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Managing Aerospace Supply Chain Disruptions of "Increased Complexity" and "Single Sourcing"

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***Abstract*- There are several influential risks in an aerospace supply chain which disruption is one of the most significant types. Many researchers believe that the impact of disruption is more considerable than other risks. There are two main reasons for aerospace supply chain disruption, which are "increased complexity" and "single sourcing". The article explains aspects of these causes as well as related solutions for each one of them. The main solutions for these two disruptions including: integrating and synchronizing planning and execution, mean and variance of lead time reduction, investing in visibility, building flexibility in supply chain, fulfilling robustness strategy, collaborating and cooperating with supply chain partner.**
Accordingly, since each one of main supply chain approaches – lean and agile- needs diverse strategies; the final step is about the strategies, which would be reached through benchmarking among them for both lean and agile series of components and raw materials.

***Index Terms*— Supply chain disruption, Aerospace industry, Increased complexity, Single sourcing**

I. Introduction

Supply chain disruption is usually considered as one of the main aspects of supply chain risk. Abundance of suppliers and complexity of the process for aerospace industry has increased probability of its occurrence. The paper tries illuminating its aspects and presents solutions for two significant causes of aerospace supply chain disruption: "increased complexity" and "single sourcing". The solutions are from the producers of commercial airplanes' viewpoint. In addition, the final strategy through benchmarking among solutions would be studied. Since managers adopt different approaches for lean and agile products of the industry; the final strategy will consider these differences.

II. Literature Review

A. The Risk of Disruption in Supply Chain

Wu et al. define disruption as any occurrence which interrupts the process of material flow in supply chain. This is a simple concept of supply chain disruption that so many researchers have been trying to identify the causes for and present related solutions [1].

Hendricks and Singhal find the probability of occurrence of the supply chain disruptions in the future more than now due to a series of causes [2]. A few of them are:

1. Increased complexity: increasing global outsourcing enhances the need to adequate cooperation across different tiers of supply chain.
2. Single sourcing: it is helpful to increase the speed of process as a central requirement for adopting agile approach; utilizing single-sourcing strategy accumulates disruption.

They suggest 8 solutions to mitigate or prevent disruption, which are:

1. Improving the accuracy of demand forecasts; 2. Integrate and synchronize planning and execution; 3. Reduce the mean and variance of lead time; 4. Collaborate and cooperate with supply chain partners; 5. Invest in visibility; 6. Build flexibility in supply chain; 7. Postponement strategy; and 8. Invest in technology.

Additionally, Tang points out "robustness strategy" which means fulfilment of efficient managerial methods to prevent supply chain disruptions [3].

In order to prevent and mitigate disruption, Sheffi suggests a 4-step hierarchical framework including:

1. Being aware and recognizing disruption adequately;
2. Adopting preventive solutions;
3. Establishing efficient and concentrated system for response management to disruptions; and
4. Achievement management [4].

The represented framework could be efficient for mentioned disruptions and its solutions. Some of the disruptions are more influential in aerospace supply chain are as follows.

B. Aerospace Supply Chain Disruption of "Increased Complexity" and "Single Sourcing"

Disruption is one of the most crucial types of risk which impact aerospace supply chain. Two causes of disruption are more influential than others; which are:

1. Increased complexity: due to abundance of components and raw material as well as multiplicity of suppliers.
2. Single sourcing: a part of crucial (especially high-tech) components are supplied by numerous suppliers worldwide.

Below are the related solutions for each one of above aspects of disruption.

III. Disruption Mitigation in an Aerospace Supply Chain

The article studies two main causes of aerospace disruption and represents related solutions for them.

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A. *Increased Complexity*

Managing supply chain is complex; its complexity in an industry like aerospace due to plenty of components and suppliers is even more significant. It results in disruption occurring across commercial airplane manufacturing supply chain.

1) *Integrate and Synchronize Planning and Execution*

It is a classic solution for increased complexity of disruption. As Arkell mentions, aerospace industries such as Boeing adopts it to coordinate their suppliers in the best manner [5].

It could be reached through customized Enterprise Resources Planning (ERP) software.

2) *Reduce the Mean and Variance of Lead Time*

Suppliers sometimes due to high mean and variance of lead time cannot synchronize their scheduled plans execution. Hence an increase in the complexity off the process. Cheng and Podolsky argue 5 kinds of lead time:

1. Waiting time: The time subsequent to the completion of operations.

2. Moving time: The duration required to move between machine operations.

3. Queuing time: The time prior to the commencement of operations.

4. Machine set-up times: The amount of time required to complete machine changeovers and set-ups.

5. Running time: The time required for Work-In-Process (WIP) parts to complete a machine operation [6]

In addition, Hendricks and Singhal (2012) mention methods to mitigate lead time, including:

1. Elimination of non-value added activities;
2. Increasing concentration and accuracy of processes and critical sources and material; and
3. Considering all 5 mentioned aspects of lead time to reach a clear prevention framework for disruption.

For instance, Airbus in order to optimize its delivery process; concentrates on lead-time reduction [5]. Additionally, Airbus tries adopting lean approach to decreasing delivery lead time [5] as well as reducing design lead time and cost of complex engineering projects through using new software [7].

On the other hand, Boeing specifies working and lead time for its work centers to follow a specific schedule to make, assemble and deliver determined components [8].

3) *Invest in Visibility*

Inaccessibility to detailed production data of higher-tiers suppliers as well as putting invalid data by them in ERP systems; cause many risks such as disruption across aerospace supply chain. Boeing, in order to prevent these problems; established an integrated information technology process to reach total asset visibility. It lets the company access the data of all suppliers and if it finds any problem, it adopts appropriate activity to respond immediately. It not only decreases disruption of Boeing but also increases the company's forecasting accuracy as well [9].

4) *Build Flexibility in Supply Chain*

The solution is applicable for so many supply chain risks. Garbar and Sarkar claim that the building flexibility across supply chain, not only decreases the risks; it is the critical reason to provide competitive advantage. From their point of view: globalization, abundance of suppliers and components as well as high-standard of products that Final Aviation Administration (FAA) considers for them; increases this complexity and need to flexibility of production process [10].

They claim, flexibility could be achieved through shortened production cycle and continuous replenishment. Moreover, Garbar and Sarkar point out 4 solutions to build flexibility in an aerospace supply chain including:

1. Supply chain network design optimization;
2. Build flexible relation with suppliers (since 40-50% of production cycles depend on suppliers)
3. Transaction and payment process simplification; and
4. Optimizing connections across suppliers [10].

Each of mentioned solutions aid to build a flexible supply chain which helps to prevent complexity of a process.

B. *Single Sourcing*

A number of components or raw material required by the manufactures are only available through a limited number of suppliers. This causes increased disruption for them. There are several solutions to mitigate or prevent possibility of their occurrence.

1) *Robustness Strategy*

Robustness strategy has various aspects most of which are appropriate for those companies who follow single-source strategy. Needles and Powers claim that the more the airplane manufacturers like Boeing adopt this strategy, they increase the risk of disruption sharply [8].

Huchzermier and Cohen suggest scattering suppliers to decrease aerospace disruption as well as risk of procurement [12]. It is one of the principal aspects of robustness strategy. Furthermore, Lee suggests that if the companies cannot cooperate with multi-suppliers to prevent the risk; adopting postponement strategy is a proper solution for them [13].

Accordingly, adopting multi-supplier strategy as the first step; and adopting postponement strategy if the former was not feasible; are appropriate solutions to mitigate the risk.

2) *Collaborate and Cooperate with Supply Chain Partner*

Suppliers play a vital role for the industry. Accordingly, commercial airplane manufacturers have to study the capabilities of them in order to optimize their cooperation and collaboration with the suppliers. For instance, as Tang and Zimmerman mention, Boeing to maximize its utilization of suppliers; contracts all-tiers of suppliers and even cites their expected progression of them in each. It helps the company prevent current disruption on one hand, and mitigate its further disruptions which probably will occur on the other hand through supervision on future facility development [14].

IV. MITIGATION AND PREVENTIVE STRATEGIES FOR AEROSPACE SUPPLY CHAIN

Two influential causes of supply chain disruption in aerospace supply chain, increased complexity and single sourcing were studied and relevant solutions for them were mentioned as well. The final strategy based on benchmarking among them are presented below for both series of agile and lean products.

A. *Mitigation and Preventive Strategies for Increased Complexity*

There are abundant components for a commercial airplane. Any shortages within final assembly result in supply chain disruption. It occurs often for lean products that suppliers who follow cost-reduction approach and cannot adopt Just-In-Time (JIT) delivery system; which causes disruption. Since utilizing ERP software is suggested to synchronize planning and execution principally for lean components. It aids the producer to know his exact time of receiving products from all suppliers.

Furthermore, lead-time reduction would be another significant strategy for lean components. It helps suppliers to prevent unpredictable disruptions and if any problem occurs during supply chain fulfilment; they will replenish those components immediately. It needs to invest in visibility across all suppliers which could be reached through applying ERP software by all tiers of suppliers.

In addition, building flexibility in supply chain is the last strategy for lean components; although it is a prerequisite for agile ones. The strategy can shorten production cycles and continuous replenishment by suppliers of lean products. Besides, it helps the producer to order customized components due to flexible machinery and facility system of suppliers.

Building flexibility follows more expanded meanings for agile components. Since 40-50% of production life cycle of these components depend on suppliers as well as manufacturing of these components have more details; flexibility in supply chain is an obligation for the industry and all suppliers who work within the process.

Moreover, transaction and payment process simplification for agile products which are typically costlier as compared to lean ones; supports disruption mitigation (and even procurement risk). Since it lets producers pay based on flexible due dates when disruptions occur for the company which has to pay for immediate disruption solutions.

Finally, supply chain network design optimization improves flexibility of supply chain and aids preventing increased complexity. It would be reached through relations among all tiers of suppliers on one hand and increasing customization of components on the other hand. All aforementioned strategies for increased complexity are summarized in table 1.

Table I: Disruption of Increased Complexity Mitigation Strategies for Lean and Agile Products

Lean Approach	Agile Approach
• Utilizing ERP software across producer and suppliers in order to synchronize and integrate design and production across the whole supply chain. • Lead-time reduction to receive components at scheduled time and replenish them if any problem occurs. • Invest in visibility to access all suppliers' information. • Building flexibility in supply chain through shortening production cycles of suppliers.	• Increasing flexibility through production cycle reduction of suppliers to receive customized products. • Transaction and payment process simplification for ordered components. • Supply chain network design optimization across all tiers of suppliers.

B. *Mitigation and Preventive Strategies for Single Sourcing*

Single-sourcing strategy is suggested by many researchers for agile products; however sometimes the strategy has been used by suppliers of lean products to reach economies of scale. This strategy merely increases the disruption of single sourcing.

Thus it is crucial to collect data about capabilities of each supplier who produce agile components about following postponement strategy. It means that each tier of suppliers needs to try conforming make-to-order system for their production to postpone their manufacturing process. Accordingly, since the main disruptions came from higher-tier suppliers in the aerospace industry; recognizing their capabilities to follow mentioned strategies and systems are more significant. As a result, adopting single sourcing strategy by first-tier suppliers, increases disruption if suppliers' suppliers cannot adopt appropriate manufacturing systems.

In addition, single sourcing is not suggested for lean products since the required characteristics for adopting lean approach, comprehensively are incompatible with this strategy. However, producers frequently prefer to follow single sourcing to achieve economies of scale. If final cost of purchasing from sole supplier surpasses cost of disruption; thus the strategy for that specific components could be reasonable (although, like agile-products; collecting information about higher-tiers suppliers about their capabilities and production systems is a prerequisite).

As a result, mentioned strategies for both agile and lean products are summarized in table 2.

Table II: Disruption of Single Sourcing Mitigation Strategies for Lean and Agile Products

Lean Approach	Agile Approach
• Comparing the cost of occurrence probable disruption with final cost of a product which is achieved by sole supplier. • Observation of the activities of all suppliers who adopt single sourcing for a part of their components (in order to prevent occurring the disruptions of higher-tiers suppliers)	• Collecting data about suppliers who can follow postponement strategy for their production. • Gathering information about the capabilities of second-or-higher-tiers suppliers who to conform make-to-order manufacturing systems.

V. Conclusion

The risk of disruption in aerospace supply chain has several causes. The paper tries to mention two crucial parts of it which are "increased complexity" and "single sourcing".

Additionally, related solutions for each one of them with examples of 2 first commercial airplane manufacturers, Boeing and Airbus, were brought.

As the final strategy, benchmarking of each series of these products based on lean and agile approach were mentioned as the last part of the research. It is hoped that the research could be instrumental and practical for researchers engaged in this field for considering and realizing their various objectives.

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