Modelling the Impact of COVID-19 Pandemic on a Hardware Retail Supply Chain

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Abstract – **Due to the current COVID-19 (SARS-CoV-2) outbreak, supply chains have been severely disrupted in long term globally. In this paper, we present the results of a simulation study conducted on a case of the global supply chain. We have discussed the impact of COVID19 on the supply chains by citing some recent examples in the retail sector in Australia. We demonstrate the use of simulation modelling to quickly and reliably model and analyze supply chain disruptions through the use of anyLogistix simulation software. In this paper, we have simulated a case of an Australian hardware retail supply chain that has a global supply network. We have investigated the impact of COVID19 disruptions on the supply chain performance. Our results highlighted the importance of waiting order cancellation strategy in the recovery period for reducing supply chain costs and maintaining service level. We also discussed the negative effect of distance between supplier and customer on the resiliency of delivery systems. This initial work was a proof of concept to simulate COVID19 disruptions on a retail supply chain.**

Keywords – **Simulation, Supply chain, COVID19, retail sector**

I. INTRODUCTION

The emergence of COVID-19 has strained the global supply chains (SC) imposing high risks to the operations and increasing the probability of a drastic failure. SCs need to deal with a range of shorter and longer-term disruptions, including extended lead times, significant production/transportation delays and renegotiating new contracts for the short term. According to [1], currently, more than 95% of the Fortune 1000 companies face uncertainty/disruptions in their SCs. One of the major reasons for such disruptions is found to be their dependence on China for the supply and manufacturing of raw materials, components, subassemblies [2]. The complete lockdown of China and other countries, subsequently, has led to significant delays in the manufacturing sector. The pandemic which was initially limited to the Wuhan region of China has now spread globally disrupting the efficient flow of goods and services. The global pandemic of the coronavirus has halted manufacturing and production in most Chinese states which have also limited the supply of those products to the rest of the world.

Disruptions in supply on hand and panic buying of customers on the other hand has led to an exponential increase in the demand for essential products like toilet paper, flour, face masks, and cleaning products. More than 80% of Australia's toilet paper comes from overseas. The sudden surge in demand for these products has led to Australian manufacturers to increase production drastically to keep up with the demand [7]. According to Ivanov [3], although the world of supply chains has faced many disruptions over the past decade, none has been this impactful which is "destroying many global supply chains" [4].

Our discussion with eight different suppliers for an Australian household hardware chain highlighted the problems they face because of the pandemic. They highlighted that social distancing measures is one of the major challenges in the organizational sector resulting in significant delays in production and transportation. The retail sector is one of the few sectors to thrive in this pandemic albeit with a few constraints. The rapid rise in the number of cases of COVID-19 has led to the consumers becoming more anxious and afraid. This led to panic buying of essential items on a large scale.

In this paper, we have developed a simulation model for a supply chain of an Australian hardware retail store that has seen disruptions in their power tools product category. Some empirical data was used together with the AnyLogistix simulation platform for simulating the disruption in the supply chain management due to COVID19 related disruptions. We have previous experiences in modelling complex supply chains in a simulation environment such as agri-food sustainable supply chains [8]. The modelling effort highlighted the impact on profits for the company. The simulation modelling capability allows us to experiment with the supply chain model under disruptive conditions and identify future mechanisms or mitigation strategies for disruptions. Although we have proposed and listed the proof-of-concept model in this paper, there is considerable potential for such approaches for better understanding and mitigating supply chain risks in the COVID19 pandemic.

II. PROBLEM DESCRIPTION

Almost all retail stores do a periodic gap check that identifies the gaps in shelves that are usually stocked and filled with products that customers need. This is done order stock and to analyze the time it takes the supplier to get the product onto the shelves. In this study, we have studied the case of an Australian hardware retail store. The gap checks at these stores are done at the end of every week to evaluate the gaps in the shelf. This is done

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to make sure consumers get the product they need without having to go to another store. The two main reasons that gaps exist in the store are because the order has been placed for an item and it has not arrived yet or the item is stored in ‘Top Stock’ which is a shelf above the retail shelf that stores all the excess stock. In January 2020, the reason that gaps existed in the store was mainly due to the unavailability of the product on the shelf but its inventory still in the store. For the last few months, the steady increase in the gaps is because of the lead time delay in getting the product to the store. This is because the store utilizes an automatic stock ordering system where all the stock has min and max order quantity. Once the stock count falls below the minimum threshold, the system automatically places an order with the supplier. The gap checks for January, April, June 2020 is reported in Figure 1. The Type 1 count represents the gaps on the shelf where inventory is available in the store, type 2 represents the stock that has still not yet been sent to the distribution centers, and type 3 highlights the gaps in the shelf where the stock that has been ordered from the supplier. It is evident that the total gaps for the store because the stock was not sent to the supplier, was a total of 356 compared to the total of 17 which was the stock that was stored in ‘Top Stock’ which is the inventory that’s stored in the shelf above the retail shelf.

Figure 1: Gap counts for the retail store in Australia during COVID19 pandemic

Figure 2 illustrates the status of product inventory, shipment details in an urban store of a hardware retail company. These statuses were recorded on January 27th, February 24th, March 23rd, April 20th, May 18th, June 15th. It provides information regarding the inventory levels at the store (stock-in-hand), stock on order, suspended items, and other promotional items.

The other columns in the table represent the stock that the distribution center that has not yet been sent to the stores. This is because the distribution centers will prioritize the inventory to different stores. So far the current scenario for the inventory is that the stock is usually sent to the bigger stores and is therefore given precedence over the smaller stores. The steady increase in the number of gaps over the weeks highlights the problems companies have been facing over the weeks to get their products to the store shelves.

The key reasons for these delays and gaps can be traced back to the travel restrictions and social distancing laws that have been enforced by the government. The increasing rise in demand for certain products has also had product manufacturers find it difficult to meet the rising demand. It was also inferred for the data collected from the gap check reports that the builders’ section specifically the tools section has suffered most from the unavailability of the stock compared to other product categories. This is because the majority of the tools section is made with power tools that are shipped from overseas. Besides the problem of transportation, power tools contain a lot of components that need to be sourced from different suppliers and since the suppliers are facing delays themselves, the time it takes to manufacture and ship their products leads to delays in product arrival. Therefore, this research will focus on the power tools product category for simulation modelling.

III. SIMULATION METHODOLOGY

A simulation model of a supply chain of power tools for an Australian hardware retail store was developed using the Anylogistix simulation platform where the supplier is providing subcomponents/parts to manufacture power tools to a factory in Malaysia. The finished products are then shipped to a port in Perth (Australia) from where it is sent to 2 different distribution centers in Melbourne and Sydney. The orders from retail stores are then fulfilled through trucks around the country from these distribution stores. Figure 3 illustrates the supply chain case considered for simulation modelling.

The number of customers in this simulation is taken as 50 spread across the country of Australia. To analyse the impact of the pandemic, a simulation model was done for a conventional supply chain that ships power tools. The inventory in the distribution centers has a minimum stock count of 2500 and a maximum stock count of 5000 with a safety stock of 5000 in both the DC’s. The system automatically places an order when the number goes down below the minimum stock count. The selling price of the power tool is set at USD$100 and the cost price set at USD$60. The first set of results is calculated based on everyday operation taking into account the risks of bad weather and fluctuations in demand. The second set of results take into account the same conditions as scenario 1 and also the added factory closure for 30 days because of the Movement Control Order (MCO) passed by the Malaysian government. Although other factors affected the supply chain like logistical and transportation problems, the factory closure was the only factor that was considered in this simulation. The modes of transportation considered in this simulation are Ships, Air Freight, and Trucks.

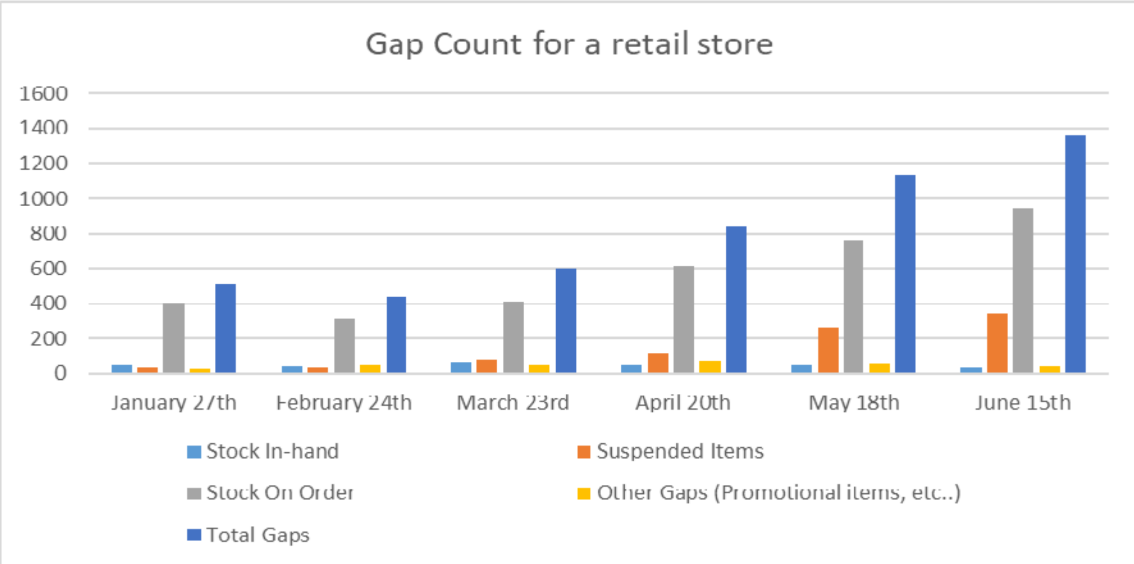

Figure 2: Inventory levels and product shipment status at a retail store

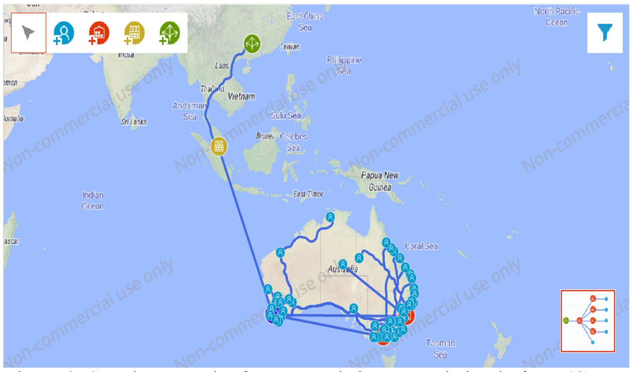

Figure 3: Supply network of power tools in anyLogistix platform (Green Icon – Supplier in the Hunan region of China; Yellow Icon – Factory in Langkawi, Malaysia; Purple Icon – Port in Perth, Australia; Red Icon – Distribution Centers in Melbourne and Sydney; Blue Icon – Customers distributed across Australia)

We have employed the discrete-event simulation methodology provided in the anyLogistix simulation platform. In particular, we have used a standard anyLogistix model "SIM Global Network Examination" for our work as we wanted to simulate the impact of COVID19 on a retail supply chain case in Australia. The model has been validated comprehensively by the Anylogic for large-scale problems as reported in [3]. We adjusted several parameters of this model such as transportation times and disruption events to make it suitable for our case study.

IV. RESULTS

In this section, we have discussed the results of the simulation model developed in section 3. Figure 3 illustrates the current model setup for supply chain entities (suppliers, manufacturing units, and distribution centers) for the hardware retail company. We have simulated two scenarios for understanding the impact of disruption due to COVID19 on the supply chain performance.

1. Scenario 1 is based on the normal flow of information and materials/products which were happening before COVID-19 incidence.
2. Scenario 2 simulates the supply chain of power tools under the impact of COVID-19.

In Scenario 1, there were minimal delays in lead times and factories were operating at their full capacity. However, the delays caused by a domino effect (in Scenario 2) were the failure to deliver certain parts from suppliers has resulted in the production delays until the parts were delivered from the suppliers.

Figure 4 illustrates the results of the model for both scenarios. It can be seen from the results of the simulation that the profits of the firm went down from USD$17.18 million to USD$9.9 million and the revenue went down from USD$43.2 million to USD$36 million due to the disruptions related to COVID19. The cost of transportation has also gone down by USD$90,000. The reduced transportation costs could be explained by the frequent border closures during the lockdown which has reduced the need for transportation.

The total supply chain cost for both the scenarios, at the end of the time period, remains similar (See Fig. 4.A). Total supply chain cost is the difference between the revenue and profits made by the firm during the entire year. The second scenario has reduced revenue and the profits (Fig. 4.B,C). The distribution centers in Sydney and Melbourne had a safety stock of 5,000 units each which is why the financial impact was not visible initially and therefore the revenue is only affected after a period of time (Fig. 4.A). The cost inventory storage has also gone down (in scenario 2) as distribution centers were running mostly out of stock after some time.

Once the border reopens there is going to be increased demand for transportation from third party logistical companies. This could lead to a potential reassessment of contracts between the supplier and the retailer.

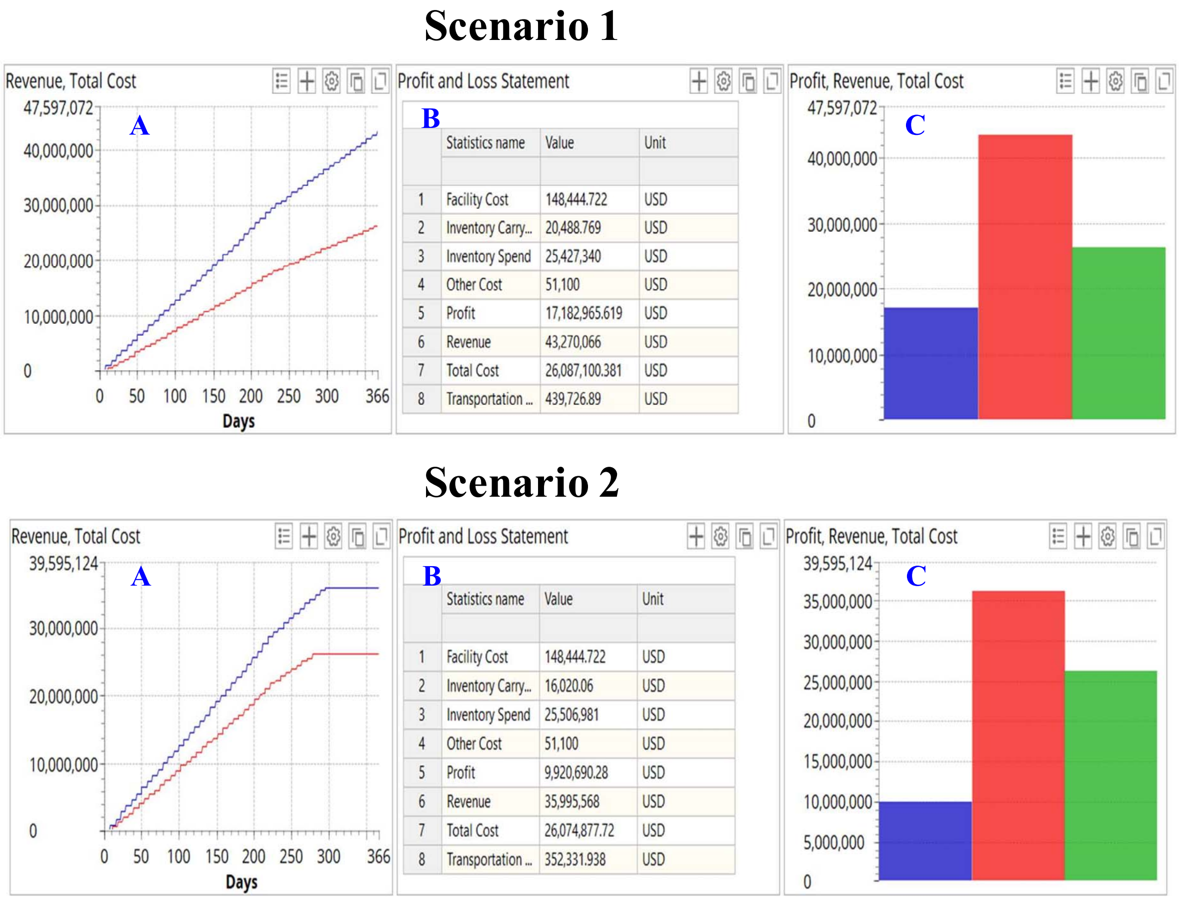

Fig 4: Simulation results for scenarios 1 and 2; A: Revenue and Total SC cost versus time; B: Breakdown of costs; C: Overall profit, revenue, and total supply chain costs

Although events like bad weather and fluctuations in demand have been taken into consideration in the simulation, the financial impact due to these risks is nearly as impactful as the complete border lockdown. The financial impact will also be in play for the next year as well.

V. DISCUSSION

Our results highlight the application of simulation and modeling to manage the information flow of logistics and production of global SCs in crisis. It provides a practical approach to optimize the transportation capacities ahead of disruptions, which largely reduces the delays and improve the service levels. Despite all advantages of mathematical modeling techniques, they do not enable agile rescheduling, which is a necessity in unforeseen situations. In DES, however, a series of events occurring at given time intervals is the most important factor to drive the simulation. We present how this simulation method can address the functional limitations of static scheduling. We observe that when a disruption occurs in the production-transportation systems, the standard planning algorithm is not optimal anymore as it pushes for the replenishment of order while the raw materials are not available. Based on our experimental analysis with the model, we understand that:

- Waiting order cancellation in the recovery period allows a reduction in inventory and write-off costs while maintaining the service level
- The longer the distance between supplier and customer is, the more sensitive the delivery systems are to negative impacts of capacity disruptions.
- The lower frequency and higher quantity of raw material order, the lower flexibility of the SC, and higher profit loss in the long run.

This emphasizes the requirement for consideration of planning in long-horizon adding resiliency to the systems, adapting to changes, and thus mitigating the effect of shortages and delays.

Although most of the results presented here are relevant to the operational aspects of the supply chain. But, future work is needed to develop and analyse various resilient and reliable supply chain strategies. As this is the proof-of-concept work, we have scoped this work to be focused on the operations aspects of the supply chain.

VI. CONCLUSION

COVID19 has undoubtedly impacted global SC in many ways. Organizations are struggling to mitigate the impact on their financial stability. With social distancing and lockdown laws in place, organizations find it increasingly complex to function efficiently at full capacity. Some of the key actions that organizations can take to minimize the impact the pandemic has had on their organizations would be to make the supply chain more visible than ever before. By going further into Tier-1 and Tier-2 suppliers, organizations can have a better understanding of where their components are being sourced from. Another important factor that has to be taken into consideration is maintaining good relationships with suppliers. Taking the COVID-19 outbreak as a lesson, companies should move towards maintaining resilience in the supply chain. Up until now, most organizations have been focused on East Asian countries for their factories and their supplier. Companies should start spreading their supplier base geographically to avoid being geo-locked in a region. COVID-19 has also taught companies to reassess their risk management strategies and to take into account pandemics in the future and also come up with mitigation strategies to avoid being impacted in the future. Shifting to digital supply chains has also proven to be a more viable option to mitigate risks.

The proposed simulation model provides a proof-of-concept tool for understanding the effect of major disruptions on a supply chain performance. As opposed to the mathematical models, simulation models are capable of being intuitive and transparent allowing for quick and reliable model development and analysis. The proposed simulation model provides a summary of our initial investigation. One of the limitations of this study is that the performance of the supply chain is only assessed in terms of costs. Given that COVID19 disruptions can significantly affect the delivery times, at least one of the key time measures should be considered in the future extension of this work. For future work, we are planning to develop a full set of potential scenarios to understand the supply chain performances and provide solutions/recommendations to mitigate the impact of pandemic risks such as COVID19.

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