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Minimizing Schedule Risk of Supply Chain

Md. Rabbi Amin[a*], Asif Iqbal[b], Animesh Kar[c], Ashraful Islam[d], Protik Dutta [e], Shadman Alvy Khan[f], Sudipta Kumar Dhali[g], Md. Makfidunnabi[h], Md. Mohabbat Hossain Rubel[i], Dr. Mohammad Alamgir Kabir[j]

[a,b,c,d,e,f,g,h,i]*Masters in Applied Statistics and Data Science, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh*

[j]*Professor & Chairman, Department of Statistics, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh*

[a]*Email: rabbiamin98@gmail.com,* [b]*Email: arid6125@gmail.com,* [c]*Email: get.mitun@gmail.com*

[d]*Email: notetoashraf@gmail.com,* [e]*Email: protik452@gmail.com,* [f]*Email: alvy.shadman@gmail.com*

[g]*Email: sudipta.k.dhali@gmail.com, sudipta.kumar.dhali@g.bracu.ac.bd*

[h]*Email: methunmakfidunnabi@gmail.com,* [i]*Email: mohabbatnsu@gmail.com*

[j]*Email: alamgir@juniv.edu, alamgirfa_juniv@yahoo.com*

Abstract

The supply chain management sector in Bangladesh faces so many challenges in minimizing schedule risk, this research paper targets to identify strategies that can help organizations to overcome this situation. The study includes a review of the literature, data collecting through surveys and interviews, and statistical data analysis. The findings demonstrate that companies in Bangladesh can reduce schedule risk by putting into practice strategies like enhancing stakeholder collaboration and communication, investing in technology to improve supply chain visibility, diversifying suppliers to lessen reliance on a single source, and creating backup plans for unforeseen disruptions. The study's conclusions offer useful advice for companies working in Bangladesh, particularly those in the industrial and retail industries, on how to manage their supply chains more effectively and lower the likelihood of schedule delays. The research adds to the sparse body of knowledge in academia about supply chain management in Bangladesh.

Keywords: Supply Chain Management; Strategy; Schedule Risk; Machine Learning; Schedule Delay.

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* Corresponding author.

1. Introduction

The Risk management in supply chain management involves identifying, assessing, and prioritizing risks to the supply chain and taking proactive steps to minimize their impact. This can be done through various methods such as data analysis, scenario planning, and risk mitigation strategies. Big data analytics can play a significant role in this process by providing real-time information on the supply chain, identifying potential risk factors, and enabling organizations to make more informed decisions.

For example, analyzing large amounts of data on supplier performance, product demand, and transportation can help organizations identify potential bottlenecks and disruptions in the supply chain. This information can then be used to implement proactive measures to minimize the impact of these risks and improve the overall resilience of the supply chain. Big data analytics can be a valuable tool in the process of risk management in supply chain management by providing organizations with real-time information and enabling them to make more informed decisions.

An unexpected situation like the COVID-19 pandemic gives us an example of how affected in the supply chain. It's proven that traditional supply chain practices and mitigation strategies are insufficient [1].

2. Literature Review

Supply chain schedule risk refers to the potential delay or disruption of the planned delivery schedule of goods or services, which can have significant impacts on a company's performance. In recent years, data analytics has emerged as a tool to help minimize schedule risk in supply chain. The following literature review summarizes the use of data analytics in managing schedule risk in supply chain.

The supply chain today is faced with many risk factors. To identify supply chain risk (SCR) factors and the impact of those risks to raise schedule risk, first, a literature review is conducted. Researchers around the world have conducted numerous pieces of research to address the underlying risks that result in schedule risk in supply chain. The author in [2] assessed to find out the type of risks involved in supply chain from Bangladesh's context. From the paper seventeen factors were mentioned as risks inside the supply chain. However, not all the risk factors contribute to schedule risk.

Table 1 groups all the supply chain risk factors that are relevant to Bangladesh's context based on various papers that were read as part of literature review section. By the author in [3] described how disruption in layers of the transportation network affects supply chain and increases the unwanted risk of schedule failure, which is identified as risk 1 on the table. Here it [4] described how delivery lead time and customers demand can disrupt supply chain in promoting schedule risk. On the other hand, author in [5] identified political and regulatory instability, natural disasters, and labor strikes as the most influencing risk factors. Relevant factors were described in the papers by the author in [6]. Moreover, expert opinions were taken from a survey conducted on various industry experts and managers to get information on underlying risk and possible risk mitigation techniques.

Table 1: Identified risk factors contributing to schedule risk.

Risk Number	Risks	Sources/References
R1	Disruption in the transportation network	(Ko and colleagues 2017; Paul & Chowdhury, 2021)
R2	Leadtime and schedule delay	(Fattahi and colleagues 2017; Kumar and colleagues 2014)
R3	Labor strikes and political instabilities	(Ali and colleagues 2021; Moktadir and colleagues 2018)
R4	Emergence of disruptive situations like pandemics, earthquakes, wars, etc.	(Ali and colleagues 2021; Silva and colleagues 2021)
R5	Lack of technological knowledge to manage risks	Expert Interviews
R6	Macro risk, demand risk, manufacturing risk, supply risk, and infrastructural risk.	Ho and colleagues (2015)

2.1. Managing Schedule Risk

From the literature review conducted, authors around the world have unveiled and proposed many techniques and ways to manage schedule risk.

One of the earliest studies on managing schedule risk in supply chain was conducted by the author in [7]. The authors proposed the use of simulation-based optimization, combined with data analytics, to minimize schedule risk in multi-tier supply chains. They found that this approach was effective in reducing the impact of schedule risk on supply chain performance.

The author in [8] used Fuzzy TISM-based hierarchical model for the SCR factors. The study is unique as it provides a unique methodology to study hierarchical relationships among risk factors. The paper also pictured the relationship impact between risk factors in supply chain. The paper will be used for further statistical modeling of the impact of 5 risk factors mentioned in Table 1 to understand schedule risk. The same study proposes Bayesian Hierarchical Model (BHM) to help decision-makers to estimate probabilities of disruption risks on multiple categories over limited knowledge availability. According to Bayesian theorem, risk variables are parent nodes and disruption risks belong to child nodes which leave impact on revenue in an accumulated way of any business organization.

The data of priori probabilities of risk variables were collected by the following processes:

1. An on-site interview was conducted with the industry experts from the company to gather detailed information of the SC risk variables[1]
2. The priori probabilities of each risk variable were collected from the experts' opinions.

The author in [9] investigates risk management in an aerospace supply chain using a discrete-event simulation technique. The goal is to analyze the supply chain performance under various risk scenarios and gather insights on the impact of potential disruptions or delay events on the time to complete components or the overall product. The simulation model includes various types of disruption/delay possibilities in the product flow and several scenarios were tested by adjusting different parameters. The simulation model targets a schedule risk issue and offers insights to industries with a similar low-throughput production setting, such as construction companies or long-term project industries. The model was developed with the collaboration of Company A, who initiated the research project with the objective of assessing their risk exposure. The only variable that monitors the system's performance is time to completion, which is the sole key indicator of supply chain performance for Company A. The model was given to the company for further review and application after its development and analysis. The factors affecting the completion time were identified and included in the model to capture the most significant risks while reducing the complexity of the system being modeled.

Relevant research papers and articles were pulled from Google Scholar, Elsevier, and other relevant websites with keywords such as "supply chain risks", "schedule risk in supply chain", "use of data science in supply chain", "supply chain risk management through technology" etc.

3. Methodology

For this research, in [10] data set named "Cargo 2000 Dataset" from Kaggle was used primarily to assess R1-R4 from the Table 1. The Cargo 2000 Dataset was originally created by the International Air Transport Association (IATA) to improve the quality and accuracy of information exchange between airlines, freight forwarders, and shippers. The dataset contains information on over 60,000 cargo shipments, including origin and destination airports, flight information, shipment weight and volume, and other details.

To analyze the dataset to find out relevant answers to risk factors impacting schedule risk, few of the following questions were taken into consideration primarily:

1. **What factors affect the transit time and cost of cargo shipments, and how can we optimize the delivery process?**
2. **How can we improve the accuracy of estimated delivery times based on historical data?**
3. **What are the most common causes of delays in cargo transportation, and how can we reduce their frequency?**
4. **How can we optimize the routes and schedules of cargo flights to minimize transit time and costs while maximizing efficiency?**

The dataset is in CSV format and can be loaded into various analysis tools, such as Python, R, or Excel. Before beginning the analysis, an inspection of the dataset was done to check for missing values, duplicates, or inconsistencies, and clean up the data as necessary. A further consideration of whether any additional data sources might be relevant to the research question and explore the feasibility of acquiring or integrating such data into the analysis.

For R5 or to assess lack of technological knowledge risk, a survey questionnaire grouped in 4 categories of timeliness was given to various industry experts.

4. Identify, Research and Idea Collection

For this dataset, after initial cleaning and organizing, a high correlation between the Shipment checked in and a receipt produced at departure airport timetable was found from principal component analysis (PCA). PCA is a technique used to reduce the dimensionality of data while retaining the most important information. In this case, we analyzed 19 components, based on our requirements. We determine that Shipment checked in and receipt produced components are most important in the dataset and can be used for further analysis or modelling. After subtracting plan time with effective time, another principal component analysis (PCA) on the resulting variable was performed. In this analysis, found a highly negative correlation between two components: "DEP" and "RCS".

This negative correlation indicates that when one of these events occurs later than expected, the other event tends to occur earlier than expected. This could be useful information for supply chain risk management, as it suggests that delays in one area may be offset by early completion of another area. To further explore this relationship by analyzing other variables in the dataset, such as the specific airlines or airports involved. By identifying patterns and trends in the data, development of strategies for minimizing risk and improving overall supply chain efficiency can be done.

The results of the analysis, it seems that there is a strong relationship between the "DEP" and "RCS" variables in the departure section of the supply chain. To minimize the impact of this relationship on the overall supply chain risk, development of a strategy is possible that focuses on improving the efficiency and reliability of the departure process. A potential approach is to streamline the check-in and departure processes to reduce the time between the "RCS" event (checking in the shipment and producing a receipt at the departure airport) and the "DEP" event (the aircraft departing with the shipment on board). This could involve implementing automated systems for tracking and processing shipments, improving communication and coordination between different parties involved in the departure process, and optimizing the use of resources such as personnel and equipment.

Another approach is to develop contingency plans for dealing with delays or disruptions in the departure process. This could involve identifying alternative departure airports or airlines that can be used in case of delays, developing protocols for rerouting or rescheduling shipments, and establishing clear communication channels for keeping all stakeholders informed of any changes or issues that arise. The key to minimizing the impact of the "DEP" and "RCS" variables on supply chain risk is to identify areas for improvement and implement targeted strategies that address these issues. By improving the efficiency and reliability of the departure process, we can reduce the likelihood of delays or disruptions and improve the overall performance of the supply chain.

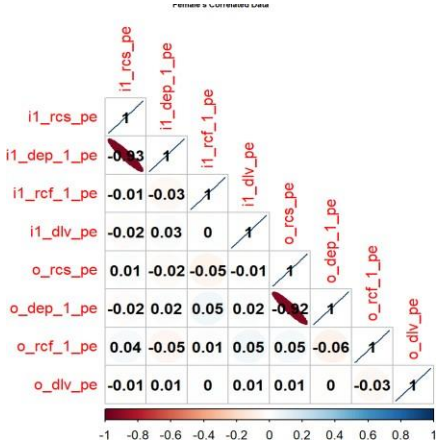

Figure 1: Correlation after disruptions; Data source: [https://rpubs.com/rabbiamin/1019826].

From the results derived from Cargo 2000 dataset analysis, it was found what questionnaire to experts can provide a more relevant result. Table 2 provides the overview of the questionnaire and their results to identify.

Table 2: Survey of Industry Experts and their answers.

SL#	Questions	Weigt-(%)	Group A	Group B	Group C	Group D
A	On a scale of 1 to 10, how frequently have you experienced stockouts or excess inventory costs in your supply chain operations?	20	**Rarely (1-3)**	**Occasionally (4-6)**	**Frequently (7-9)**	**Always (10)**
			20	60	15	5
B	How often do supply chain risks (such as natural disasters, labor disputes, or transportation disruptions) impact your supply chain operations?	20	**Rarely (less than once a year)**	**Occasionally (once or twice a year)**	**Frequently (several times a year)**	**Very frequently (almost every month)**
			20	70	7	3
C	What percentage of your overall supply chain costs are attributed to transportation and logistics?	20	**Less than 10%**	**10-20%**	**20-30%**	**More than 30%**
			60	20	17	3
D	What percentage of your inventory carrying costs are attributed to safety stock?	5	**Less than 10%**	**10-20%**	**20-30%**	**More than 30%**
			55	25	20	0
E	What types of inventory management techniques are used in your supply chain operations?	5	**Economic order quantity (EOQ)**	**Safety stock**	**Just-in-time (JIT)**	**Vendor-managed inventory (VMI)**
			60	35	5	3
F	What types of transportation management techniques are used in your supply chain operations?	5	**Routing optimization**	**Mode optimization**	**Carrier selection**	**Transportation tracking and visibility**
			40	5	33	22

G	What types of supply chain risk management techniques are used in your supply chain operations?	5	**Risk assessment and analysis**	**Risk mitigation planning**	**Risk monitoring and control**	**Crisis management and response**
			10	5	5	80
H	What types of statistical or machine learning techniques are used in your supply chain operations?	5	**Regression analysis**	**Time series analysis**	**Artificial neural networks**	**Random forest**
			0	100	0	0
I	How do you prioritize supply chain risks for mitigation?	5	**Based on probability and impact**	**Based on available resources**	**Based on stakeholder input**	**Based on intuition and experience**
			50	50	0	0
J	How do you measure the effectiveness of your supply chain risk mitigation strategies?	5	**Cost reduction**	**Service level improvement**	**Risk reduction**	**Time reduction**
			80	5	0	15
K	What additional data sources would be useful in improving your supply chain risk mitigation strategies?	5	**Weather data**	**Social media data**	**Economic data**	**IoT sensor data**
			20	50	25	5

From the questionnaires results it can be identified that policies and best practices can lead to lower schedule risk. This identification can also be related to many published papers and articles.

Maintenance management policies are strategies and procedures that are implemented to ensure that maintenance activities are conducted in an efficient and effective manner. Information systems are used to record and track all maintenance activities, including scheduling, budgeting, and reporting according to [12]. This allows organizations to better understand the maintenance activities that are being conducted, and to ensure that they are being conducted in an efficient and cost-effective manner.

Maintenance and inventory management are two critical components of a company's operations, and they are strongly interconnected. Effective inventory management requires accurate and up-to-date information about the condition and availability of inventory items according to the author in [13]. Without proper maintenance, inventory items can quickly become damaged, obsolete, or otherwise unusable, leading to increased costs and reduced productivity according to the author in [14]

Several other studies have highlighted the importance of considering maintenance and inventory management

together when optimizing a company's operations. For example, in a study of manufacturing firms in [15] researchers found that companies that integrated maintenance and inventory management were able to achieve significant improvements in both areas. Another study of a hospital supply chain found that integrating inventory management and maintenance led to improved equipment availability and reduced inventory costs.

5. Findings and Studies

Supply chain practitioners usually deal with parameters that generate risk in each touchpoint. For this research, schedule risk can arise from the following parameters.

Lead time Lead time is the time between placing an order for a product and receiving the product. Sharing lead time information between companies in the same supply chain can be useful for mitigating supply chain risks, particularly the risk of stockouts. By sharing lead time information, companies can coordinate their production schedules and adjust their inventory levels to ensure that they have enough products on hand to meet anticipated demand. Time series analysis and forecasting can be applied to lead time data to identify patterns and trends in lead time, which can be used to develop more accurate lead time estimates and reduce the risk of stockouts. For example, if historical lead time data shows that lead times tend to increase during certain times of the year due to factors such as increased demand or supplier capacity constraints, companies can adjust their production schedules and inventory levels accordingly to ensure that they have enough products on hand during these times. Time series analysis can also be used to forecast lead times, allowing companies to plan for future demand and adjust their production schedules and inventory levels accordingly. In addition to lead time data, time series analysis and forecasting can also be applied to other types of supply chain data, such as sales data, production data, and inventory data. By analyzing these data sets, companies can identify patterns and trends that can be used to optimize their operations and reduce the risk of supply chain disruptions. There are several factors that can influence the trend of increasing lead times during certain periods of the year in a supply chain. Some of these factors include:

Seasonal demand Many industries experience seasonal demand fluctuations, which can lead to increased lead times during peak demand periods. For example, retailers may experience increased demand for products during the holiday season, leading to longer lead times as suppliers struggle to keep up with demand.

Supplier capacity constraints Suppliers may have limited capacity to produce and deliver products during certain periods of the year, leading to longer lead times. For example, a supplier may experience increased demand from multiple customers during the same period, leading to delays in production and longer lead times.

Transportation disruptions Transportation disruptions, such as severe weather or labor strikes, can lead to longer lead times as products are delayed in transit. For example, a major snowstorm may disrupt transportation routes and cause delays in the delivery of products, leading to longer lead times.

Production delays Production delays can also lead to longer lead times as products are delayed in the manufacturing process. For example, a manufacturing plant may experience equipment breakdowns or labor shortages, leading to production delays and longer lead times.

Inventory shortages If a supplier or manufacturer experiences inventory shortages, they may need to wait for raw materials or components to arrive before they can produce products. This can lead to longer lead times as they wait for inventory to arrive.

Based on the analysis and survey findings, strategies to be considered are listed in this section.

1. **Inter Organizational Inventory:** Integrating several company inventories can be a useful strategy for mitigating supply chain risks such as stock outs or excess inventory costs. This can be achieved through collaboration between companies in the same supply chain to share inventory information, coordinate production schedules, and optimize resource allocation. Supply chain companies can share several types of information to avoid stock outs or excess inventory, including:
2. **Inventory levels:** By sharing information on their inventory levels, companies can coordinate their production schedules and resource allocation to avoid stockouts or excess inventory.
3. **Production schedules:** By sharing information on their production schedules, companies can coordinate their production activities to ensure that they are producing the right number of products at the right time.
4. **Sales forecasts:** By sharing information on their sales forecasts, companies can adjust their production schedules and inventory levels to meet anticipated demand and avoid stockouts or excess inventory.
5. **Lead times:** By sharing information on their lead times, companies can coordinate their production activities to ensure that they are able to meet customer demand in a timely manner.
6. **Supplier information:** By sharing information on their suppliers, companies can coordinate their purchasing activities and ensure that they have access to the necessary raw materials and components to meet production schedules and avoid stockouts.
7. **Transportation information:** By sharing information on their transportation activities, companies can coordinate their logistics activities and ensure that products are delivered to customers in a timely and efficient manner.

Overall, by sharing information on inventory levels, production schedules, sales forecasts, lead times, supplier information, and transportation information, supply chain companies can collaborate to optimize their operations and avoid stockouts or excess inventory.

By analyzing historical lead time data and identifying patterns and trends, companies can better understand the factors that influence lead times during certain periods of the year. This can help them adjust their production schedules and inventory levels to avoid stockouts and ensure that they have enough products on hand to meet demand.

Let's say there are two factories that are part of an integrated inventory system - a manufacturer and a supplier. The manufacturer relies on the supplier to provide raw materials to produce its products, and the two factories are connected through an integrated inventory management system. During the summer months, the manufacturer experiences a spike in demand for its products due to increased consumer demand. However, the supplier is also experiencing high demand from other customers during the same period, leading to supplier

capacity constraints. As a result of the capacity constraints, the supplier is unable to provide the manufacturer with the necessary raw materials in a timely manner, leading to longer lead times. The longer lead times mean that the manufacturer has to hold more inventory in order to avoid stockouts, which increases inventory carrying costs. In addition, the longer lead times may also result in delayed production schedules and missed delivery deadlines, which can impact customer satisfaction and lead to lost sales. The manufacturer may need to consider sourcing raw materials from alternative suppliers, but this can also lead to increased costs and potential quality issues. To mitigate the impact of supplier capacity constraints on lead times, the manufacturer and supplier can work together to improve communication and coordination. They can share production and inventory data in real-time to ensure that they are aligned on production schedules and inventory levels. They can also explore alternative sourcing options to reduce the impact of capacity constraints. By analyzing historical lead time data and identifying patterns and trends, the integrated inventory system can also develop more accurate lead time estimates, allowing them to better plan for future demand and adjust their production schedules and inventory levels accordingly.

Model as a Solution of increasing lead time trend on uncertain section of a year

When facing an increasing trend of lead times that yield stockouts, one potential solution is to implement a model of multiple suppliers. This involves sourcing materials or products from multiple suppliers, rather than relying on a single supplier. This can help to mitigate the risk of stockouts caused by longer lead times from a single supplier.

Here's an example of how a model of multiple suppliers could be implemented

Let's say a manufacturing company currently sources all of its raw materials from a single supplier, which is experiencing longer lead times due to capacity constraints. The longer lead times are resulting in stockouts and production delays, which are negatively impacting the company's operations and customer satisfaction. To mitigate this risk, the company could identify and engage with additional suppliers that can provide the same raw materials. By sourcing materials from multiple suppliers, the company can diversify its supply chain and reduce the impact of longer lead times from a single supplier. The company would need to evaluate potential suppliers based on factors such as price, lead time, quality, and reliability. Once additional suppliers are identified and vetted, the company would need to estab. To effectively manage the model of multiple suppliers, the company would need to implement an integrated inventory management system that can track inventory levels and lead times from each supplier in real-time. The system would need to be able to dynamically adjust inventory levels and production schedules based on lead time estimates from each supplier.

While implementing a model of multiple suppliers can help to mitigate the risk of stockouts caused by longer lead times from a single supplier, it can also come with its own set of challenges. For example, managing relationships with multiple suppliers can be complex and time-consuming, and sourcing materials from additional suppliers can increase costs. However, by effectively managing the model of multiple suppliers, companies can reduce the risk of stockouts caused by longer lead times and improve their overall supply chain resilience.

6. Scope of Further Studies

The There are several potential areas for further work in the project:

I. Research: Conducting further research on the topic can help provide additional insights and data that can be used to inform the project. This may include conducting surveys, analyzing market trends, or reviewing industry reports.
II. Prototype development: Building a prototype of the product can help test the feasibility of the idea and provide a tangible representation of the concept. This can also help identify potential challenges and areas for improvement.
III. User testing: Conducting user testing can help ensure that the product is user-friendly and meets the needs of its target audience. This may involve creating user personas and scenarios, conducting focus groups, and collecting feedback.
IV. Marketing and promotion: Developing a marketing strategy and promoting the product can help increase visibility and generate interest among potential customers. This may include creating a website, social media marketing, and attending industry events.
V. Business planning: Developing a business plan can help ensure that the project is financially viable and sustainable in the long term. This may involve creating financial projections, identifying potential funding sources, and exploring partnerships and collaborations.

7. Conclusion

Based on the information provided throughout this conversation, it appears that we were analyzing a dataset related to the supply chain management process. Specifically, we were examining the relationship between different events or variables within the departure section of the supply chain, such as the time of shipment check-in and the time of receipt production at the departure airport.

Our analysis revealed that there was a highly correlated relationship between the Shipment checked in and receipt produced components in the dataset. We used principal component analysis (PCA) to reduce the dimensionality of the data and found that these two components were the most important. This suggests that they can be used for further analysis or modeling to improve supply chain management.

Furthermore, we performed another principal component analysis on the resulting variable of subtracting plan time with effective time. This analysis showed a highly negative correlation between the "DEP" and "RCS" components. This negative correlation indicates that delays in one area of the supply chain may be offset by early completion of another area, which can be useful information for supply chain risk management.

To minimize the impact of this negative correlation on the overall supply chain risk, we can develop a strategy that focuses on improving the efficiency and reliability of the departure process. This could involve implementing automated systems for tracking and processing shipments, improving communication and coordination between different parties involved in the departure process, and optimizing the use of resources such as personnel and equipment.

Overall, our analysis provides valuable insights into the departure section of the supply chain management process. By identifying patterns and trends in the data, we can develop strategies to minimize risk and improve overall efficiency. Further work could involve analyzing other variables in the dataset, such as specific airlines or airports, to gain a more detailed understanding of the supply chain process and identify further opportunities for improvement.

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Appendix

Table 3

SL#	Questions	Weight (%)	Group A	Group B	Group C	Group D
A	On a scale of 1 to 10, how frequently have you experienced stockouts or excess inventory costs in your supply chain operations?	20	Rarely (1-3)	Occasionally (4-6)	Frequently (7-9)	Always (10)
			20	60	15	5
B	How often do supply chain risks (such as natural disasters, labor disputes, or transportation disruptions) impact your supply chain operations?	20	Rarely (less than once a year)	Occasionally (once or twice a year)	Frequently (several times a year)	Very frequently (almost every month)
			20	70	7	3
C	What percentage of your overall supply chain costs are attributed to transportation and logistics?	20	Less than 10%	10-20%	20-30%	More than 30%
			60	20	17	3
D	What percentage of your inventory carrying costs are attributed to safety stock?	5	Less than 10%	10-20%	20-30%	More than 30%
			55	25	20	0
E	What types of inventory management techniques are used in your supply chain operations?	5	Economic order quantity (EOQ)	Safety stock	Just-in-time (JIT)	Vendor-managed inventory (VMI)
			60	35	5	3
F	What types of transportation management techniques are used in your supply chain operations?	5	Routing optimization	Mode optimization	Carrier selection	Transportation tracking and visibility
			40	5	33	22
G	What types of supply chain risk management techniques are used in your supply chain operations?	5	Risk assessment and analysis	Risk mitigation planning	Risk monitoring and control	Crisis management and response
			10	5	5	80
H	What types of statistical or machine learning techniques are used in your supply chain operations?	5	Regression analysis	Time series analysis	Artificial neural networks	Random forest
			0	100	0	0
I	How do you prioritize supply chain risks for mitigation?	5	Based on probability and impact	Based on available resources	Based on stakeholder input	Based on intuition and experience
			50	50	0	0
J	How do you measure the effectiveness of your supply chain risk mitigation strategies?	5	Cost reduction	Service level improvement	Risk reduction	Time reduction
			80	5	0	15
K	What additional data sources would be useful in improving your supply chain risk mitigation strategies?	5	Weather data	Social media data	Economic data	IoT sensor data
			20	50	25	5