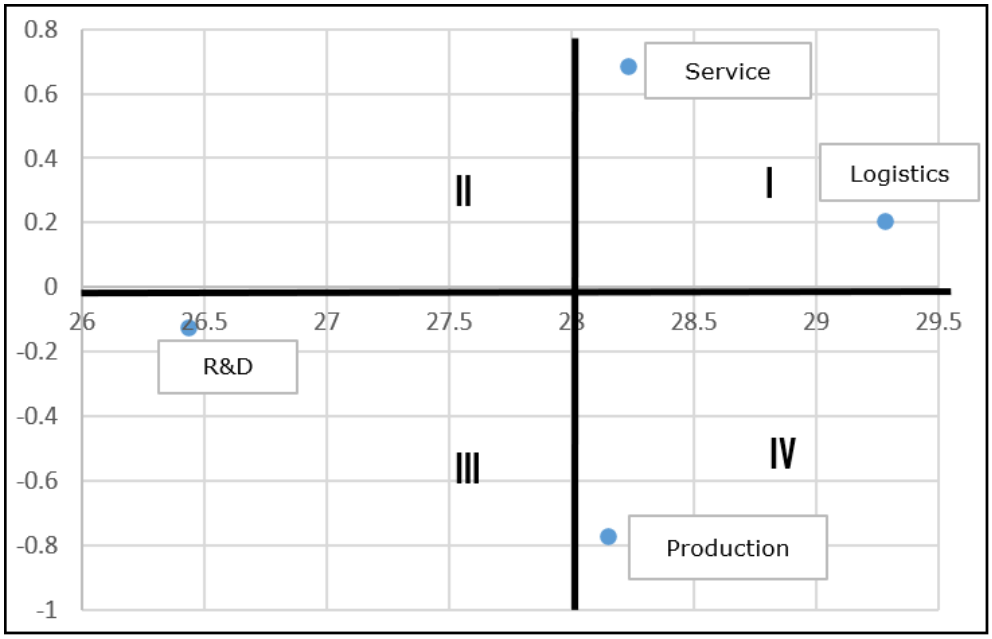

Figure 1 - Prominence-Causal Diagram

5. Discussion

With the advent of vaccines, the boarders between countries will gradually reopen and in-country lockdowns lessened and removed. With globalization, no country is completely self-sufficient and there are varying resources each country can utilize. Business activities will be the first activities to re-connect countries. The flow of goods can gradually resume, and people's lives can return to their normal states before the pandemic. Because of the closure of the world that has spanned many months, and because the access to and roll-out of effective vaccines vary from country to country, the speed of recovery is unpredictable. The four lean supply chain business settings proposed in this study will be applied in the three periods of economic recovery, i.e., repair, shock, and rebound. Combining with the cause-and-effect analysis results shown in Figure 2, the following is the description of each period.

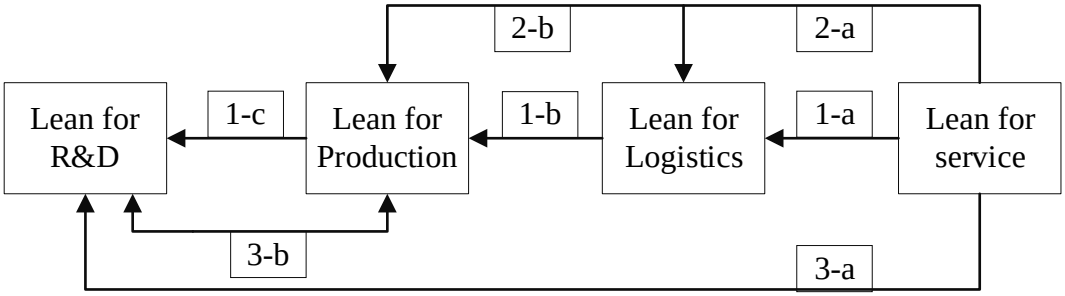

Figure 2 - Sustainable Lean Supply Chain Framework

Repair period: This period is represented by small quantities, quick delivery, and low prices. Link 1-a presents the application of Lean for service which pulls products from Lean for logistics. There are five factors relevant here: (1) customers place small quantity orders because of cash limitations, (2) companies test the market situation using low-price items, (3) companies test logistics as it is also recovering area by area, (4) consumption of current inventory is prioritized, (5) demand is related to customer needs during lockdown. Link 1-a refers to the start of the contracting between logistics and customers regarding goods delivered.

Link 1-a follows a pull pattern and the efficient planning of inventory costs for goods that have been produced during the COVID-19 pandemic. It provides the preliminary information of the logistics network which has been suspended during the pandemic, thus allowing manufacturers to optimize costs and provide fast and effective

services. Link 1-a refers to when cross-docking systems are set in place and the products arrive at the cross-docking centre from the manufacturer, where all the allocated outbound vehicles are immediately loaded with the packages before delivering them to the customer as quickly as possible.

Link 1-b: Production can also start manufacturing because market information has been reconnected in Link 1-a. The purpose of Link 1-b is to (1) reconnect with suppliers to understand the recovery situation of the supply chain and (2) test production capability, such as operator proficiency, and manufacturing capability. The production line may even be reset to face the coming shock period. Logistic IT practices, are to be applied based on customer pull, namely, customer demand. The IT practices of Link 1-b minimize the supply chain's inventory risk by guaranteeing the visibility of information between customers and production. By facilitating this visibility through IT practices, the supplier can also recover its inventory management, whereas the customers replenish their needs as required through small batch orders. By resetting production management, the chance for overproduction is minimized, which is crucial as cashflow is critical in this stage. The proposed framework is a customer focused framework because the customers located at the end of the chain trigger the start of the flow.

Link 1-c: By reviewing the R&D plan and focusing on historic products along with production reset in Link 1-b, companies can quickly adjust and develop new product items with low development costs to prepare for the growing market demand of the coming shock period.

To sum up, the focus of the repair period is information status and recovery of the supply chain. Information covers the areas of the market, production, manufacturing, supply chain, and logistics. Because cash flow is recovering, companies can slightly make up for losses incurred during the pandemic.

Shock period: As the borders between countries gradually reopen, business and transportation will gradually return to normal. However, sporadic regional infections are still inevitable because it will take time for the world to produce antibodies. Shipment plans will have to be adjusted frequently for item changes, temporary shipment suspensions, or re-transfers through un-planned countries. The following methods can be applied to deal with the vibrations during the shock period.

Link 2-a illustrates the method through which logistics management is affected by sideways pushing and pulling responsibilities within a globalized lean supply chain. It also refers to the start of the contracting between logistics and customers regarding goods delivered and the efficient planning of inventory costs after goods have been manufactured. Because there will still be occasional outbreaks or there may be outbreaks in places where the shipment passes, sales orders may be suspended at any time. Logistics need to be flexibly re-scheduled to be delivered to customers from alternative paths. Flexibility is a key focus of Link 2-a.

Link 2-b involves Lean for service and Lean for production and sets its origin on customer orders. This means that the production start must be pulled by accurate customer order information no matter what changes may occur. It guarantees a pull production under the JIT philosophy and provides the flexibility of production to meet the variance of sales changes. After production is prepared in Link 1-b, production also needs to flexibly adjust items and orders in different regions. When an order is temporarily stopped, production can quickly switch items and change production to manufacture other items.

Overall, although the shock period will cause people to feel uneasy, it is foreseeable that the unmet needs during the pandemic will be gradually met through the repair period and shock period. It will not cause a rapid increase in demand.

Rebound period: The pandemic has had an impact on the lives of many people. It makes people also begin to reflect on what kind of future they want to be in. People focus more on environmentally friendly lifestyles and products, placing this hope and expectation on new products. So, different from the past, various new technologies and applications will emerge to meet people's hope of new life and a new future. When the vaccines' effectiveness gradually plays out, the number of healthy people in each country will increase again. Only when people are confident will the demand for consumer products officially start to grow. New technologies and products will then be adapted.

Link 3-a illustrates the pull between product R&D and services requested by customers. The market's demand for new technologies and new products is increasing, and the direction of new products will be toward human safety and environmental friendliness. The 4R principles can be applied to new product development. Companies

must adjust product designs and product lines in line with market needs to provide the services customers want.

Link 3-b highlights that because the direction of new products will be different from the past, the manufacturing methods will need to be adjusted accordingly, and sometimes even completely different production lines will need to be installed to meet the needs of the new products. Meanwhile, renewable energy can be applied to reduce costs and support sustainability. During this stage, business contacts will gradually be restored, the economy will be slowly recovering, job opportunities will be beginning to flourish, and people will be more confident in the future. There will be different demands for new products. Therefore, R&D must adjust product lines to respond to the new market. Manufacturing should use the lean concept to design flexible production methods to face changes and small market demands.

In summary, the proposed framework uses a pull-based and minor push-based approach. The framework allows mostly end pull throughout the four business settings. Post-COVID-19 will open a new world. Customers are expecting an increasingly sophisticated and flexible set of components that fulfil their individual demands of a new future. The only method through which a retailer can create a flexible service framework is by aligning the business around the customer. Production companies are facing significant operational challenges in providing consistent product content, pricing, promotions, and inventory across multiple sales channels, store formats, and international borders while simultaneously attempting to avoid excess inventory. The proposed framework can enable production companies to focus on optimizing their planning, manufacturing, merchandising, and supply chain operations.

Global lean logistics also faces the challenge of the additional time required for shipments to move door-to-door over long distances. The proposed framework is made using the best practices in each of the four business settings. The framework also integrates lean management under each business setting by linking their rear and front ends to make each setting pull the other, respectively. In other words, it serves to strengthen the links between these business settings to meet the needs of post-COVID-19 globalization.

6. Conclusion

This study applies sustainability, lean production, and supply chain management to propose a sustainable lean supply chain framework for enterprises with global supply chains. This framework includes four business settings and practical tools within each setting. This study then discusses the use of the framework during the repair, shock, and rebound periods of the business recovery stage post-COVID-19, allowing enterprises to flexibly adjust their supply chains and prepare in advance for business recovery.

Declaration of Conflicting Interests

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