Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 6, July 2021: 6230- 6243

Research Article

AHP (Analytical Hierarchical Process): A novel approach of decision making in Aerospace industry supply chain optimization

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Abstract

There is always a big challenge for business managers to improve business performance consistently and develop firm capabilities and productivity. Improvement of business performance need learning of required skill and application of gained skill through knowledge sharing with the co-operation of all employees across the supply chain of the industry. Supply chain management became a great source for making high profit at low cost. Fundamental characterise of supply chain management is a holistic structure with integration of all business functions including physical, logistical, managerial, decisional, legal etc. Compared to other industry aerospace industry deals with many challenges like limited vendor, low volume, high investment, high quality product, high end technology, geo-political uncertainty, and complex supply chain network, greater obsolesce of product, high reliability, more stringent regulatory standards and long procurement and manufacturing lead time. Resources (Man, machine, material, methods, money) allocation and vendor selection are two main decision for aerospace supply chain managers in supply chain management. A supply chain manager solves problems considering single criterion, for instance, cost, and customer satisfaction, and quality, reliability of service or delivery time. Normally various operational excellence techniques like Lean, six sigma, Theory of constraints (TOC), methods of optimization is being used to address the optimization of processes or product performance relating to aerospace business.

Analytic Hierarchy Process (AHP) is a Multi Criteria decision making technique for organising and analysing complex decisions based on mathematics and psychology in a structured way. It was originally developed by Prof. Thomas L. Saaty. AHP decomposes decision problem into hierarchy, goal and alternatives. It represents most accurate approach for quantifying weights of the criteria basing on the opinions of experts. Individual expert's field experiences are utilised to estimate the relative magnitude of factors through pair wise comparison methods. Each expert is has to compare relative importance between two factors under specially designated questionnaire. Small inconsistency in judgment is also happened as human judgement is not always consistent. The judgment factors of highly experience and less experience are also taken care of in this method using geometric mean of weightages given in comparison. The ratio scales are made using principal Eigen vectors and the consistency index is derived from the principal Eigen value. Consistency ratio (CR) is derived and compared with standard values using Satty's table conformance. This paper present two case studies of decision taking mostly occurred in aerospace industry.

AHP (Analytical Hierarchical Process): A novel approach of decision making in Aerospace industry supply chain optimization

Keywords: Lean, Six Sigma, Theory of Constraints (TOC), Analytical Hierarchy Process (AHP), Consistent Ratio (CR)

1. Introduction

Business performance of an organisation is a drastic function of decisions taken on its physical sectors. Normally decisions were taken based on economics of scale resulting excess waste and difficulty in reconfiguration. Present global competitiveness necessitates efficient and effective decisions across all segments of business activity. Lean application targets elimination of all non-value-added activities while agile manufacturing focuses on the lead to market responsiveness. Benefits of Six Sigma reduces the variability in product performance resulting improved business performance and customer satisfaction. The application of TOC (Theory of Constraints) improved the process flow resulting improved productivity, capacity and quality. A hierarchical framework can be used measure leanness, agility, overall performance of an organisation and further can be compared with the performance of different organisation. Aerospace industry is currently at inflection point and struggles to meet unprecedented challenges to meet their business requirement. With the use of new technology like IoT (Internet of Things) and Block chain, supply chain of each industry is undergoing tremendous change. Organisations maintain their legacy systems, processes and supplier relationship to boost their efficiency of supply chain. This needs bold decisions and out of box thinking to reinvent the complete supply chain of aerospace business ecosystem.

2. Supply Chain:

The success of any business depends not only the output of product or services it delivered but also the inputs affecting quality, services, delivery time and price of these outputs. A supply chain is nothing but a relationship and connections that enable movement between processes, suppliers, products, services, manufactures, distributors and finally customers/consumers/end users. With the increased demand of supply chain, many areas like sales, production, inventory management, procurement, sales, marketing, and customer service are also being covered. As per the order, raw materials and other components are converted into product or services and supplied to the customer. So, first link must be customer and last link must be supplier. Since production is for the customer, so it is important to provide back flow of customer thought/demand towards information. Hence supply chain must include elements like production, distribution, and marketing and after sale service to meet customer requirement.

The philosophy behind supply chain management is to minimize the cost of total supply chain as per demand and maintain competitive advantage in the market. With the increased global competition, companies have to offer quality products with lower cost and more design flexibility and called for integration of logistics. Combining firms strategic decision with logistics oriented approach a complete supply chain for the total firm was evolved .The new success methods is to deliver the product/services to customers at desired time, place shape, quantity, quality and reliability and after sale service in a cost effective way .As a result of this development, business managers realize that both upstream od business and downstream of business must be well connected to meet the desired requirement/demand from customer. This above stage is called integrated supply chain management. Each company has its own supply chain management system. Many of them are complex and uncontrollable or not developed. Organisations having developed competition need thoroughly their supply chain management and continuously evolve new methods to find the optimality of the systems. Sometimes supply chain activities consumes more time and resources and because of priority of various works, it can be taken at desired level.

3. Need for Supply Chain

The basic purpose of supply chain optimization is to with the low cost with desired quality as effective for all system. All associated cost be minimized, processes must be improved, process wastes must be eliminated, optimal use of resources and finally product must be delivered at right time with quality to the customer. The supply chain management also include many activities at strategic, tactical and operational and decisional level. Every supply chain activity has its own peculiarities, many needs definition of the problem, many needs identification of targets and execution steps. Supply chain problems are factor based and number of alternative decisions that business can choose. Constraints are mainly: Cost, capacity, desired quality level, demand etc. Because of these limits, decision generally varies and need an increased performance at functional and strategic level. Hence performance matrix can be expressed as function decision variables. Our objective is to optimize the functional variable to get the maximize the benefits or minimize the loss.

4. Current situation in Aerospace industry Supply Chain

Supply chain is the heart of aerospace business. Efficient and effective use of management of supply chain business enable aerospace organisations to meet their strategic and financial goals. It is indeed a complex ecosystem of different tier of suppliers, original equipment manufacturer (OEM), service providers for repair, maintenance and overhaul activities, customers including defence and airliners. It is also much global and diversified in nature spread over many geographical locations, highly technology intensive and sales and supply depend on geo-political situation.

Supply chain means network of activities/processes used to deliver product and services from raw material to end customer requirement through an engineered flow of information, physical distribution and cash. Normally in aerospace supply chain management, resource allocation (RA) and vendor selection (VS) are two major problems. Changing defence and passenger requirement and emerging technologies have driven aerospace manufactures to create competitive strategies to grab bigger share in global civil/ defence market. These strategies define complexity of aerospace design, manufacturing process, supply chain management. A business manager has to solve this problem by considering criteria's involved and to take an optimised decision. Few supply chain management issues that contribute to the issues of supply chain and need serious consideration.

4.1 Sourcing of Raw Material:

Metals such as titanium, magnesium, manganese, nickel, chromium and copper are widely used in aerospace industry. Not a single country supplies these metals and market is widely distributed across the globe. Timely delivery with required quality depends upon geophysical and political situation create an uncertainty in supply chain. Non-metals like wood, plastic, rubber, chemical etc. are also critical components need attention of procurement manager. Purchase managers find great difficulty with the decision of getting suppliers based on clear cut material specification, cost, quality standards, delivery time payment norms and transportation modes.

4.2 Mitigating supply Risks:

Due to incorrect prediction of future demand, inaccurate pricing projections, design changes, invention of new technologies/processes, political disruptions and limitation of suppliers, the risk of supply is always constrained. To avoid these, companies follow short term approach to take care of monthly, quarterly, annually as spot buys and long-term approach considering for five to ten-year lock- in -contracts as primary or secondary buyers. To make this happen, supplier business is equally important for aerospace companies and maintained a long-term supplier relationship and work closely with suppliers to reviewing cost drivers and market trends.

4.3 Coping with Emerging Technologies:

Aerospace companies always struggles with modernisation of technologies like robotics, automation, standardisation, new safety feature, environment norms, new software etc. caused production delays.

4.4 Availability of Skilled Labour:

Due to huge demand and non-availability of skilled manpower, production managers always find difficulty in supporting the demand. Training manpower as per the growing need takes lot of time and resources. Technological development is always remained at the centre of aerospace business and aerospace supply chain need to train the human capital on emerging technologies to drive their business.

5. Strategies followed in Aerospace Supply Chain Management for optimization of processes:

Management collaboration and long lead time are two import issues can be addressed across the complex supply chain to help companies, control cost, mitigate risk and enable the value to customers. Few strategies adopted by aerospace companies are:

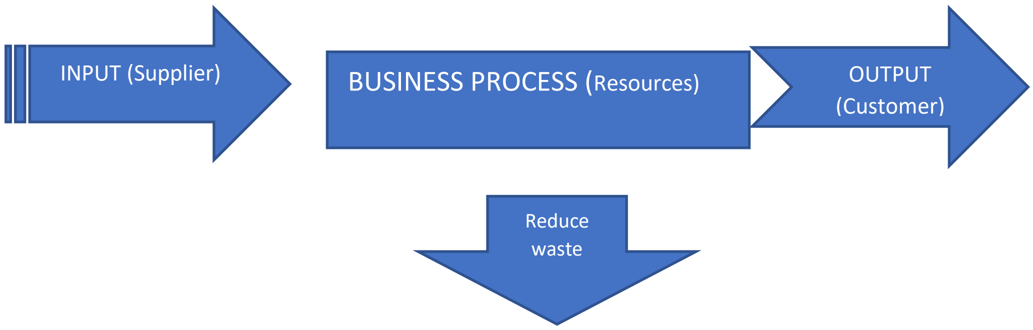
1. **Adoption of digital technology**: To increase the overall efficiency of the supply chain, various functional areas are interconnected with sensors, common data platform for information sharing and adoption of 3D printing technology. Flexible production systems with joint innovation are further driving evolution aerospace ecosystem.
2. **Vertical Integration**: Aerospace players adopt vertical integration to gain control over critical requirements or process and reduce the operating cost. It makes them more flexible and agile with changing specification, market demand and impact of changes.
3. **Partnering local players in global network**: It helps the offset obligation on foreign players that sell equipment to government of different countries specially countries having emerging economy.
4. **Risk-Sharing Partnership**: Top companies follows collaborative agreements through which development and production are made risk and revenue sharing agreement between suppliers and OEMs.

5. **Monitoring networking of suppliers**: Large aerospace companies ensure their network stronger on cyber security aspects also ensure their key suppliers are protected.
6. **Building alternative sourcing**: Aerospace companies build more than two alternate sources of suppliers to ensure uninterrupted supply of their product, minimize the risk and develop a competition among suppliers to avoid monopoly.
7. **Shared supply chain across common platform**: It allows aerospace players to leverage maximum possible advantage of existing supplier base and control costs.
8. **Sales and operation planning and assessment of manufacturing readiness**: It help operating unit's faster, better-informed decisions, that incorporate demand, supply and financial data in multiple levels and dimensions across the organisation.

6. Traditional Approach in Optimization in business:

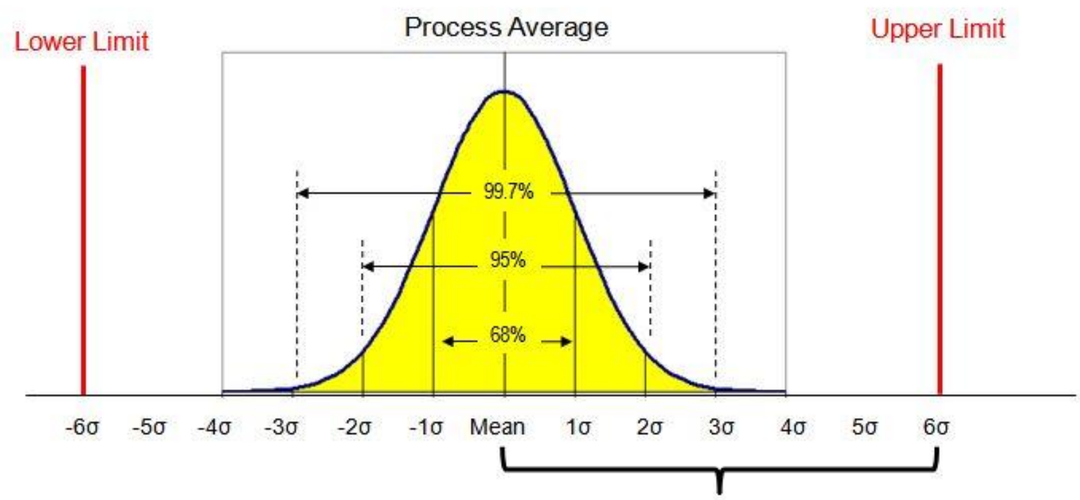
6.1 Implementing Lean Approach in production processes:

Lean manufacturing methodology revolving around the philosophy of minimizing waste and maximizing productivity within the manufacturing system. Complete Lean approach centred around five principles: value, value stream, flow, pull and perfection. Lean identify eight wastes which add no value to (Processing, Overproduction, waiting Inventory, transportation, motion and Non-utilised talent. (Fig-1)



6.2 Optimization by Practicing Sig Sigma:

Six Sigma is a disciplined data centric approach and continuous improvement methodology for reducing defects in product, process and services. Initially started in Motorola in 1990's and subsequently hundreds of organisations across the world has adopted this method as a way of their business. Sigma (σ) represent the variation of the data taken from the process and defined by the specification limits (upper and lower). Six sigma compares process mean average with respect to (6σ) from the nearest specification limit. Current process performance is measured and continuously improved, with (6σ) being the final goal. Current performance is measured initially for the product/ process or and then continually improve the sigma level.



(Fig-2)

6.3 Optimization using Theory of Constraints:

The theory of constraints (TOC) is an integrated problem-solving tool based on cause –effect logic. It enables to create solutions by identifying, challenging and correcting unexamined assumptions. TOC assumes that every complex problem starts from a deep-rooted issue-a core conflict. This problem identifies the most limiting factor that stands in the process of achieving the goal and systematically improve the limiting factor till it achieves the goal. TOC provides set of powerful set of tools to help in achieve the goals are: (a) Five focussing steps-methodology for identifying and eliminating constraints. (b) Thinking Process-tool for analysis and resolving problems. (c) It has an advantage of accounting for measuring performance and guiding management decisions. TOC is being used as a process improvement tool in the world of management practices.

(Fig-3)

7. Analytical Hierarchical Process (AHP):

Managers are required to take decisions at individual and collective levels in day to day of their business activities. Decision making is a process of analysing a problem and seeking solutions. Decision making is always a difficult task. Normally it is based on complex search of information, conflicting requirement, uncertainties and individual preferences. The bias factors and increasing complexity of problems make it extremely important to adopt a methodology for making straight forward, effective and safe decisions. Analytical Hierarchy Process (AHP) meet all the requirements and has been adopted by large number of organisations across the world. When the decision is based on single attribute and attribute is tangible and measurable, then then no decision is implied in the measurement. But when there are multiple attributes criteria and functions, then there will be confusion and without adopting logical procedure, there will be high probability of wrong decision. The AHP methods is a multistage decomposition method used to solve decision-making problems involving more than one criterion of optimality. The prime idea is to create a decision-making structure based on hierarchical requirement and the subsequent evaluation of importance of the individual element among the interconnected elements. These evaluations are represented by weights, which can be determined based on Saaty method of pair comparison or by normalizing direct measurements. The AHP method in which the structure is formed as a hierarchy. The hierarchy is always linear and may contain any number of levels and elements. The arrangement of levels in a hierarchy goes from the general (higher level) to the specific (lower level). There are certain links and relations between the elements in successive levels. The intensity of these relations is expressed numerically.

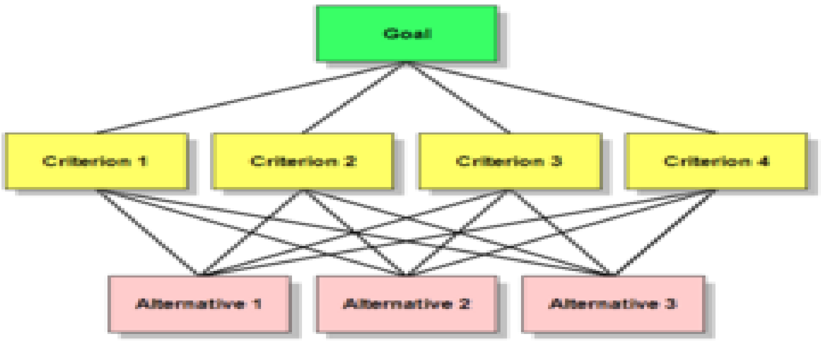
Few examples of decision making in Aerospace industry supply chain functions with multiple attributes where AHP can be used are:

-Selecting a project –Cost involved, Completion time, ease of doing
-Choosing a company-Salary, city, work life, reputation, growth
-Selecting a supplier-Delivery, quality, price, service, reputation
-Purchasing a machine-Cost, Performance, Maintenance, user friendliness
-Selecting an online course-Price, demand, employability, duration, validity of certificate

In all these problems, there are conflicting requirements and the decision maker must prioritize some attributes over other. Normally decision maker give priority to the points he likes over other. However, a mathematical procedure exists to resolve this dilemma called AHP (Analytical Hierarchical Process). AHP is a powerful and understandable methodology that allows group or individuals to combine quantitative and qualitative factors during decision making process for complicated and unstructured problems. AHP approach uses hierarchical models having level of goal, criteria and sub-criteria and alternatives.

7.1 Steps of AHP:

1. Model a decision Problem. Then break it into hierarchy of interrelated decision elements, decision criteria and decision alternatives**.**
2. Develop a judgemental preference of all decision alternative and give importance to all decision criteria by pairwise comparison
3. Compute relative priority of each decision elements through a set of numerical calculations.
4. Aggregate the relative priority to arrive at priority ranking of alternatives.



(Sample AHP Process)
Fig-3

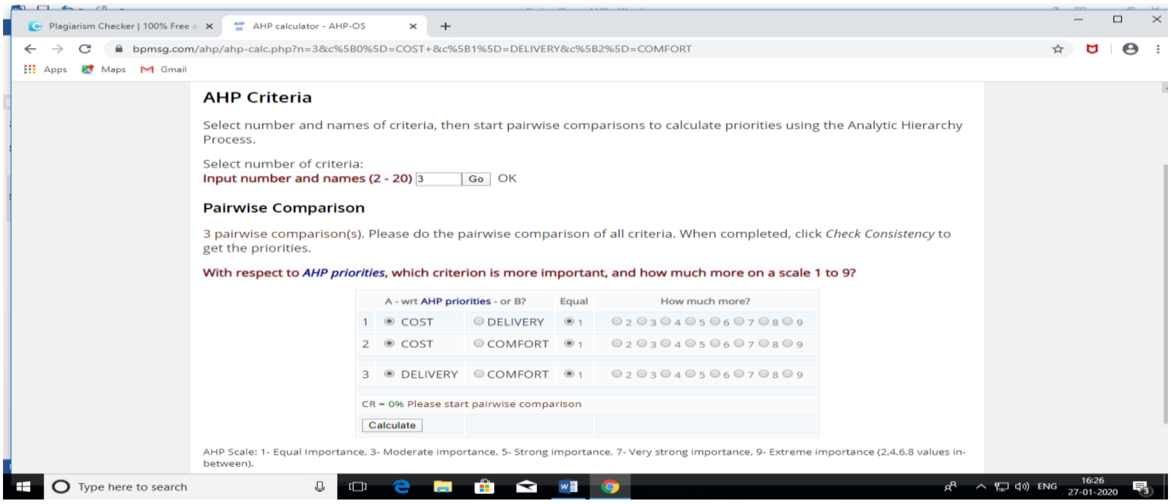
CASE-I: Project Selection Problem:

Considering an aerospace industry problem of selecting a project X, Y, Z. The criteria of selection are with respect to: Cost, Delivery period, Comfort. Criteria's are decided by the supply Chain Manager. Rating are made (scale of 1-9.) in by experts in supply chain assessment field considering impact of one criteria over the other .Comparison values are given by the experts by considering the importance of one criteria over other.

Scales of Preference: (Table-1)

Points (Low to High)	**Points (High to Low)**	**Weightage**
1	1	Equal
2	1/2	Between equal and Moderate
3	1/3	Moderate
4	1/4	Between Moderate and Strong
5	1/5	Strong
6	1/6	Between strong and Very strong
7	1/7	Very Strong
8	1/8	Between Very strong and Extreme
9	1/9	Extreme

If an individual prefer cost over Delivery time and think it as Moderate, then Value is 3 or 1/3. Similarly, if cost is preferred over Comfort as Strong then select value as 5 or 1/5. Similarly, if ease of operation is preferred over delivery time as moderate select value as 3 or 1/3.Another way of assigning values: Importance of one criteria over other (how much more/Less) by giving values.



Project Details (Table-2)			
Attribute	**Cost (Crores)**	**Delivery in months**	**Comfort**
X	8.5	12	6
Y	9	11	8
Z	10	9	10

Assigning Values against each comparison of criteria's is obtained from the opinions or values of preferences given the field experts. If no of experts having 1. Equal weightage is selected for evaluation of criteria preference, then geometric mean of values was taken for calculation. $R= (R_1 *R_2 * R_3 \ldots\ldots R_n)^{1/n}$. 2. If the weightage of selectors is different w.r.t. their expertise and experience then $R= \{(R1) * (R2)^{1/2} * (R3)^{1/3}\}^{1/3}$ ie. R2 is twice influential or knowledgeable compared to R1 and R3 is thrice influential than R1.

Table-3

Pairwise comparison of Criteria			
ATTRIBUTE	**COST**	**DELIVERY**	**COMFORT**
COST	1	3	5
DELIVERY	1\3	1	1\3
COMFORT	1\5	3	1

Sum of the Matrix Column wise			
ATTRIBUTE	**COST**	**DELIVERY**	**COMFORT**
COST	15\23	3\7	15\19
DELIVERY	5\23	1\7	1\19
COMFORT	3\23	3\7	3\19
SUM	23/15	7	19/3

Normalised Matrix (Col. Value/Col. Sum)			
ATTRIBUTE	**COST**	**DELIVERY**	**COMFORT**
COST	0.65217	3\7	15\19
DELIVERY	5\23	1\7	1\19
COMFORT	3\23	3\7	3\19
SUM	1	1	1

Normalised Eigen Value/Priority Vector						
ATTRIBUTE	**COST**	**DELIVERY**	**COMFORT**	**SUM**	**PRIORITY VECTOR**	**PRIORITY**
COST	0.6521739	0.4286	0.7894737	1.870219	0.623406342	1
DELIVERY	0.2173913	0.1429	0.0526316	0.41288	0.137626675	3
COMFORT	0.1304348	0.4286	0.1578947	0.7169009	0.238966983	2
SUM	1	1.0	1	3	1	
EIGEN VALUE	=15/23*0.06234 =0.95588	=7*0.13762 =0.9632	=19/3*0.238966 =1.5136667	Principal Eigen Value λmax =3.43275		

The priority vector shows the relative weights among attributes are 62.34% for cost, 13.76% for Delivery

& 23.90% for Comfort. To know consistency of comparison we have to compare calculate Consistency index.

As per Satty, degree of consistency index **CI= λmax-n / (n-1)** where n is no. of attributes. In this case CI= 3.43-3/ (3-1) =0. 215. This index is compared with Satty's random index (RI) table:

Random Consistency Index (Table-4)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.59	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Consistency Ratio (CR) = CI/RI if CR is found within 10%, then decision taken as consistent.

In this case **CR**= 0.215/0.59=.0.37 ie.37%. Hence the decision is inconsistent and needs revision of values.

(Table-5)

Revised Pairwise comparisons of criteria				
	COST	**DELIVERY**	**COMFORT**	**PRIORITY VECTOR**
COST	1	3	5	0.63333
DELIVERY	1\3	1	3	0.2605
COMFORT	1\5	1\3	1	0.1062
SUM	23\15	13\3	9	λmax =3.055

Revised Consistency Index **CI**= λmax-n / (n-1) =CI=0.028, CR=0.028/0.58=4.8% which is a consistent.

The revised pairwise comparison may took for few iterations till the consistency index fall within acceptable limit.

The judgemental value has to be adjusted or re-looked into to overcome above situation.

Finally, the project selection will depend upon final weightage associated with criteria like: Cost 63.33%, Delivery26.05% and Comfort 10.62%. To find out the best alternative, weighted sum of the alternative having highest value is preferred. The attributes must be normalised based on the type: higher the better or lower the better. Rules of normalizations are:

1. For higher the better, takes the highest value of the denominator and divide all the element of the column.

2. For lower the better, take the highest value of the numerator and element as denominator for each cell of respective column.

(Table-6)

Project/ Attribute	**Cost in Crores**	**Normalised value**	**Delivery Period**	**Normalised value**	**Comfort**	**Normalised value**
X	8.5	10/8.5=1.18	12	12/12=1	6	6/10=o.6
Y	9.0	10/9=1.11	11	11/12=0.92	8	8/10=0.8
Z	10	10/10=1.0	9	9/12=0.75	10	10/10=1.0

The normalized table is: The weight of each criteria is multiplied by its cell value of row of each alternative

And values are added up to get final score.

Table-7

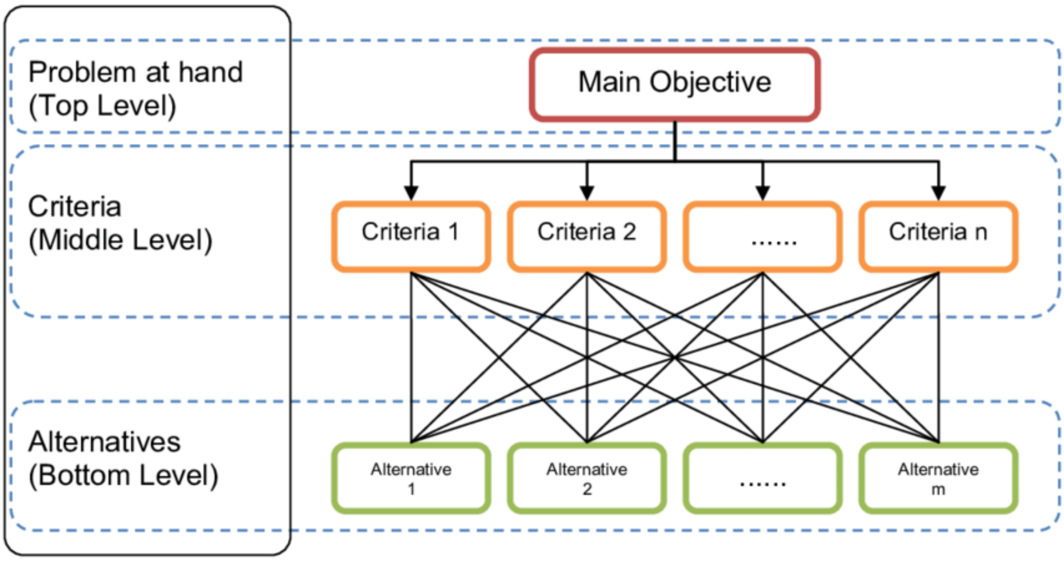
Project/ Attribute	**Cost in Crores**	**Delivery Period**	**Ease of operation**	**Best Score**
Weight				
	0.6333	0.2605	0.1062	
X	1.18x0.633=0.7462	1.18x0.2605 =0.3074	1.18x0.1062 = 0.1479	**1.2015**
Y	1.11x.0.633 =0.7026	1.11x0.2605 = 0.2892	1.11x0.1062 = 0.1179	1.1097
Z	0.633x1.0= 0.633	0.2605x1 = 0.2605	0.1062x1 = 0.1062	1.000

In this case Project-X found to be best option. This case is simple 3x3 matrix. But when no of attributes are high say 10 and no of basis are 10, then it will be 10x10 matrix. These calculations can be done by using MS Excel. Also, few AHP software's available to use and these calculations can be done in short period of time.

CASE-II: Vendor Selection (V1, V2, V3, and V4) with criteria (Cost (C1), Quality (C2), Delivery speed (C3), Reliability (C4): Stepwise details procedure of AHP of selection of vendor is given below by using MS Excel.

First and foremost, supply item in an aerospace industry is raw materials and spares. Hence it is an important criterion for purchase manager to select a best vendor for his requirement. Vendor selection involves criteria like cost (cost of material, operating cost, maintenance cost, development cost, supporting cost, tooling cost), quality, reliability, delivery time, technology support, warranty etc. Hence there is a strong need for criteria evaluation and priority lines of criteria for systematic evaluation about efficiency and performance rating. AHP allows managers to model the problem into a hierarchical structure consisting main objective, problem criteria and sub criteria and alternatives. It involves objective and subjective idea of managers in the decision-making process. It combines knowledge, experience and intuitive capability of manager logically. Another important feature of AHP is segregation of problem during the formation of hierarchical structure. Initially binary comparison matrix is established with vendor alternative which is evaluated basing on each criterion. The comparison table is made by two expert people in the field on mutual discussion considering vendor's market share, image, and credibility.

SWOT analysis of for Supply Chain Vendor Selection in an Aerospace Industry	
Strength: Technology, Infrastructure, Image, Product Range, Capacity, Certification for Quality standards	Weakness: Loss of Customer, Time taken for decision making process, Less Design facility, High man hour rate
Opportunity: New market opportunities, structure of develop new products, financial strength, high tech capability	**Threats**: Pricing by private players, New entrants in this business, Customer dis-satisfaction, New defence procurement policy



Hierarchical Structure of AHP process

In Case II: Main Goal**:** Vendor selection

Criteria: Cost, Quality, Delivery Speed, Reliability

Alternatives: Vendor-Vendor-II, Vendor-III, Vendor-IV

Comparison Matrix and Priority Vector calculation Sheet of all criteria. (Table-8)

Using AHP calculator www.bpmsg.com

Comparison Matrix Goal					Priority Vector Goal					
	C1	C2	C3	C4	Cat		Priority	Rank	(+)	(-)
C1	1	2	3	4	1	C1	46.20%	1	9.10%	9.10%
C2	0.5	1	2	3	2	C2	27.40%	2	5.30%	5.30%
C3	0.33	0.5	1	3	3	C3	17.80%	3	5.30%	5.30%
C4	0.25	0.33	0.33	1	4	C4	8.60%	4	2.30%	2.30%
No of Comparison=6 Consistency Ratio=3.2%					Principal Eigen Value=4.088 Eigen Solution,4 iteration Delta=2.7E-8					

Comparison Matrix Cost						Priority Vector Cost					
	V1	V2	V3	V4		Cat		Priority	Rank	(+)	(-)
V1	1	3	4	0.33		1	V1	25.20%	2	7.00%	7.00%
V2	0.33	1	3	0.2		2	V2	12.00%	3	3.80%	3.80%
V3	0.25	0.33	1	0.14		3	V3	5.90%	4	1.60%	1.60%
V4	3	5	7	1		4	V4	56.80%	1	13.70%	13.70%
No of Comparison=6 Consistency Ratio=4.3%						Principal Eigen Value=4.119 Eigen Solution45 iteration Delta=8.4E-8					

Comparison Matrix Quality						Priority Vector Quality					
	V1	V2	V3	V4		Cat		Priority	Rank	(+)	(-)
V1	1	0.5	1	1		1	V1	56.80%	1	13.70%	13.70%
V2	2	1	2	2		2	V2	25.20%	2	7.00%	7.00%

V3	1	0.5	1	1		3	V3	12.00%	3	3.80%	3.80%
V4	1	0.5	1	1		4	V4	5.90%	4	1.60%	1.60%
No of Comparison=6 Consistency Ratio=0.00%						Principal Eigen Value=4.0 Eigen Solution,1 iteration Delta=0E+0					

Comparison Matrix Delivery						Priority Vector Delivery					
	V1	V2	V3	V4			Cat	Priority	Rank	(+)	(-)
V1	1	0.5	0.3	1		1	V1	12.30%	3	1.00%	1.00%
V2	2	1	0.5	3		2	V2	27.40%	2	4.20%	4.20%
V3	4	2	1	4		3	V3	49.20%	1	4.10%	4.10%
V4	1	0.3	0.3	1		4	V4	11.20%	4	1.50%	1.50%
No of Comparison=6 Consistency Ratio=0.8%						Principal Eigen Value=4.021 Eigen Solution,4iteration Delta=3.2E-8					

Comparison Matrix Reliability						Priority Vector Reliability					
	V1	V2	V3	V4			Cat	Priority	Rank	(+)	(-)
V1	1	0.25	0.5	2		1	V1	14.50%	3	3.00%	3.00%
V2	4	1	1	6		2	V2	46.10%	1	12.60%	12.60%
V3	2	1	1	2		3	V3	29.90%	2	10.80%	10.80%
V4	0.5	0.17	0.5	1		4	V4	9.50%	4	3.40%	3.40%
No of Comparison=6 Consistency Ratio=5.2%						Principal Eigen Value=4.143 Eigen Solution,5 iteration Delta=4.0E-8					

Table- 9

Priority Matrix of Goal	
COST (V1)	0.462
QUALITY (V2)	0.274
DELIVERY (V3)	0.178
RELIABILITY (V4)	0.086

Table-10

Priority Matrix of Vendor Selection				
	V1	V2	V3	V4
COST	0.252	0.568	0.123	0.145
QUALITY	0.12	0.252	0.274	0.461
DELIVERY	0.059	0.12	0.492	0.299
RELIABILITY	0.568	0.059	0.112	0.095

The most important criteria for decision making was found out to be quality based on the priority matrix value of goal. This criterion followed respectively by reliability, delivery speed and cost. Businesses that have a high priority in the priority matrix for vendor selection problem determined as V4 business based on cost, V2 business based on quality, V3 business based on delivery etc. In order to determine business priorities, priority matrix for vendor selection problem in Table- 9 and priorities matrix for target in Table- 10 multiplied and the final table provided in Table 16 &Table-17

Table-11

AXB	V1	V2	V3	V4		**Business Priority**	
COST	0.1164	0.262	0.056	0.066		COST	0.1164
QUALITY	0.069	0.155	0.033	0.039		QUALITY	0.069
DELIVERY	0.044	0.101	0.021	0.025		DELIVERY	0.044
RELIABILITY	0.021	0.048	0.01	0.012		RELIABILITY	0.021

Best vendor selection as per AHP is V1. This example is very simple, but in practice there are cases when you have multiple bidders (m) to be qualified based on multiple attributes (n). The matrix will have m x n cells. The important thing is to understand the method and rest of calculations can be made by AHP software application or by MS excel.

7.2 Strengths of AHP:

AHP is loosely untold in scholastic cluster and connected in distinctive fields like Engineering, Medicine, Management, Agriculture and other sciences. The qualities incorporate

1. Its usability
2. It is an effortlessly reasonable system
3. It disentangles a hard issue by separating it into littler steps.
4. It does not need authentic data. The structure of AHP gives an easy route for a scholastic individual to take care of complex issues.

7.3 Weaknesses of AHP:

AHP utilizations accurate qualities for judgments. i.e., in helpful in cases where the human emotions are obscure, and the chiefs may be not able fix the careful numerical qualities to the examination judgments. For this situation AHP is not right method of optimization, but it advises to make direct models.

7.4 Limitations of AHP:

AHP aggregates user priority vectors with assumptions that every individual contributes equal to the process. But however, it is rarely valid. User profile varies greatly and AHP lacks the ability to consider the diversity into account. The limitation of AHP technique is as follows: a) Categorization of disparities among users b) current AHP based strategies and its limitations c) Current qualitative strategies and its limitations d) Current quantitative strategies and its limitations e) cluster accord approach. Sensitivity method will address user disparities in AHP.

There are many more methods which are also called as MCDM (Multi criteria decision making models). Few popular ones are:

1. SMART (Simple multi attribute technique)

2. TOPSIS (Technique for order preference by simplicity to ideal solution)

3. ELECTRE (Eliminations of EX Choux Traducing laR Elaite elimination and choice expressing reality)

7.5 Use of Sensitivity Analysis in AHP for decision making:

Sensitivity Analysis is a popular multi objective tool of decision analysis helpful in eliminating alternatives, enhancing a group decision process, or in providing information as to the robustness of a decision and same is applicable in AHP. All the criteria needed for the decision model can be fully applicable only through the repeated application of sensitivity analysis. It helps decision makers to understand the uncertainties, pros and cons with the limitation and scope of a decision model. Most of decisions we make contains many uncertainties. By doing sensitive analysis, decision makers can get optimal solution for parameters that are nearly approximations. One approach to come to conclusion is by replacing all the uncertain parameters with expected values and carry out sensitivity analysis. It will be much useful for a decision maker if he/she has got some clues as to how sensitive will the affect the choices with changes in one or more inputs. The main uses of sensitivity analysis are:

- Main use of sensitivity analysis is to indicate the sensitivity of simulation to uncertainties in the input values of the model.

- It gives clarity in decision making
- It is a method for predicting the outcome of a decision if a situation turns out to be different compared to the key predictions.
- It also helps in assessing the riskiness of a strategy.
- It helps in identifying how dependent the output is on an input value
- It helps in taking appropriate decisions
- It aids searching for errors in the model

7.6 Best Practices for improvement of Supply Chain in Aerospace industry:

1. Redefining the supply Chain: It start with redefining the supply chain and its scope. Focus on optimizing entire finish to finish supply chain from the supplier's supplier, to the four walls of the business, to the customer's customer.
2. Creation of cross functional team: This process will help in visualising entire supply chain of business including every details of complexity and its impact on financial matrix.
3. Focus on Right Matrices: To increase the visibility, focussing on logical aspect of cross functional team is next step. It will increase interconnectivity between supply chain parameters which are linked to monetary matrix. Making connections will help managers to visualise how their decision impact the affect monetary performance of company.
4. Connecting with C-Suite: Another essential advantage of supply chain management is to interact with CFO and key executives. This will help manager to forge relationship in supply chain optimization effort and to better create and execute strategic supply chain initiatives that transcend basic cost-cutting measures.
5. Managing Risk: Long standing supply relationship has value and disruption in this has devastating effect. Decision makers who have begun to mature, have started to determine risks in the supply chain and do a risk assessment at the beginning of every major supply chain project can visualise the risk better and can take appropriate action. Aerospace companies with most mature levels of supply chain best practices have a formal, documented and implemented process to identify, prioritize and mitigate supply chain risks looking years ahead.
6. Total value of Optimization (TVO): TVO framework promotes greater collaboration, integration and transparency. It focuses on finding value drivers for cost, cash and growth, and building an action plan to achieve those drivers by leveraging the end-to-end supply chain, implementing supply chain improvements and building on long-term risk management.

8. Conclusion and Recommendation

Analytical Hierarchy Process (AHP) provides a simple approach in solving complex MCDM problems in various engineering industry. There is as a software package called "Expert Choice" which has contributed a larger extent in acceptance of AHP methodology. This paper has shown two problems where AHP can be used. But there is enough evidence that the recommendation given by AHP should not be taken literally because closer the final priority values are each other, more careful the user should be. This is true for all MCDM methods. Hence MCDM methods should be used as decision support tools but not as a means for final decision. The search for finding best MCDM is a never-ending process in the area of decision making and still it is critical and valuable in scientific and engineering applications. Results basing on Satty's pair-wise comparison method show that judgement scales play significant role in AHP decision making. Hence it should be recommended to give greater attention to their use. AHP results also likely to classify judgement scales to three groups based on consistency and allocation of priorities. The consistency is measured by consistency ratio using its calculations random index (RI). The Saaty's original 9-point linear scale is set as benchmark for comparison of other judgment scales. Using this decision-making model an inconsistent and consistent matrix is used to investigate changes in consistency. Basing on evidence from given AHP example, judgment scales can be classified in to three groups: highly sensitive, moderate sensitive and low sensitive. Another characteristic is allocation of priorities. Basing on AHP use, judgment scales can be divided into three groups as well: high variance of priorities' values, moderate and low. Decision-maker may face selection the most suitable scale for his problem. According to presented results the Linear Saaty's scale is still a favourable option. However, if the supply chain manager prefers higher consistency, then Root square or Logarithmic scales can be selected as well. Concerning priorities values and selecting the most important criterion, the decision maker can select Power or Geometric scale to clearly highlight the most preferred criterion. Using mathematical programming and simulation with comparison of results for all judgement scales could be a best approach. For successful supply chain management, business managers must use the scientific methods to optimize the qualitative and quantitative factors to arrive in the decisions. The factors considered and using multi criteria methods of AHP suitable vendor is selected among the limited number of alternatives. The decision is found by ranking the alternatives. This technique can be applied many situations in contracts and industry situations where conflicting choices and too many of them. This is a mathematical way to decide and almost without any discretion and everything is quantified.

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