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Research Article

Assessment and prioritization of Supply Chain Risk: Development of AHP model in Aerospace Industry

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Abstract

In 21st century, competition has shifted from companies to supply chain systems of the industry and aero industry is not an exception. As the industries is highly technology intensive, involve huge cost, operate within stringent quality standards and safety norms, managing industry supply chain becomes a tremendous task of supply chain managers. The risk associated with supply chain affects industry performance, hence needs greater attention. This paper presents general risk taxonomy specifically the risks affects the industry supply chain. AHP (Analysis of Hierarchical Process) method is used for analysis of risk factors. It is hoped that this method will help manager, suppliers, auditors, and consultants etc. to manage their systems better. All risks involved in aerospace supply chain are identified, classified, ranked basing on their risk exposure in aero industry eco system. AHP analysis shows that critical risk originate from suppliers risk chain side. The most important risks in aerospace supply chain is found out to. Risk of improving engineering process (RI1) ranked one with weightage 18.87% followed by incident impacting supplier facility, breakdown of IT infrastructure, risk of not retaining talented workforce and supplier quality problem rank second, third, fourth, five respectively with global weights 9.93%,7.57%,5.43 and 4.97%.

Keywords: Supply chain Risk factors, AHP, Risk Prioritization, risk exposure, risk assessment

1. Introduction

By definition, risk in any business means anything that affect company's ability to achieve its financial goals called business risk. Risk comes from variety of sources. It is always not come from company head or managers fault but many times it comes from other sources may be within the company or outside the company or from regulation to overall economy or global situation. As supply chain of any aero industry is not limited to any country, the company may not able to take shelter itself from the risk completely, there are various ways it can help to protect itself from the impact of business risk by managing risk management strategy.

Supply chain risk in literature is relatively a new concept and first given by Zissudin in 2003.It is defines as the potential occurrences of activities or events associated inbound, outbound supply and internal process delays resulting inability of the firm to meet customer demand .These risk of supply chain failures risks are very costly leading to significant delay in customer deliveries and payment of huge amount towards liquidated damages. Hence analysis of supply chain risk plays an utmost important in supply chain management. Consequently it is an important factor for firm's success to understand the source of supply chain risk and act accordingly to minimize the impact caused.

Supply chain is the heart of any aero industry success. Effective and efficient supply chain management enables aerospace industry's to meet their strategic and financial goals.

Typically aerospace supply chain is large in scale having many tiers of suppliers and each tier of supplier provides goods and services to the next level of supplier. The details of activity involved and level of supply chain are given in **Fig.1 (a) & 1(b)** respectively. Each tier has multiple level of components creating a mesh of network within the supply chain and linear flow of goods and services are rare phenomenon. Managing supply chain network is very complex and dynamic in nature. The supply chain system is dynamic with respect to various risk associated with it like uncertainty in demand, capacity, delivery schedule, manufacturing time and cost. Risk of the supply chain system are identified depending upon the perspective adopted. Risk events then can be classified as risk in material flows or risk in information flows or risk in finance flows or other external factors. Perspective of risk with respect to material flow can be further classified to stages of source, delivery, certification, mode of transport, quality, reliability, process involved etc. Among risk factors identified, few have greater impact in supply chain and others may have lesser impact. Then identify risk factors that affect supply chain goals like delivery schedule, cost, quality, flexibility and reliability. Accordingly these risk can be classified as few categories like strategic risk, tactical risk, operational risk for which firm has to take necessary preventive action to minimize or eliminate the risks.

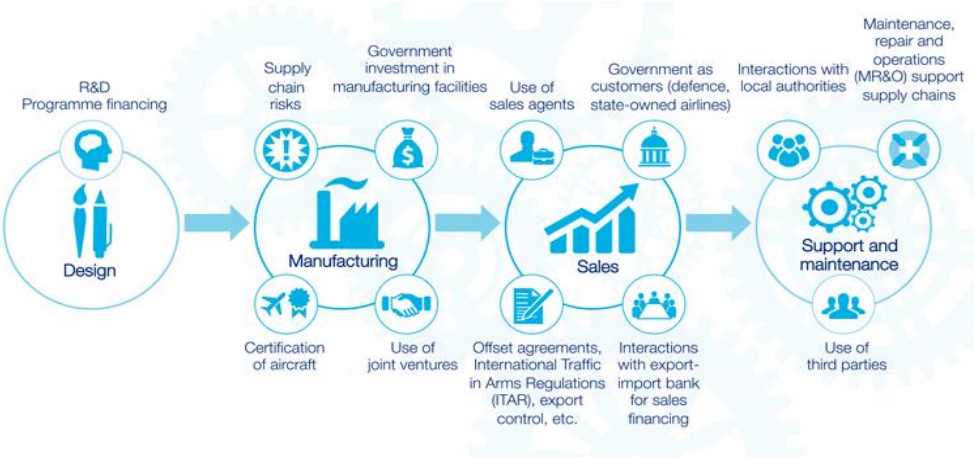


Fig (1a)

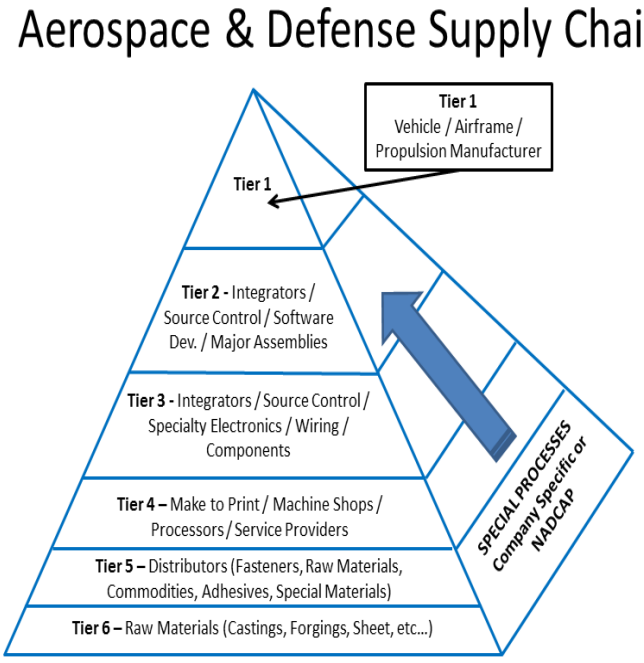


Fig (1b)

2 Supply Chain Risk in Aero Industry:

Risk and uncertainty are inherent part of every industry especially large industry**.** Many researcher suggest that managing risk should follow formal and structured approach in identification, quantification and prioritization in reduction. (Fosdick, 1997; Khan and Burns, 2007; Steele and Court, 1996; Yates and Stone, 1992) {1}. Similar argument also proposed by Manuj and Mentzer (2008) {2} to identify the risks is the first step of risk management. Risk management increasingly become difficult in complex global economy and also increasingly become important (Sheffi, 2005) {3}. Hence point to ponder that clearly identify the potential source of risk in the supply chain. Rao et al. (2009) {4} argue that business and organizational risks emerge from one or more of the following sources:

1. Environmental factors
2. Industry factors
3. Organizational factors
4. Problem-specific factors and
5. Decision-maker related factors.

Chopra and Sodhi (2004){5} categorized supply chain risks like disruptions, delays, systems, forecasts, intellectual property, procurement, receivables, inventory and capacity. In aero industry, (Sinha et al., 2004) classified risks in four areas which include: standards, suppliers, technology, and practices. In all four areas, there are a number of supply chain risks that could happen.

In 2004, Flinch {6} classified supply chain risks into three broad categories which include three levels of coverage: application level, organizational level, and inter-organizational level. Application level risk includes, natural disasters, accidents, deliberate acts, data/information security risks, and management issues. Organizational level risk includes, legal and strategic changes in decisions could happen, while at the inter-organizational level, there are possible uncertainty from the outside of the organization which could pose risks.

In 2008 Tapiero and Grando {7} classified supply chain risks into operational risks (within the industry), external risks (outside the industrial operation but within the network), strategic risks and external externalities. Risks belongs to third party where no control over how that cost or benefit impact the organization was created. It can be both positive and negative and can come from producing or consuming a good or service

In 2004, Norrman and Lindroth {8} categorized the type of risks as strategic uncertainty, operational accidents, and operational catastrophes. . Strategic uncertainty could be in the form of a volatile demand, supplier bankruptcy, increasing competition, market constraint, and certainly, each company would have a different set of typical risks. The operational accidents are those affecting the operational process or resources related to logistics, such as fires, truck accidents, machine failures, labor strikes, etc. Operational failures are risks associated with the process of business and are rare/difficult to predict events, but once they have occurred; they have severe impacts on the company.

Only a handful of papers have addressed all three types of risks (Juttner et al., 2003; Zsidisin, 2003; Christopher and Peck, 2004; Norman and Jansson, 2004; Peck, 2005; Wagner and Bode, 2008; Wu et al., 2006) {9}.

In a true sense, informed decisions can only be made for known risks only, not for unknown risks, hence there is a need for greater understanding of consequential risk linkage at these levels (Peck, 2005){10}:

- Process/product level
- Infrastructure/assets
- Organization level
- Inter organization level
- Environmental level

Decision making situations in the supply chain in which the decision maker does not know for certain cases as what to decide as he is unclear about the objectives; lacks information about or understanding of the supply chain environment; and unable to predict the impact of possible control actions on supply chain behavior or lacks effective control systems (Van der Vorst et al., 2002) {11}.It is very much essential to identify disturbance sources and individualize each one namely, customer, supply, own organization, nature and manmade, etc. Disturbances can be taken as critical/non-critical, severe/non-severe, short run/long run, local/ global and

predictable/non-predictable. One more category of risk, where companies have no control but it affects supply chain in different ways are industry specific risks.

As mentioned by Ritchie and Brindley {12}, 2007 the following function explain the supply chain risk.

Aggregate supply chain risk = f (External environment * Industry specific * Supply chain specific * Node specific).

Supply chain of each is exposed to different types of risks as above function portraits. Each supply chain is different in terms of sector or industry. It may be due to the supply chain configuration risks and node specific risks. Each company has different and diverse kind of risk profiles. To develop more analysis on this subject would be interesting to see if different types of risks are associated with different industry sectors. Risk construct in organizational performance has become need of organization (Ritchie et al., 2008) {12}. Management of supply chain risks and identification of risk sources and their assessment is the first key step in this context.

Risk classification given by Jotter (2005) {13}, in short description of each is as follows.

2.1 Downstream Risk/Demand Side Risks:

Demand side risks are risks that originate from the uncertainty of random consumer behavior (Nagurney et al., 2005){14} that affects forecast quality, and causes amplification in volatility in demand in the direction of upstream supply chain, characterized by bullwhip effect (Lee et al., 1997){15}. Bullwhip effect namely distorted information, sales promotion, order batching, over reactions, unnecessary interventions, second guessing and mistrust. Risk management (Demand side) is bread and butter for firms, but still represents a major risk source for many firms. Speckman and Davis (2004) {16}. Violent swing in market demand encourage "bullwhip effect "prompting customer demand prompt retailer to under order so as to reduce their inventories.

2.2 Upstream Risk /Supply Side Risks:

Supply side risks reside in supplies, purchasing, and supplier relationship. Kraljic (1983). Supplier side risks include supplier business risks, production capacity constraint on supply market, quality problems, and changes in supplier's technology (Zsidisin et al., 2000) {17}. Risk management (Supplier side of business) relate specifically to financial instability of suppliers, their insolvency or bankruptcy (Wagner and Johnson, 2004). Capacity constraints or shortages also drive the delivery problems (Lee and Billington, 1993). Inferior quality in purchased products can have a cascading effect through the supply chain to the final customer (Zsidisin et al., 2000). Noncombatant to generate cost reduction and adept technological design changes by suppliers may have detrimental effects on customer's costs and competitiveness (Zsidisin and Ellaram, 2003).

2.3 Process Risks:

Process risk source includes the disruptions that materialize from the assets that a firm maintains for its supply chain operations. It is generally considered as operational disruption and tactical disruption (Kleindorfer and Wassenhove, 2003; Paulson, 2004) {18} including accidents such as machine breakdowns, disruptions in supply of utilities like electricity or water, equipment malfunctions, machine breakdowns also caused by human centered issues like labor strikes, sabotage and industrial actions (Speckman and Davis, 2004){19}. These disruptions are very critical and relevant for supply chain management functions build on information processing and ERP system of firms forces them to open their internal processes and databases to supplier and customers.

2.4 Managing Talent Risks:

Because of specialized nature of business, aerospace companies are highly depending upon continued service of key personnel and key executives. They are also depending upon development of additional management personnel, qualified engineering personnel, sales, and marketing and management personnel for operations. The product and services provided by A&D players are highly diversified in nature involving sophisticated engineering along with complex manufacturing and system integration. Because of specialized nature, aerospace and defense companies hire and retain skilled and qualified persons necessary to perform critical business processes. Ineffective succession planning, lack of diversity and limited options for talent mobility are major challenges in talent management of A&D business. A highly talented pool helps A&D companies to gain competitive advantage in market and critical in success of the organization.

2.5 Managing key Contract Risks:

A&D companies typically involved multimillion-dollar contracts and have huge backlogs. New development involves complex design and new technologies in many cases unproved and untested. As a result, A&D players faces many technological challenges and other performance hindrances resulting delays, setbacks, cost overrun and product failures. In many cases product specification also changes in last moment of certification. The delays result huge financial loses may be termination of contracts. Aircraft OEMs loses billion of dollar contracts due to delays in deliveries in manufacturing of next generation aircraft programs. Continuous increase commitment of Aerospace &Defense companies to guarantee certain level of performance are translating to higher risk of exposure.

2.6 Managing Supply chain Risks:

A&D depends upon thousands of suppliers and subcontractors to procure raw materials, parts, sub-assemblies and outsourced processing for their manufactured product. They depend upon supplier network to meet performance specification, quality, certification and delivery schedule of product and services. The cost associated is to be per the cost budget so that overall cost production is under control. Aerospace industry does not have lean production process like automobile industry, the supply chain is highly interlinked globally. Ability of supply of products by OEMs depend upon number of suppliers supporting right product at right time with quality. There is a chance that the company has disputes with suppliers related to work specification, quality of supply and customer concerns. The inability of key suppliers will delay the process leading to cost overrun and delay in production schedule.

In some cases, companies depend on single supplier for a particular part or process. In case of supply disruptions of these parts, companies have limited options to restore the supply even at the cost of additional expenses.OEMs have expanded their business in emerging countries to capitalize on the increasing demand and low-cost environment. Working with local supplier have significant cost benefits but gives additional risk of political instability, intellectual property rights violation, product delays and quality issues. Investment in new programs require huge funding and OEMs moved to a model where suppliers are expected to co fund the development in exchange for anticipating long term contracts

2.7 Competition & Market Risks:

In A&D business Boeing and Airbus holds 80% of world market. Both aggressively pursued orders in with emerging market of airlines and low-cost carrier segments. However, in the medium term, new players are likely to be given limited dominance and order books like Boeing & Airbus, which effectively locked out new entrants. The defense industry counts few large players like US based and European based and dominates global market. More than 200 M&A deals are signed every year as a part of ongoing consolidation in the industry. A& D companies' participation in the bidding competitions involve large cost and effort for large contracts. Competition within industry lead to increase the bid protest as companies in the peer group and at times pressurize government to provide the rationale of awarding contract to specific players. Such bidding protest result in delay in starting of contract works. Government also reaching nontraditional players for IT solutions. This create increase competition among large players.

2.8 Geo-Political & Economic Environment Risks:

Most of aerospace players have global presence and their operational and financial performance significantly depends on geo-political and economic condition in their key markets. In last five years there have been much volatility in GDP of top five defense markets and economic growth has a strong correlation with growth in demand of commercial aircraft. Due to slow in economic slowdown and rising political tension, uncertainty A& D market will increase further. As the world is more unstable, fastest growing A&D market will be around the regions of national security tension. Accordingly companies will prepare themselves to counter the threat of tight credit environment and order cancellations.

2.9 Regulation Risks:

Aerospace and defense suppliers operate in a business environment which is global in nature and across many jurisdiction. Managing business in this sector has to comply with laws and regulations elated to award of work, administration, and performance contracts specifically government contracts and also face regulations relating to export of product and services. Failure to comply will result into severe consequences such as imposition of huge fine, penalties, termination of whole contracts, suspension or debarment from bidding process or civil/criminal proceedings. A&D companies including government agencies work in a highly regulating environment exposure to bribery and corruptions. Operating in countries with high level of corruption

multiplies with multiple exposures to corruptions and bribery litigations. Involvement in bribery practices have fatal consequences leading to order cancellations and black listing.

A&D players comply with several procurement regulations and several mandates around information security, contract pricing and bidding costs and also subjected to various audits and product integrity requirements. These regulations make it imperative for OEMs and supplier to maintain high quality standards of their product and services.

2.10 **Capacity to innovate Risk**:

Innovation in the field of aerospace business involves large amount of fund due to high end technologies, and complex manufacturing process and system integration. It is important for companies to create right infrastructure for fostering innovation through in-house R&D, collaborating with industry partners and partnering with academia. Some companies need to upgrade their facilities to stay competitive in regular basis. Advancement in Internet of Things (IoT) and digital technologies makes it more important for manufactures and suppliers to look for the new opportunities in new products and services in both original equipment (OE) and market supply sides of their business. A&D companies need to improve their engineering process to improve time to the market, improved quality, product reliability, product reuse and reduction in cost.

Inability to innovate new products and services hamper significantly their future business. Innovation requires huge investment and players need to continuously invest financial resources to develop new offerings. Investment in innovation could divert resources from other ongoing projects leading to delay in those projects.

2.11 Managing Merger & Acquisitions Risk:

Improper due diligence can result undesired results in M&A and partnerships. By doing M&A, aerospace companies identify the opportunities by complementing their existing product, services and expand their offerings to new markets. During evaluation of new M&A transactions, companies need to take decisions on the value of their business opportunities, technologies and other assets and potential liabilities. Poor decision will result over valuation, failure in achieving synergies and financial challenges. In developing countries as a part of their offset obligation and need transfer of technology to local players many Aerospace companies form JVs. These TOT relating to JVs create risk of IP violation and copyright infringements.

2.12 Cyber security Risks:

Increased digitization increases the threat of cyber-attacks. Companies involved in A&D value chain regularly exchanges confidential data on specification, technology, performance equipment with an objective to enhance collaboration in design development and support. All data are available to cyber terrorist with unethical clients who use the stolen data to copy the product and undercut the price of outperform competition. Also cyber-attack leading to compromise of confidential data of suppliers, customers or government agencies and can lead to a legal trouble. Most of the contracts in A&D business have strict rule on loss of confidential and critical information and can attract contractual penalties for data loss. Loss of confidential data exposes companies to legal claims and affect upstream and downstream companies of the supply chain.

2.13 Foreign Currency & Commodity Price Risks:

Revenues from international operations are strongly affected by foreign currency fluctuation. Business operating in number of countries and continents are more susceptible to fluctuation in foreign currency exchange rate. Since most of A&D companies have global foot print and significant part of their revenue comes from other country operation, variation in exchange rate affect their revenues and affect the overall financial performance. Again currency fluctuation also affect the receivables, payables ,return on assets denominated in foreign currencies .Furthermore ,production in various countries add to the risk is also associated with fluctuation in foreign currency exchange rate is as compared with home currency. Commodity price increase will also put pressure on the profitability of A&D companies. A fluctuation in key commodity prices affects financial performance. Increase in prices of raw material like Aluminum, Titanium, Composites, Chromium etc. will directly affect the production cost and also impact the cost associated in all production stages of supply chain resulting cascading effect on the final product.

2.14 Logistic Risks:

Logistic glitches affect the delivery to ultimate customer. Research shows in automobile industry, finished cars spend two weeks in transit. The poor performance of logistic are lack of professionalism in logistic sector, traffic congestion and malpractices at toll gates. Lack of skill truck driver and strikes or road blockage is also cause disruption in logistics. Logistics service (understood as air and maritime connectivity and logistics performance) is wide and varied and include the whole range of transportation infrastructure and services from

seaports, land based transportation systems as well as air transport, the corridors within and the interconnectedness with these modes of transport. In trade logistics, transport is the single most expensive component. An adequate infrastructure is required to facilitate transportation and difficult for a manufacturer to export at a competitive price or import at a competitive cost if the transport and logistics sector is inefficient or even dysfunctional. "A&D industries have moved some spares manufacturing and sub-assembly activities to low-cost countries," says Wertheimer. “Supply chains extension to 3PLs (Third Party Logistics) to support the manufacturing process. Providing visibility to the order and part level, determining total delivered cost. Synchronizing the flow of material from suppliers using tools reduces the logistic cost. Manufacturing supply chains requires to become more disciplined. As supply chain managers monitoring the flow, Inward materials movement is becoming less urgent and more synchronized. To transport parts cost effectively, aerospace supply chain managers must meet increasingly tight delivery time windows. Earlier meeting delivery schedules was easy because companies held one month's supply of buffer stock close to the plant. Today, however, the increased production tempo results in less inventory held at the plant or with vendors. Aerospace companies are more frequently requesting that their 3PLs manage vendor relationships and inbound logistics.

Table-1 represent the categories of risk and sub risks identified from literature and expert opinions in supply chain systems in the field of A&D business. The model proposed for classification of risks in the supply chain are three types: **First part** is within the organisation, **second** part is outside the organisation and within the network of industry **third** part is outside the network.

3.0 Proposed method for Risk identification for aerospace manufacturing Industry

In this section supply chain risk assessment methodology is illustrated in phases given below:

3.1 Risk Identification:

There are many ways to identify the risk associated with the process. Some common method used to identify the risks are: Interview of key stakeholder, Brainstorming, checklists, assumption analysis, cause and effect diagrams, nominal group technique and affinity diagram.

There are also other methods available in literature for identification of risk like: force field analysis, SWOT analysis, TOWS analysis, constraint analysis, process flow techniques etc. For the purpose of this paper, expert opinion with industry experts are taken into account with the use of ranking method in a scale of 1 to 10 considering the impact of criteria’s of sub-risk factors with risk factors and risk factors with supply chain risk.

Risk Categories and subcategories (Table-1)

Sl No	Risk Factors	Risk Sub Factors
1	Upstream side / Supplier Side Risks	Supplier quality problem (SR1),supply delay(SR2),Financial delays by supplier(SR3),capacity shortage in supplier market(SR4),key supplier failure to reduce costs(SR5),unethical practice by supplier revealed in public(SR6),Sudden increase in purchase price(SR7),leakage of core competency by supplier to competitors(SR8)
2	Downstream side Risk / Demand Side Risks	Volatile demand (DR1), Forecast Error (DR2), Insufficient or distorted information from customer (DR3), Key customer churn (DR4), Credit Risk (DR5)
3	Process Risks	Physical incident impacting supplier facility (PR1), Breakdown of IT infrastructure (PR2), Breakdown of plant machineries (PR3), Labor strike (PR4), Poor inventory control (PR5)
4	Managing talent Risks	Risk of non-retaining talented workforce (HR1), Risk of ineffective succession planning (HR2), Risk of lack of diversity (HR3), Risk of limited option of mobility (HR4), Risk of not giving right training (HR5)Risk of not maintaining cultural, cross cultural, competencies with supplier, customer, partner (HR6)
5	Managing key contract risks	Risk of failure of product at development stage(KR1),Risk of technical failures(KR2),Risk of quality issues on product(KR3),Risk of problem with design(KR4),Failure on time delivery(KR5),Failure on Quality(KR6),Failure due to Specs(KR7),Risk of delivery during production ramp(KR8)
6	Managing supply chain risks	Risk of Product Delays(MR1), Risk of Cost overrun(MR2),Risk of Quality in Product(MR3),Risk of Performance Specification(MR4),Risk of Stage Cost(MR5),Risk of disputes with sub-contractors (MR6),Risk of Niche Parts & Process(MR6),Risk with low cost Suppliers on quality & Delivery(MR7),Risk on new investment on new programmes & technology areas(MR8)

7	Competition and market risks	Risk of maintenance like global player (RM1), Risk of rebalancing of portfolios& consolidation (RM2), Risk of selecting right bidding (RM3), Risk of reaching nontraditional players for IT solutions (RM4)
8	Geo-political & Environment Risks	Government regulatory concern (ER1), Changes in exchange rate (ER2), Rapid change in technology (ER3), Competition risk (ER4),Insufficient public utility supply (ER5)
9	Regulatory Risk	Risk of operating highly regulated environment & Jurisdiction (RR1), Risk of Corruption (RR2), Risk to comply large set of laws(RR3),Maintaining Intellectual property infringement risks(RR4),Risk of not following export control laws & regulations(RR5)
10	Capacity to innovate risk	Risk of maintaining huge upfront financial investment for innovation (RI1), Risk of improving engineering process (RI2), Risk of expenses in streamlining operations (RI3), Risk of inability to innovate new product (RI4), Risk of expenses creating new innovation centers (RI5)
11	M&A risks	Risk of improper due diligence in M&A partnership (MA1), Risk of taking decision in evaluation M&A transaction (MA2), Risk of managing many integrations (MA3), Risk of non-performance by divested business (MA4)
12	Cyber security Risk	Risk of increased digitization leading to cybersecurity attacks (CS1), Risk of compromising confidential data suppliers/customer leading government to legal trouble (CS2), Risk of expenses managing cyber threat across the total supply chain of business (CS3)
13	Foreign currency & Commodity price Risks.	Risk of international operation function with exchange rate (RF1), Risk on receivables. payables and ROA in varies with exchange rate (RF2),Risk associated with exchange rate of home currency(RF3),Risk of fluctuation commodity price leading to issues in supply chain (RF4)
14	Logistic Risks	Lack of drivers (LR1), Lack of professionalism in logistic sector (LR2), Poor Infrastructure (LR3), Corruption at port and toll gates (LR4)
15	Catastrophic Risk	Natural disaster like earthquake (CR1), Flooding and extreme climate (CR2), War (CR3), Terrorism (CR4), Fire (CR5)

3.2 Risk Classification:

The primary purpose of classifying the risk factors is to get a feeling of collective view point of group of factors which will help the managers to identify the group that contribute the maximum risk. This will also help the help the supply managers to give required level of importance in the risk management process for every group or subgroup of factors. List of factors and sub factors associated with each type of risk is given in Fig.2.Based on the literature and interviews of industry experts, hierarchical risk classification system was created basing on the source of risk in the supply chain. The factors are grouped as per the type/level of risks and subcategories associated with each level/category are given in the table.

Hierarchy of Risk factors in aerospace & defence Industry Table-2

Goal			**Total Supply Chain Risks**				
Level I	Risks within Organisation (Internally Controllable) **(Type-I)**		Risk outside the Org. & within the Network (Externally Controllable) **(Type-II)**		Risk outside the Network (Uncontrollable) **(Type-III)**		
Level-II	Process Risks	PR1	Supply side Risks	SR1	Competition & Market Risks	RM1	
Level III (Su		PR2		SR2		RM2	
		PR3		SR3		RM3	

		PR4		SR4		RM4
		PR5		SR5	&	ER1
	Talent	HR1		SR6		ER2
		HR2		SR7		ER3
		HR3		SR8		ER4
	Managing Risks	HR4	side	DR1	Geopolitical Environmental Risks	ER5
		HR5		DR2		
		HR6		DR3		RR1
	Managing Contract Risks	KR1	Demand Risks	DR4	Regulatory Risks	RR2
		KR2		DR5		RR3
		KR3	Managing Supply Chain risks	MR1		RR4
		KR4		MR2		RR5
		KR5		MR3		CS1
		KR6		MR4	Cyber Security Risks	CS2
		KR7		MR5		CS3
		KR8		MR6		RF1
	Innovation Risks	RI1		MR7		Rf2
		RI2		MR8	Foreign Currency Risks	RF3
		RI3		LR1		RF4
		RI4		LR2		CR1
		RI5		LR3		CR2
		MA1		LR4		CR3
	Merger Acquisition Risks	MA2	Logistic Risks		Catastrophic Risks	CR4
		MA3				CR5
		MA4				

3.3 Risk Assessment:

The factors identified in the above table and their impact on overall risk need to be evaluated to assess risk in the supply chain. This can be called as a decision support system for predicting the impact of each risk factors. The objective of this analysis to find out the importance of each risk factor that contribute to the total risk. Gardens and Borghese (2008) used analytic hierarchy process (AHP) methods to prioritize risk in supply chain. The risks can be assessed with cause effect analysis and risks impact on supply chain objectives. His model first prioritized the supply chain objectives and based on the effect of each risk on supply chain objectives, authors then prioritized risks. Zsidisin and Ellram (1999){20} proposed a ten-step approach for risk assessment by giving equal importance for eight identified risk factors and using a five-point nominal risk scale. The maximum of the factorial risk is assigned as the overall risk of a project. In 2003, Zsidisin extended his work to propose a new supply risk classification system and identified key risk factors based on case studies and managerial interviews

Wu et al. (2006) classified supply risks in three major categories as internal controllable, internal partially controllable, internal uncontrollable, external controllable, external partially controllable and external uncontrollable. Wu et al. (2006) identified the risk factors in inbound supply and used enhanced AHP model to prioritize inbound supply risks. In enhanced AHP model was limited to only inbound supply risks.

During this study, I took the opinion of supply chain professionals in aerospace industry on major risks that their supply chains faced. I conducted focus group study and with the consensus of all experts in focus group we rated all identified risks in a pair wise comparison matrix. AHP is a methodology, which incorporates human subjective analysis and judgment (Saaty, 1980).

In this model, I have constructed a hierarchy of risks as shown in Figure 2 and then we used pair wise comparisons (Saaty, 1980) to assess the importance of risks based on their impacts on supply chain profitability. Risks that have high business impact on profitability are severe risks. The various phases of supply chain risk assessment methodology are:

1. Construct pair wise comparison matrices for each risk factor

2. Calculate the relative weights (priority vector= λmax) of the risk factors at level 1 of the classification (global weight)

3. Calculate the relative weights (priority vector) of the risk factors at level 2 of the classification (local weight)

4. Calculate the consistency ratio of each pair wise comparison matrix at both levels 1 and 2

5. Then we calculated severity of each risk factor by multiplying local weight of risk factor and its global weight

6. Based on severity calculated in step 5, each risk was prioritized. Next section illustrates all AHP calculations.

4. Data Analysis

This section represent the pairwise comparison of each risk factor of level-I and their impact on the total supply chain. Priority matrix is calculated for each factor. A consistency check on pairwise matrix is carried out and criteria for consistency ratio CR<0.1 is ensured.

Consistency test: For testing consistency of decision makers, priority vector is multiplied with the decision matrix that is first column of consistency check box. Then we divide first column with the priority vector, that is shown in second column and then take average of it and we λmax value.

Level-1 Pairwise Comparison major risk factors in **Table-3**

Pairwise Comparison of Major Groups			
RUC	RI	RE	RUC
RI	1	2	5
RE	0.5	1	3
RUC	0.2	0.33	1
No of Comparison=3 Consistency Ratio=0.4%			

Decision Matrix					
Cat		Priority	Rank	(+)	(-)
1	RI	58.20%	1	3.50%	3.50%
2	RE	30.90%	2	1.90%	1.90%
3	UC	10.90%	3	0.70%	0.70%
Principal Eigen Vector=3.004 Eigen solution 3 iteration delta 1.4E-9					

AHP priorities		
No of Criteria= 3		
RI	RE	RUC
1	2	5
0.5	1	3
0.2	0.333333	1
0.58155	0.308996	0.109
3.0037	0.003857	

Level-2 Pairwise Comparison of risks (Risk within Internal control organization) **Table-4a**

Pairwise Comparison Int. Control Risk

	Process	Man. Talent	Man. Talents	Innovation	M&A
Process	1	4	6	3	5
Man. Talents	0.25	1	4	2	4
Man. Contracts	0.17	0.25	1	0.5	0.5
Innovation	0.33	0.5	2	1	1
M&A	0.2	0.25	2	1	1
No of Comparison=10 Consistent Ratio CR=4.4%					

Decision Matrix of Int. Control Risks

Cat		Priority	Rank	(+)	(-)
1	Process	49.90%	1	22.70%	22.70%
2	Managing Talents	23.10%	2	8.50%	8.50%
3	Managing Contracts	5.90%	5	1.30%	1.30%
4	Innovation	11.70%	3	2.60%	2.60%
5	M&A	9.40%	4	2.40%	2.40%
Principal Eigen Value=5.196 Eigen vector solution,5 iteration, delta=3.5E-8					

Level-2 Pairwise Comparison of risks (Risk within control organization & within network) **Table-4b**

Pairwise Comparison within Risk Outside Organisation.

	SS	DS	SC	LO
SS	1	2	3	3
DS	0.5	1	3	3
SC	0.33	0.33	1	3
LO	0.33	0.33	0.33	1
No of Comparison=6 Consistency Ratio CR-2.6%				

Decision Matrix of Risks Outside Organisation.

Cat		Priority	Rank	(+)	(-)
1	SS	44.80%	1	10.20%	10.20%
2	DS	28.30%	2	4.60%	4.60%
3	SC	16.40%	3	3.10%	3.10%
4	LO	10.60%	4	2.90%	2.90%
Principal Eigen Value=4.071 Eigen vector Solution,4 iteration, delta=1.8E-8					

Level-2 Pairwise Comparison of risks (Risk beyond control organization) **Table-4c**

Pairwise Comparison of factors beyond control						
	MAC	ENV	REG	CYS	FCU	CAT
MAC	1	3	5	6	8	9
ENV	0.33	1	4	6	5	8
REG	0.2	0.25	1	2	3	7
CYS	0.17	0.17	0.5	1	2	6
FCU	0.12	0.2	0.33	0.5	1	3
CAT	0.11	0.12	0.14	0.17	0.33	1
No of Comparison=15 Consistent Ratio CR=7.0%						

Decision Matrix of Beyond Control factors					
Cat		Priority	Rank	(+)	(-)
1	MAC	45.60%	1	19.30%	19.30%
2	ENV	27.80%	2	12.60%	12.60%
3	REG	11.60%	3	3.60%	3.60%
4	CYS	7.70%	4	3.20%	3.20%
5	FCU	4.80%	5	1.20%	1.20%
6	CAT	2.40%	6	1.40%	1.40%
Principal Eigen Value=6.438 Eigen vector Solution,6 iteration, delta=5.3E-8					

Level-3 Pairwise Comparison & decision matrix Process Risks Table-5a

Pairwise comparison between Process Risks					
	PR1	PR2	PR3	PR4	PR5
PR1	1	2	3	2	2
PR2	0.5	1	3	2	2
PR3	0.33	0.33	1	2	2
PR4	0.5	0.5	0.5	1	2
PR5	0.5	0.5	0.5	0.5	1
No of Comparison=10 Consistency Ratios CR= 7.0%					

Decision Matrix of Process Risks					
Cat		Priority	Rank	(+)	(-)
1	PR1	34.20%	1	12.40%	12.40%
2	PR2	26.10%	2	11.00%	11.00%
3	PR3	15.80%	3	7.00%	7.00%
4	PR4	13.60%	4	4.50%	4.50%
5	PR5	10.40%	5	3.90%	3.90%
Principal Eigen Value=5.315 Eigen vector Solution,6 iteration, delta=5.1E-9					

Level-3 Pairwise Comparison of risks& decision matrix (Managing Talent Risk) **Table-5b**

Pairwise Comparison of HR Risk Factors						
	HR1	HR2	HR3	HR4	HR5	HR6
HR1	1	2	4	4	5	5
HR2	0.5	1	3	4	3	2
HR3	0.25	0.33	1	1	2	1
HR4	0.25	0.25	1	1	1	1
HR5	0.2	0.33	0.5	1	1	1
HRD	0.2	0.5	1	1	1	1
No of Comparisons =15 Consistency Ratio CR=1.6%						

Decision Risk of HR Risk Factors					
Cat		Priority	Rank	(+)	(-)
1	HR1	40.40%	1	5.30%	5.30%
2	HR2	24.50%	2	5.80%	5.80%
3	HR3	10.00%	3	2.60%	2.60%
4	HR4	8.40%	5	1.50%	1.50%
5	HR5	7.60%	6	1.40%	1.40%
6	HR6	9.10%	4	1.70%	1.70%
Principal Eigen Value=6.099 Eigen Vector Solution ,4 iteration, delta=9.9E-10					

Level-3 Pairwise Comparison & decision matrix of risks (Managing Contract Risk) **Table-5c**

Pairwise Comparison of Contract Risks								
	KR1	KR2	KR3	KR4	KR5	KR6	KR7	KR8
KR1	1	1	3	5	7	2	3	6
KR2	1	1	2	3	6	5	3	3
KR3	0.33	0.5	1	3	5	4	3	2
KR4	0.2	0.33	0.33	1	2	4	2	6
KR5	0.14	0.17	0.2	0.5	1	1	1	2
KR6	0.5	0.2	0.25	0.25	1	1	1	3
KR7	0.33	0.33	0.33	0.5	1	1	1	5
KR8	0.17	0.33	0.5	0.17	0.5	0.33	0.2	1
No of Comparisons=28 Consistency Ratio CR=9.2%								

Decision Matrix of Contract Risks					
Cat		Priority	Rank	(+)	(-)
1	KR1	27.40%	1	13.50%	13.50%
2	KR2	23.40%	2	6.70%	6.70%
3	KR3	16.50%	3	8.00%	8.00%
4	KR4	11.20%	4	6.40%	6.40%
5	KR5	4.70%	7	1.30%	1.30%
6	KR6	6.10%	6	3.30%	3.30%
7	KR7	7.20%	5	3.80%	3.80%
8	KR8	3.60%	8	2.40%	2.40%
Principal Eigen Value=8.904 Eigen vector solution,6 iteration, delta=8.0E-8					

Level-3 Pairwise Comparison of risks& Decision matrix (Managing Contract Risk) **Table-5d**

Pairwise Comparisons of Innovation Risks					
	RI1	RI2	RI3	RI4	RI5
RI1	1	2	4	5	5
RI2	0.5	1	2	5	6
RI3	0.25	0.5	1	3	7
RI4	0.2	0.2	0.33	1	2
RI5	0.2	0.17	0.14	0.5	1
No of iterations=10 Consistent Ratio CR=6.0%					

Decision Matrix of Innovation Risks					
Cat		Priority	Rank	(+)	(-)
1	RI1	43.00%	1	18.10%	18.10%
2	RI2	27.70%	2	5.50%	5.50%
3	RI3	17.90%	3	7.50%	7.50%
4	RI4	6.80%	4	1.50%	1.50%
5	RI5	4.50%	5	2.20%	2.20%
Principal Eigen Value=5.27 Eigen Vector Solution,6 iterations, delta=1.1E-8					

Level-3 Pairwise Comparison of risks& decision matrix (M &A Risk) **Table-5e**

Pairwise Comparisons of M&A Risk Factors				
	MA1	MA2	MA3	MA4
MA1	1	5	3	4
MA2	0.2	1	0.5	2
MA3	0.33	2	1	3
MA4	0.25	0.5	0.33	1
No of Comparisons=6 Consistency Ratio CR=3.8%				

Decision Matrix of M&A Risk Factors					
Cat		Priority	Rank	(+)	(-)
1	MA1	54.90%	1	14.40%	14.40%
2	MA2	13.10%	3	3.10%	3.10%
3	MA3	23.00%	2	3.80%	3.80%
4	MA4	9.00%	4	3.10%	3.10%
Principal Eigen Value=4.102 Eigen Vector Solution,4 iteration, delta=6.8E-8					

Level-3 Pairwise Comparison of risks& decision matrix (Supply side Risk) **Table-5f**

Pairwise Comparisons of Supply Side Risk Factors								
1	SR1	SR2	SR3	SR4	SR5	SR6	SR7	SR 8
SR1	1	2	6	6	5	4	4	9
SR2	0.5	1	3	4	3	4	5	4
SR3	0.17	0.33	1	1	3	3	2	3
SR4	0.17	0.25	1	1	2	2	2	3
SR5	0.2	0.33	0.33	0.5	1	3	2	4
SR6	0.25	0.25	0.33	0.5	0.33	1	1	3
SR7	0.25	0.2	0.5	0.5	0.5	1	1	4
SR8	0.11	0.25	0.33	0.33	0.25	0.33	0.25	1
No of Comparisons=28 Consistency Ratio CR=6.3%								

Decision Matrix of Supply Side Risk Factor					
Cat		Priority	Rank	(+)	(-)
1	SR 1	35.90%	1	14.50%	14.50%
2	SR 2	22.50%	2	7.50%	7.50%
3	SR 3	10.80%	3	5.40%	5.40%
4	SR 4	9.00%	4	3.10%	3.10%
5	SR 5	8.00%	5	3.70%	3.70%
6	SR 6	5.20%	7	2.00%	2.00%
7	SR 7	5.80%	6	2.40%	2.40%
8	SR 8	2.80%	8	1.30%	1.30%
Principal Eigen Value=8.614 Eigen Vector Solution,6 iterations, delta=1.0E-8					

Level-3 Pairwise Comparison of risks& decision matrix (Demand side Risks) **Table-5g**

Pairwise Comparison demand side Risks					
	DR1	DR2	DR3	DR4	DR5
DR1	1	2	4	4	3
DR2	0.5	1	2	4	2
DR3	0.25	0.5	1	2	3
DR4	0.25	0.25	0.5	1	1
DR5	0.33	0.5	0.33	1	1
No of Comparisons=10 Consistency Ratio CR=4.5%					

Decision Matrix Demand side risks					
Cat		Priority	Rank	(+)	(-)
1	DR1	41.60%	1	13.80%	13.80%
2	DR2	24.80%	2	6.00%	6.00%
3	DR3	16.00%	3	6.70%	6.70%
4	DR4	8.10%	5	1.50%	1.50%
5	DR5	9.50%	4	3.30%	3.30%
Principal Eigen Value=5.201 Eigen Vector Solution,5 iteration, delta=6.9E-9					

Level-3 Pairwise Comparison of risks& decision matrix (Managing Supply Chain Risks) **Table-5h**

Pairwise Comparisons of Supply chain risks								
	MR1	MR2	MR3	MR4	MR5	MR6	MR7	MR8
MR1	1	2	4	7	4	6	6	9
MR2	0.5	1	1	4	5	6	3	9
MR3	0.25	1	1	4	5	7	4	5
MR4	0.14	0.25	0.25	1	2	6	4	8
MR5	0.25	0.2	0.2	0.5	1	2	2	6
MR6	0.17	0.17	0.14	0.17	0.5	1	1	2
MR7	0.17	0.33	0.25	0.25	0.5	1	1	2
MR8	0.11	0.11	0.2	0.12	0.17	0.5	0.5	1
No of Comparisons=28 Consistent Ratio CR=7.8%								

Decision Matrix of supply Chain Risks					
Cat		Priority	Rank	(+)	(-)
1	MR1	35.20%	1	21.00%	21.00%
2	MR2	20.30%	2	8.30%	8.30%
3	MR3	19.10%	3	9.60%	9.60%
4	MR4	10.10%	4	5.20%	5.20%
5	MR5	6.20%	5	2.50%	2.50%
6	MR6	3.20%	7	1.10%	1.10%
7	MR7	3.90%	6	1.30%	1.30%
8	MR8	2.00%	8	1.00%	1.00%
Principal Eigen Value=6.763 Eigen Vector Solution,6 iteration, delta=6.7E-8					

Level-3 Pairwise Comparison of risks& decision matrix (Logistic Risks) **Table-5i**

Pairwise comparisons of Logistic Risks				
	LR1	LR2	LR3	LR4
LR1	1	0.5	2	5
LR2	2	1	2	9
LR3	0.5	0.5	1	4
LR4	0.2	0.11	0.25	1
No of Comparison=6 Consistency Ratio CR=1,7%				

Decision Matrix of Logistic Risks					
Cat		Priority	Rank	(+)	(-)
1	LR1	28.80%	2	6.50%	6.50%
2	LR2	46.80%	1	7.80%	7.80%
3	LR3	19.20%	3	3.70%	3.70%
4	LR4	5.20%	4	0.40%	0.40%
Principal Eigen Value=4.926 Eigen Vector Solution,3 iteration, delta=5.0E-8					

Level-3 Pairwise Comparison of risks& decision matrix (Competition & Market Risks) **Table-5j**

Pairwise comparisons of Market Risks				
	RM1	RM2	RM3	RM4
RM1	1	2	4	6
RM2	0.5	1	0.5	4
RM3	0.25	2	1	2
RM4	0.17	0.25	0.5	1
No of Comparison=6 Consistency Ratio CR=9.5%				

Decision Matrix of Market Risks					
Cat		Priority	Rank	(+)	(-)
1	RM1	51.60%	1	18.40%	18.40%
2	RM2	20.20%	3	7.80%	7.80%
3	RM3	20.90%	2	11.80%	11.80%
4	RM4	7.40%	4	2.10%	2.10%
Principal Eigen Value=4.26 Eigen Vector Solution,5 iteration, delta=8.7E-8					

Level-3 Pairwise Comparison of risks& decision matrix (Geo-Political &Environmental Risks) **Table-5k**

Pairwise comparisons of Environment Risks					
	ER1	ER2	ER3	ER4	ER5
ER1	1	2	4	4	6
ER2	0.5	1	3	6	5
ER3	0.25	0.33	1	2	5
ER4	0.25	0.17	0.5	1	2
ER5	0.17	0.2	0.2	0.5	1
No of Comparison=10 Consistency Ratio CR=5.1%					

Decision Matrix of Environment Risks					
Cat		Priority	Rank	(+)	(-)
1	ER1	42.10%	1	14.70%	14.70%
2	ER2	31.40%	2	10.50%	10.50%
3	ER3	14.10%	3	5.10%	5.10%
4	ER4	7.60%	4	2.00%	2.00%
5	ER5	4.70%	5	1.60%	1.60%
Principal Eigen Value5.23 Eigen Vector Solution,5 iteration, delta=9.8E-8					

Level-3 Pairwise Comparison of risks& decision matrix (Regulatory Risks) **Table-5l**

Pairwise comparisons of regulatory Risks					
	RR1	RR2	RR3	RR4	RR5
RR1	1	1	2	3	4
RR2	1	1	2	5	3
RR3	0.5	0.5	1	2	2
RR4	0.33	0.2	0.5	1	2
RR5	0.25	0.33	0.5	0.5	1
No of Comparison=10 Consistency Ratio CR=2.4%					

Decision Matrix of Regulatory Risks					
Cat		Priority	Rank	(+)	(-)
1	RR1	31.40%	2	1.40%	1.40%
2	RR2	33.80%	1	9.50%	9.50%
3	RR3	16.70%	3	1.80%	1.80%
4	RR4	10.10%	4	3.40%	3.40%
5	RR5	7.90%	5	2.20%	2.20%
Principal Eigen Value=5.109 Eigen Vector Solution,5 iteration, delta=6.9E-10					

Level-3 Pairwise Comparison of risks& decision matrix (Regulatory Risks) **Table-5m**

Pairwise comparisons of Cyber Security Risks			
	CS1	CS2	CS3
CS1	1	2	3
CS2	0.5	1	2
CS3	0.33	0.5	1
No of Comparison=3 Consistency Ratio CR=1.0%			

Decision Matrix of Cyber Security Risks					
Cat		Priority	Rank	(+)	(-)
1	CS1	54.00%	1	5.20%	5.20%
2	CS2	29.70%	2	2.80%	2.80%
3	CS3	16.30%	3	1.60%	1.60%
Principal Eigen Value=3.009 Eigen Vector Solution,5 iteration, delta=9.9E-9					

Level-3 Pairwise Comparison of risks& decision matrix (Regulatory Risks) **Table-5m**

Pairwise comparisons of Foreign exchange Risks				
	RF1	RF2	RF3	RF4
RF1	1	2	4	5
RF2	0.5	1	2	3
RF3	0.25	0.5	1	3
RF4	0.2	0.33	0.33	1
No of Comparison=6 Consistency Ratio CR=3.0%				

Decision Matrix of Foreign exchange Risks					
Cat		Priority	Rank	(+)	(-)
1	RF1	50.20%	1	9.90%	9.90%
2	RF2	26.10%	2	3.60%	3.60%
3	RF3	15.90%	3	4.90%	4.90%
4	RF4	7.80%	4	2.00%	2.00%
Principal Eigen Value=4.081 Eigen Vector Solution,4 iteration, delta=2.4E-8					

Level-3 Pairwise Comparison of risks& decision matrix (Catastrophic Risk) **Table-5n**

Pairwise comparisons of Catastrophic Risks					
	CR1	CR2	CR3	CR4	CR5
CR1	1	2	4	6	9
CR2	0.5	1	3	8	9
CR3	0.25	0.33	1	4	8
CR4	0.17	0.12	0.25	1	5
CR5	0.11	0.11	0.12	0.2	1
No of Comparison=6 Consistency Ratio CR=3.0%					

Decision Matrix of Catastrophic Risks					
Cat		Priority	Rank	(+)	(-)
1	CR1	43.00%	1	15.90%	15.90%
2	CR2	32.50%	2	12.40%	12.40%
3	CR3	15.50%	3	6.10%	6.10%
4	CR4	6.40%	4	3.50%	3.50%
5	CR5	2.60%	5	1.30%	1.30%
Principal Eigen Value=4.081 Eigen Vector Solution,4 iteration, delta=2.4E-8					

5. Discussion and Managerial Implication:

Table 6(a) presents rankings of risks associated with Aerospace supply chain. Major Risks (Level-I category).

Rank	Major Risk Factors of A& D Supply Chain	Local Weight
1	Internal Controllable (Manageable within Organisational preview)	0.582
2	External Risk within Organisation Network (Partially Manageable)	0.309
3	Totally Uncontrollable (beyond Organisational Preview)	0.109

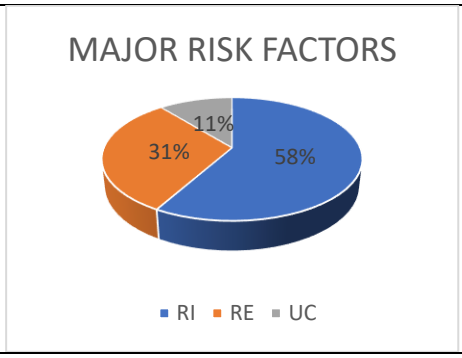


Table 6(b) presents rankings of risks of level-II category in the supply chain.

	Internally Controllable Risks	Local Weight	Global Weight	Rank
1	Process Control	0.499	0.290	1
2	Managing Talents	0.231	0.134	3
3	Managing Contracts	0.059	0.034	10
4	Innovation	0.117	0.068	5

5	M&A	0.094	0.055	6
	External Risks (Partially Controllable Risks)	**Local Weight**	**Global Weight**	
1	Supply side	0.448	0.1384	2
2	Demand side	0.285	0.0881	4
3	Managing Supply Chain	0.164	0.0507	7
4	Logistic	0.103	0.0318	9
	Totally Uncontrollable Risks	**Local Weight**	**Global Weight**	No ranking
1	Competition & Market	0.456	0.0497	
2	Environment	0.278	0.0303	
3	Regulatory	0.116	0.0126	
4	Cybersecurity	0.077	0.0084	
5	Foreign Currency	0.048	0.0052	
6	Catastrophic	0.024	0.0026	

Analysis of Table 6(b) represents that Process Control is the most critical factor with risk exposure of 29% (Process Control Risks). The second most important factor is supply side risk with risk exposure of 13.84% (Supply Side) and third most important factor is risk of managing talent within organization 13.4%. Similarly risk due to demand side and innovation are ranked as fourth and fifth in level-II risk category of aerospace supply chain.

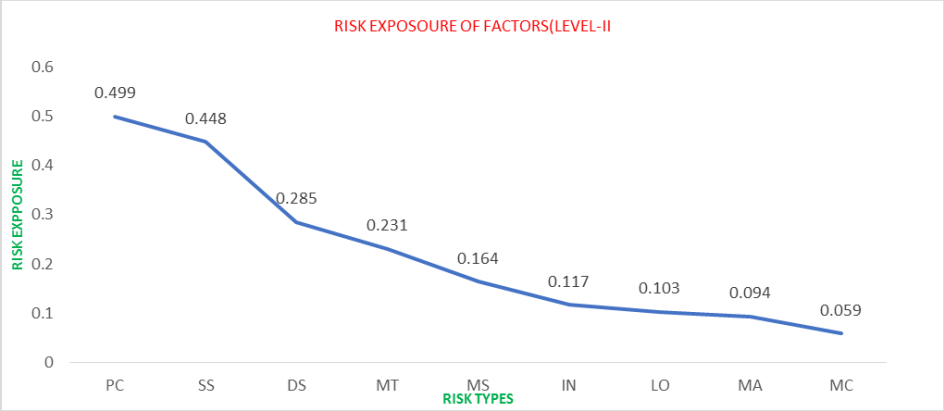
Table 6(c) presents rankings of risks of level-III category in the supply chain. The impact of risks pertaining to detail sub groups are arranged in descending order. Risk of improving engineering process (RI1) ranked one with weightage 18.87 % followed by incident impacting supplier facility, breakdown of IT infrastructure, risk of not retaining talented workforce and supplier quality problem rank second, third ,fourth, five respectively with global weights 9.93%,7.57%,5.43% and 4.97%. The details are shown in table 6(c). Still other risks cannot be ignored just for not being in ten important risks. If we carefully analyze the risks exposures relatively, then we can understand the relative importance of each risk event. If we can arrange the risks decreasing order of their risk exposure, at certain risk exposure, it drops sharply.

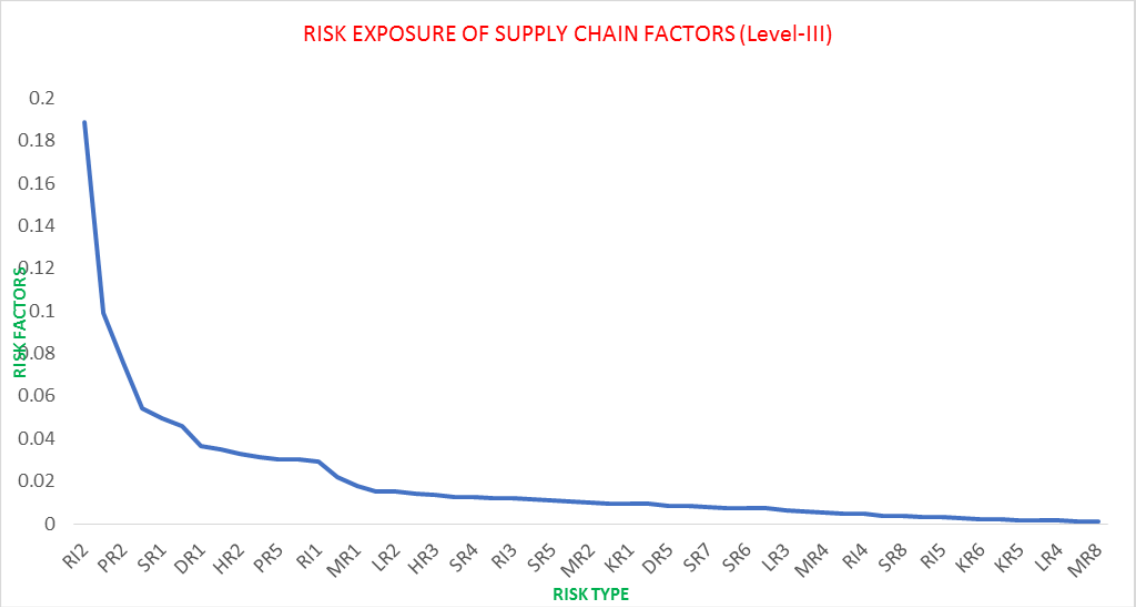
Level-III RiskTable-6(c)

Sl No	Code	Risk Description	Global weights	Rank
1	RI2	Risk of improving engineering process	0.1887	1
2	PR1	Physical incident impacting supplier facility	0.0993	2
3	PR2	Breakdown of IT infrastructure	0.0757	3
4	HR1	Risk of non-retaining talented workforce	0.0543	4
5	SR1	Supplier quality problem	0.0497	5
6	PR3	Breakdown of plant machineries	0.0459	6
7	DR1	Volatile demand	0.0366	7
8	PR4	Labor strike	0.0349	8
9	HR2	Risk of ineffective succession planning	0.0329	9
10	SR2	Supply delay	0.0311	10
11	PR5	Poor inventory control	0.0302	11
12	MA1	Risk of improper due diligence in M&A partnership	0.03	12
13	RI1	Risk of maintaining upfront financial investment for innovation	0.0293	13
14	DR2	Forecast Error	0.0219	14
15	MR1	Risk of Product Delays	0.0178	15
16	SR3	Financial delays by supplier	0.0149	16
17	LR2	Lack of professionalism in logistic sector	0.0149	17
18	DR3	Insufficient or distorted information from customer	0.0141	18
19	HR3	Risk of lack of diversity	0.0134	19

20	MA3	Risk of managing many integrations	0.0125	20
21	SR4	capacity shortage in supplier market	0.0125	21
22	HR6	Risk of not maintaining cultural, cross cultural, competencies with supplier, customer, partner	0.0122	22
23	RI3	Risk of expenses in streamlining operations	0.0122	23
24	HR4	Risk of limited option of mobility	0.0113	24
25	SR5	Key supplier failure to reduce costs	0.011	25
26	HR5	Risk of not giving right training	0.0102	26
27	MR2	Risk of Cost overrun	0.0101	27
28	MR3	Risk of Quality in Product	0.0096	28
29	KR1	Risk of failure of product at development stage	0.0094	29
30	LR1	Lack of drivers	0.0092	30
31	DR5	Credit Risk	0.0083	31
32	KR2	Risk of technical failures	0.0081	32
33	SR7	Sudden increase in purchase price	0.008	33
34	MA2	Risk of taking decision in evaluation M&A transaction	0.0071	34
35	SR6	Unethical practice by supplier revealed in public	0.0071	35
36	DR4	Key customer churn	0.0071	36
37	LR3	Poor Infrastructure	0.0061	37
38	KR3	Risk of quality issues on product	0.0056	38
39	MR4	Risk of Performance Specification	0.0051	39
40	MA4	Risk of non-performance by divested business	0.0049	40
41	RI4	Risk of inability to innovate new product	0.0046	41
42	KR4	Risk of problem with design	0.0038	42
43	SR8	Leakage of core competency by supplier to competitors	0.0038	43
44	MR5	Risk of Stage Cost(MR5),Risk of disputes with sub-contractors	0.0031	44
45	RI5	Risk of expenses creating new innovation centers	0.003	45
46	KR7	Failure due to Specs	0.0025	46
47	KR6	Failure on Quality	0.0021	47
48	MR7	Risk with low cost Suppliers on quality & Delivery(	0.0019	48
49	KR5	Failure on time delivery	0.0016	49
50	MR6	Risk of Niche Parts & Process	0.0016	50
51	LR4	Corruption at port and toll gates	0.0016	51
52	KR8	Risk of delivery during production ramp	0.0012	52
53	MR8	Risk on new investment on new programs & technology areas	0.001	53

Fig-2 Supply Chain Risk Exposure





6 Conclusion

Supply chain risk and its management got recent attention of industries and academics. Very often business managers manage supply chain issues like demand and supply issues and others glitches in supply chains without discerning risks. As supply chains are becoming more competitive, and involve more level of functions, supply chain risk awareness is require more importance. Still then the risks affecting supply chains and their importance have not been studied sufficiently so far. In past few papers were published and studies were limited to set of risks like inbound risk (Wu et al., 2006), outbound risks, transportation risks (McKinnon, 2006) {21} or enterprise risks. This gap in literature and the professional need, the present paper is analyzed the risk factors. I have classified the risks in 3(level-I) events under 15 major risk (level-II) factors. I use multi-criteria decision making, called AHP for risks assessment. The results were used to compute risk exposure and prioritization of the all 53 risk factors (level-III).The author conclude that engineering process, incidents at supplier facility, breakdown of IT infrastructure, and not retaining of skilled workforce are most important risks. Now a days, customers are more demanding and more informed. There are so many other factors that are outside the control of company's which affect the customers demand. Companies are investing more in measures like sophisticated forecasting tools and collaborative forecasting etc. In discussion section, I made three clusters of supply chain risks. This study came out with risks in aerospace supply chain in a prioritized order, which may help professionals to make decisions for risk mitigation and strategy selection. This study was carried out in an Indian premiere aerospace company including professionals from same industry supply chain during brainstorming session. This study is relevant to any A&D industry. Of course, each supply chain different, but similar studies can be carried out in other industries. In pair wise comparison, the author asked managers about importance of various risks prevalent in their supply chain. The author did not consider the parameters of risks assessment (probability and impact) together. Pair wise comparison can be made for these parameters as well. This paper provides comprehensive review of supply chain risks and how AHP can be applied for risk prioritization. The findings can also help the professionals to achieve effective risk management..

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