**IMPACT: International Journal of Research in Engineering & Technology**
**ISSN(P): 2347-4599; ISSN(E): 2321-8843**
**Vol. 6, Issue 3, Mar 2018, 53-64**


# MULTI CRITERIA DECISION ANALYSIS (MCDA) AS PROGRAMME MANAGEMENT TECHNIQUE IN DESIGN & DEVELOPMENT OF ADVANCED FIGHTER AIRCRAFT DEVELOPMENT

***C. S. Ananda[1], H M Nanjundaswamy[2] & B. Ashok[3]***

*[1,3]Research Scholar, Aeronautical Development Agency, Bangalore, India*

*[2]Professor, Industrial and Production Engineering, PES College of Engineering, Mandya, India*

**Received: 22 Feb 2018** **Accepted: 06 Mar 2018** **Published: 31 Mar 2018**

## *ABSTRACT*

*The Design & Development of Advanced fighter Aircraft is quite complicated. Nowadays military aircraft, like any other engineered products, are required to be produced with a shorter product life cycle at lesser costs which would also be of huge benefit to the country's security apart from lowering the costs of development and incorporating the current technologies.*

*Programme Management Plays a vital role in successful design & development of Advanced Fighter Aircraft. The management of the project has three main considerations: performance, time and cost. Unfortunately, many of our projects are not completed in time due to technological complexities, uncertainties, and risks inherent in R&D work and dynamics of technology control regimes. Delays cause cost overruns and loss of opportunities. It is inconceivable that a program of this complexity can be run efficiently without the assistance of professional programme management. It is necessary to adopt programme Management Techniques for the entire product life cycle to meet the performance requirements within the Budget & schedule.*

*From the research & experience, it is evident that multiple criteria are involved in the design & development of Complex Advanced Fighter Aircraft. These criteria could be in terms of Goals to be achieved and also key success factors which are required to achieve the stated goals. It is necessary to adopt suitable execution model, which would provide key success factors to realize the goals for the design and Development of Advanced Fighter Aircraft. Suitable Programme Management technique is required to identify the most preferred execution model which would address multiple criteria. In this paper, an effort has been made to devise a suitable programme management technique by utilizing MCDA /AHP which would help the programme Manager to identify/select the most preferred execution model from the proposed feasible execution models.*

***KEYWORDS***: *Military Aircraft, Programme Management, Cost, Schedule, Performance Requirements, Multiple Criteria, Eigen Vector, MCDA, AHP*

## INTRODUCTION

Country's military power is often decided by the superiority of its Airpower. Fighter Aircraft are an important asset of Airpower asset inventory. The Design of fighter Aircraft is quite complicated. Apart from the design complications, there is lots of Aircraft sub-component whose availability is based on R&D outcomes. Design & Development of a Military aircraft either for developed or developing countries require a minimum of 13 years from the launch of the project to the first flight [1]. Typically an aircraft project even in advanced countries takes over one decade from conception to service. In our country, this time factor could be much longer. During this time, there could be quantum changes in various System/Component technologies. Modern Aircraft Projects ,especially of military versions, are beset with a host of design integration and mission suitability problems. Added to these most of the aircraft Subsystem / Components would be at various stages of R &D whose outcome is not certain. It is very important for the designers to provide with improved information flow, process optimization, use of advanced computational methods to overcome the multi-criteria problems with a diverse set of constraints and objectives.

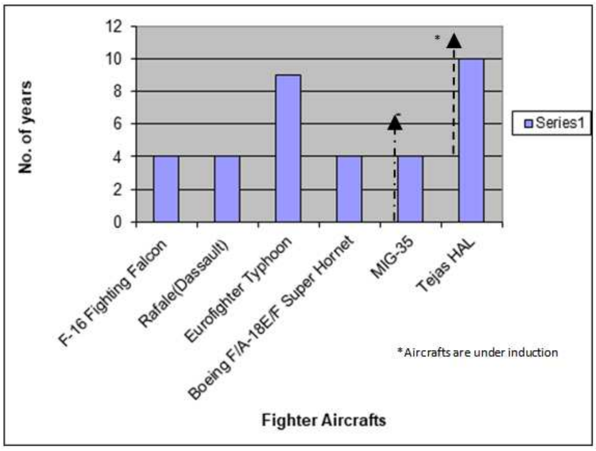



**Figure 1: Lead Time Required From Launch of Project to First Flight of Major Military Aircraft of the World**

The success of Design & Development of Advanced Fighter Aircraft, a fifth-generation Fighter Aircraft, which has many important Programme Goals to be met, depends on multiple criteria like availability of complex technologies, development of technologies, availability of skilled manpower and infrastructure, knowledge of advanced design practices etc. Based on the existing in-house capability analysis, it is found that there are resource gaps in terms of technology, Availability of Skilled Human Resources and infrastructure. From this, it is found that these gaps are major risk factors and leads to schedule risk. Unless until these problems are not addressed, it is sure that the programme may not meet the schedule and also it may not be possible to complete the program within the budget. This leads to time delay & cost overrun and also it affects the performance requirements due to non-availability of required technologies and skilled manpower, required infrastructure.

Extensive research has been carried out to address this issue by interacting with various Experts in the Field of Aerospace and it is found that it is not possible to address all the issues under one roof. Also, there is a time constraint within which the development of Advanced Fighter Aircraft needs to be completed, otherwise End user may be in deep trouble by not having the required squadron to defend the country and also there will be technological obsolesce if the development takes too long time.

There is no guarantee that many of the advanced technology development projects will reach maturity state so that it can be utilized in the design & Development of Advanced Fighter Aircraft. All these factors lead to out of the box thinking and it was felt that it is necessary to identify different execution models which would mitigate the risk factors to the maximum extent.

It is not easy to select the suitable execution model for the design & development of Advanced Fighter Aircraft. Suitable programme management technique needs to be developed and adapted to select the most preferred execution model so that it meets major requirements, i.e. reduced time delay &cost overrun & meeting the performance requirements.

Many strategic options have been suggested to meet these requirements which have finally been narrowed down to the four feasible execution models. Selection of the best strategic option ( most preferred) for Design & development of advanced Fighter Aircraft is typically a multi-criteria decision problem, and one approach is to apply the Multi-Criteria Decision Analysis technique. Multi-criteria analysis establishes preferences between options by reference to an explicit set of objectives that the decision-making body has identified, and for which it has established measurable criteria to assess the extent to which the objectives have been achieved. In simple circumstances, the process of identifying objectives and criteria may alone provide enough information for decision-makers.

In this paper, we discuss how an MCDA/AHP could be used as decision aid tool to select most preferred execution model out of feasible execution models for the design and development of advanced Fighter aircraft.

## LITERATURE REVIEW

The Department of Defense (DoD) considers program management to consist of the tasks and activities that must be done in order to design, develop, field, and support a weapons system [2]. Four key considerations typically involved in a program are: Cost to produce the system, Time required completing the effort, Capability/technical performance required to meet needs, Performance requirements and Contribution of the system to the overall defense operational and strategic plans. Program management is a diverse field, and a number of definitions for both “program” and “program management” exist [3.] Systems engineering (SE) and program management (PM) are important components in the development and production of complex military weapons systems [4]. Decision making is one of the important programme management skills and is one of the most important skills for the program manager[6]. Programme management techniques of complex projects with several variables and uncertainty levels are essentially decision theoretical techniques. Some of the techniques discussed in the literature are:[5,7,8,9]

- Multiple criteria decision analysis (MCDA)
- Multiple criteria decision making (MCDM)
- Multi-attribute utility theory (MAUT)
- Analytic hierarchy process (AHP)
- Elimination and choice expressing the reality (ELECTRE)

MCDM approaches are often used in decision theory and analysis. They seek to take explicit account of more than one criterion in the decision making process and effect optimal tradeoff. MCDM emphasizes more on methodology and induces a structured thinking process. AHP is a multiple criterion decision-making tool. As the name itself indicates, the problem is structured in terms of different levels of goals, criteria, sub-criteria and alternatives. And pairwise comparison is made by reducing these elements in the Matrix form and evaluating its Eigen Value. In the context of data analysis, Eigenvalues are a measure of data variability. Hence the selected decision options can be based on a given or least possible outcome variability. ELECTRE is based on outranking criteria.

**The Choice of Analytic Hierarchy Process (AHP) Method**

In the context of programme management tool the criteria of choice are based on:

- Sound theoretical basis.
- Probability of minimal flaws in execution.
- Ease of understandability and use.
- Ability to run as computer based template
- Ability to break complex tasks to simpler ones and proper connections between sub elements.
- Ability to redflag delays or unacceptable gaps in expected and actual outcomes.

Although no method can fulfil all the above criterion, AHP scores better over other methods in inducing structured approach and ability to be automated to a large extent. The AHP developed by Saaty [10] is a robust, popular and flexible multi-criteria decision analysis methodology.

**Use of AHP as Programme Management Tool in Advanced Fighter Aircraft Development**

The following section of paper illustrates, how AHP has been made use to devise a programme management Technique for Design & development of an Advanced Fighter Aircraft. To begin with, it is necessary to identify the multiple criteria associated with Design & Development of Advanced Fighter Aircraft. Multiple criteria are in terms of Goals & key success factors which are required to realize the goals. Following steps describe how the AHP tool has been made use of.

Step I : To determine the relative importance of goals ( Eigen Vector)

**Program Goals**

- Meeting Performance Requirements
- Meeting Schedule
- Meeting the requirements within Budget(D & D))
- Lower Acquisition cost
- Higher Product Value
- Domestic Capability Development

**Strategic Alternatives to Meet the Program Goals**

- JV with IAH
- JV with IAH & DAH
- JV with DAH, IAH as consultant
- IAH as Consultant

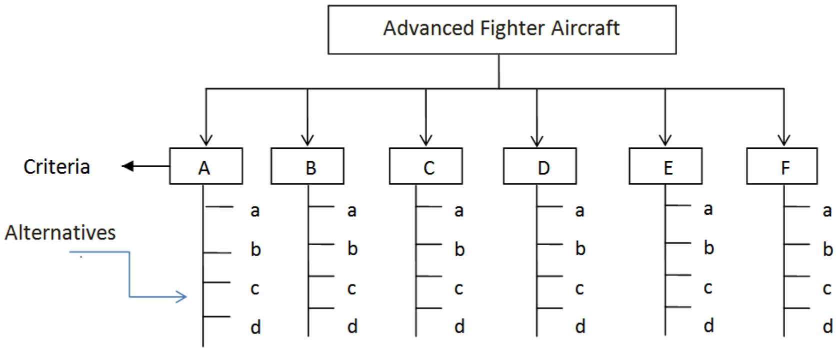



**Figure 2**

**Step 3: To Determine the Relative Importance of Criteria by Pairwise Comparison by Using a Likert Scale**

Description of the Scale used in AHP tool is provided below :

| Intensity of Importance | Definition | Explanation |
|---|---|---|
| 1 | Equal Importance | Two elements contribute equally to the objective |
| 3 | Moderate Importance | Experience and judgment slightly favor one element over another |
| 5 | Strong Importance | Experience and judgment strongly favor one element over another |
| 7 | Very Strong Importance | One element is favored very strongly over another, it dominance is demonstrated in practice |
| 9 | Extreme Importance | The evidence favoring one element over another is of the highest possible order of affirmation |
| 2,4,6,8 can be used to express intermediate values | | |

**Step-I**

$$
\begin{array}{c}
 \\ A \\ B \\ C \\ D \\ E \\ F
\end{array}
\left(
\begin{array}{cccccc}
A & B & C & D & E & F \\
1/1 & 3/1 & 3/1 & 5/1 & 7/1 & 5/1 \\
1/3 & 1/1 & 1/1 & 5/1 & 5/1 & 5/1 \\
1/3 & 5/1 & 1/1 & 5/1 & 5/1 & 5/1 \\
1/5 & 1/5 & 1/5 & 1/1 & 2/1 & 2/1 \\
1/7 & 1/5 & 1/5 & 1/2 & 1/1 & 1/2 \\
1/5 & 1/5 & 1/5 & 1/2 & 2/1 & 1/1
\end{array}
\right)
$$

**Step -2: Convert into Fractions: Remove the Names and Convert Fractions into Decimals**

$$\begin{bmatrix} 1.0000 & 3.0000 & 3.0000 & 5.0000 & 7.0000 & 5.0000 \\ 0.3333 & 1.0000 & 1.0000 & 5.0000 & 5.0000 & 5.0000 \\ 0.3333 & 5.0000 & 1.0000 & 5.0000 & 5.0000 & 5.0000 \\ 0.2000 & 0.2000 & 0.2000 & 1.0000 & 2.0000 & 2.0000 \\ 0.1428 & 0.2000 & 0.2000 & 0.5000 & 1.0000 & 0.5000 \\ 0.2000 & 0.2000 & 0.2000 & 0.5000 & 2.0000 & 1.0000 \end{bmatrix}$$

**Step 3: Squaring the Matrix**

$$\begin{bmatrix} 1.0000 & 3.0000 & 3.0000 & 5.0000 & 7.0000 & 5.0000 \\ 0.3333 & 1.0000 & 1.0000 & 5.0000 & 5.0000 & 5.0000 \\ 0.3333 & 5.0000 & 1.0000 & 5.0000 & 5.0000 & 5.0000 \\ 0.2000 & 0.2000 & 0.2000 & 1.0000 & 2.0000 & 2.0000 \\ 0.1428 & 0.2000 & 0.2000 & 0.5000 & 1.0000 & 0.5000 \\ 0.2000 & 0.2000 & 0.2000 & 0.5000 & 2.0000 & 1.0000 \end{bmatrix} X \begin{bmatrix} 1.0000 & 3.0000 & 3.0000 & 5.0000 & 7.0000 & 5.0000 \\ 0.3333 & 1.0000 & 1.0000 & 5.0000 & 5.0000 & 5.0000 \\ 0.3333 & 5.0000 & 1.0000 & 5.0000 & 5.0000 & 5.0000 \\ 0.2000 & 0.2000 & 0.2000 & 1.0000 & 2.0000 & 2.0000 \\ 0.1428 & 0.2000 & 0.2000 & 0.5000 & 1.0000 & 0.5000 \\ 0.2000 & 0.2000 & 0.2000 & 0.5000 & 2.0000 & 1.0000 \end{bmatrix}$$

$$= \begin{bmatrix} 5.7996 & 24.4000 & 15.4000 & 46.0000 & 64.0000 & 53.5000 \\ 3.7139 & 9.9999 & 5.9999 & 21.6665 & 37.3331 & 29.1665 \\ 5.0471 & 13.9999 & 9.9999 & 41.6665 & 57.3331 & 49.1665 \\ 0.9619 & 2.8000 & 2.0000 & 6.0000 & 11.4000 & 8.0000 \\ 2.4189 & 2.0284 & 1.2284 & 3.964 & 5.9996 & 4.714 \\ 1.8189 & 3.4000 & 1.7000 & 5.000 & 7.2700 & 6.0000 \end{bmatrix}$$

**To Compute Eigen Vector ( To Sum the Rows)**

$$\begin{array}{lll} \left.\begin{matrix} 5.7996+ & 24.4000 + 15.4000 + 46.0000 + 64.0000 + 53.5000 \\ 3.7139+ & 9.9999+ 5.9999+ 21.6665 + 37.3331 + 29.1665 \\ 5.0471+ & 13.9999 + 9.9999+ 41.6665 +57.3331 + 49.1665 \\ 0.9619+ & 2.8000 + 2.0000+ 6.0000 + 11.4000 + 8.0000 \\ 2.4189+ & 2.0284+1.2284 + 3.964+ 5.9996 + 4.714 \\ 1.8189+ & 3.4000 + 1.7000 + 5.000 + 7.2700 + 6.0000 \end{matrix}\right) & \begin{matrix} = 209.0996 \\ =107.8798 \\ =177.2130 \\ =31.1619 \\ =20.3533 \\ =25.1889 \end{matrix} & \begin{matrix} 0.3662 \\ 0.1890 \\ 0.3104 \\ 0.0546 \\ 0.0356 \\ 0.0441 \end{matrix} \\ \text{Sum The Row totals} & 570.8965 & 0.9999 \approx 1.000 \end{array}$$

## NORMALIZE BY DIVIDING THE ROW SUM BY THE ROW TOTALS

| | | | | |
|---|---|---|---|---|
| The Result is Eigen vector = | A | g1 ->0.3662 | → | Priority No :1 |
| | B | g2 ->0.1890 | → | Priority No :3 |
| | C | g3 ->0.3104 | → | Priority No :2 |
| | D | g4 ->0.0546 | → | Priority No: 4 |
| | E | g5 ->0.0356 | → | Priority No: 6 |
| | F | g6 ->0.0441 | → | PrioroityNo :5 |

This process should be iterated until the eigenvector solution does not change from the previous iteration.

**I Step Completed: Relative ranking of goals have been determined.**

**Step 2: Mapping of Key Success factors to realize the goals: and calculate Eigen Factors**

**Key Success Factors**

K1 Access to technology

K2 Access to skilled Manpower

K3 Program management effort

K4 Availability of adequate infrastructure

K5 Supply chain efficiency

K6 Model implementation cost

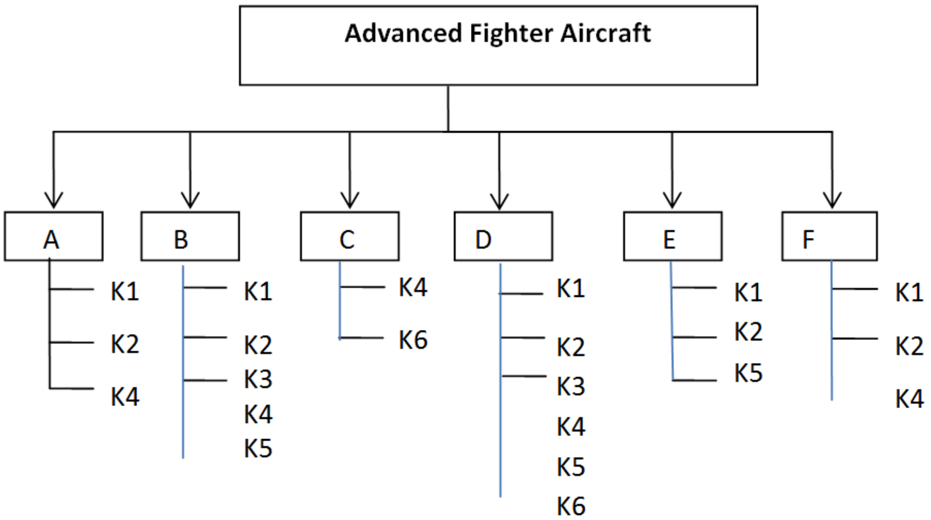



**Figure 3**

**To Determine the Relative Importance of Key Success Factor with Reference to Each of the Goal**

**GOAL A :Meeting Performance Requirements**

$$\begin{array}{cc} & \begin{array}{ccc} K1 & k2 & k4 \end{array} \\ \begin{array}{c} K1 \\ K2 \\ K4 \end{array} & \begin{pmatrix} 1/1 & 5/1 & 5/1 \\ 1/5 & 1/1 & 3/1 \\ 1/5 & 1/3 & 1/1 \end{pmatrix} \end{array}$$

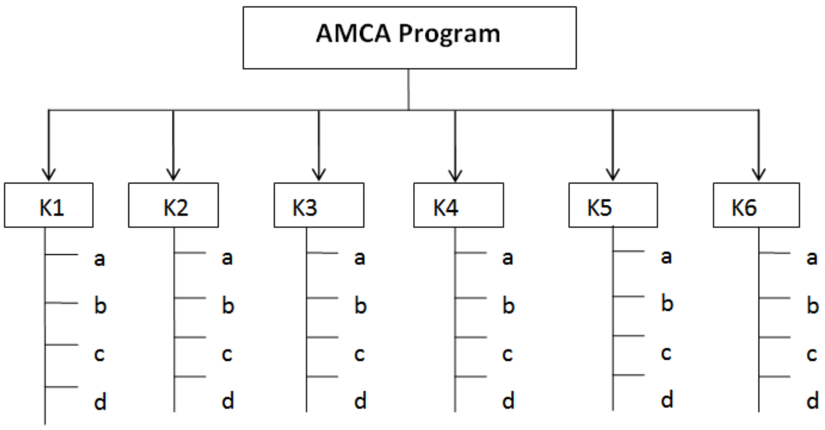
**Next Step is to Convert Into Fractions and Determining the Eigen Vector.**

$$\text{Eigenvector} \quad \begin{pmatrix} EaK1 & 0.5678 \\ EaK2 & 0.2932 \\ EaK4 & 0.1390 \end{pmatrix}$$

**Similar Calculations Needs to be Done For Goal B, C, D, E, F**

| A | B | C | D | E | F |
|---|---|---|---|---|---|
| EaK1 | EbK1 | EcK4 | EdK1 | Eek1 | Efk1 |
| EaK2 | EbK2 | EcK6 | EdK2 | Eek2 | Efk2 |
| EaK4 | EbK3 | | EdK3 | Eek5 | Efk4 |
| | EbK4 | | EdK4 | | |
| | EbK5 | | EdK5 | | |
| | | | EdK6 | | |

**Step 3: Next Step is to Determine Relative Importance of Strategic Alternatives Which Provide the Required Key Success Factors to Realise the Goals**




**Figuer 4**

**With Reference To Key Success Factor k1,ie Access to Technology**

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1/1 & 1/1 & 5/1 & 7/1 \\ 1/1 & 1/1 & 5/1 & 7/1 \\ 1/5 & 1/5 & 1/1 & 5/1 \\ 1/7 & 1/7 & 1/5 & 1/1 \end{pmatrix} \end{array}$$

**To Convert in to Fractions**

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1.0000 & 1.0000 & 5.0000 & 7.0000 \\ 1.0000 & 1.0000 & 5.0000 & 7.0000 \\ 0.2000 & 0.2000 & 1.0000 & 5.0000 \\ 0.1478 & 0.1478 & 0.2000 & 1.0000 \end{pmatrix} \end{array}$$

$$\text{Eigenvector} \quad \begin{array}{c} sa1 \\ sb1 \\ sc1 \\ sd1 \end{array} \begin{pmatrix} 0.3509 \\ 0.3509 \\ 0.1789 \\ 0.1399 \end{pmatrix}$$

**Similarly Determine Eigen Vector For Strategic Alternatives with Reference to Key Success Factor K2, K3, K4, K5, K6**

$$\begin{array}{c} \begin{array}{cccccc} K1 & k2 & K3 & k4 & K5 & k6 \end{array} \\ \begin{pmatrix} sa1 & sa2 & sa3 & sa4 & sa5 & sa6 \\ sb1 & sb2 & sb3 & sb4 & sb5 & sb6 \\ sc1 & sc2 & sc3 & sc4 & sc5 & sc6 \\ sd1 & sd2 & sd3 & sd4 & sd5 & sd6 \end{pmatrix} \end{array}$$

**Step 4: To Determine Goal Score for Each of Goal with Reference to Each of Strategic Option**

**To determine Score for Goal A**

$$\begin{array}{cc} \text{Criteria} & \text{Criteriawtsa} \\ K1 & EaK1 \\ K2 & Eak2 \\ K4 & EaK4 \end{array} \begin{array}{c} \begin{array}{cccc} b & c & d & \end{array} \\ \begin{pmatrix} sa1 & sb1 & sc1 & sd1 \\ sa2 & sb2 & sc2 & sd2 \\ sa4 & sb4 & sc4 & sd4 \end{pmatrix} \end{array}$$

With reference to Strategic **Option a**, Aa = Eak1 *sa1 + Eak2 * sa2 + Eak4 * sa4

With reference to Strategic **Option b**, Ab = Eak1 * sb1 + Eak2 * sb2 + Eak4 * Sb4

With reference to Strategic **Option c**, Ac = Eak1 * sc1 + Eak2 * sc2 + Eak4 * Sc4

With reference to Strategic **Option d**, Ad = Eak1 * sd1 + Eak2 * sd2 + Ek4 * Sd4

Similarly Total Score for Goal B, C, D,E & F are determined

$$\begin{array}{cccccc} A & B & C & D & E & F \\ \end{array}$$
$$\begin{pmatrix} Aa & Ba & Ca & Da & Ea & Fa \\ Ab & Bb & Cb & Db & Eb & Fb \\ Ac & Bc & Cc & Dc & Ec & Fc \\ Ad & Bd & Cd & Dd & Ed & Fd \end{pmatrix}$$

**Step 5 :This Step Describes the Methodology to Determine the Final Score for Strategic Options**

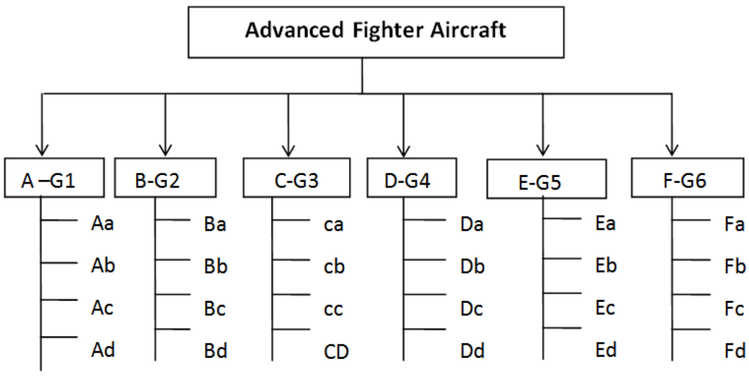



**Figure 5**

**Table 1**

| **Goals** | | **Strategic Options** | | | |
|---|---|---|---|---|---|
| **Criteria Goals** | Wt | **a** | **b** | **c** | **d** |
| A | G1 | Aa | Ab | Ac | Ad |
| B | G2 | Ba | Bb | Bc | Bd |
| C | G3 | Ca | Cb | Cc | Cd |
| D | G4 | Da | Db | Dc | Dd |
| E | G5 | Ea | Eb | Ec | Ed |
| F | G6 | Fa | Fb | Fc | Fd |

**Final Score For Strategic Option "a" =FSa= G1 * Aa + G2 * Ba + G3 * Ca + G4 * Da + G5 * Ea + G6 * Fa**

**Final Score for strategic Option "b " = FSb= G1 * Ab + G2 * Bb + G3 * Cb + G4 * Db + G5* Eb + G6 * Fb**

**Final Score for strategic Option "c " = FSc= G1 * Ac + G2 * Bc + G3 * Cc + G4 * Dc + G5* Ec + G6 * Fc**

**Final Score for strategic Option "d " = FSd= G1 * Ad + G2 * Bd+ G3 * Cd + G4 * Dd + G5* Ed + G6 * Fd**

The final score of Strategic Option k is given by $A_k = \sum_i g_i \sum_j y_{jk} s_{ij}$. These scores are normalized and they sum to 1. The higher the overall score of a Strategic Option, the greater is the likelihood of that Option attaining the Goals of the Programme. It is to be noted that this is an integrated score taking into account all the Programme Goals and all the Key Success Factors

## CONCLUSIONS

Programme management plays a vital role in design & development of Fighter Aircraft. Design & development of advanced fighter aircraft are very complex in nature and is MOD's costliest acquisition. The major challenge in design & development of Advanced Fighter Aircraft is that, it has to be developed within the time schedule and resource budget and also it should meet performance requirements. Uncertainty or delay in development of advanced technologies, inadequate infrastructure and non-availability of skilled manpower leads to time delay and cost overrun.A suitable programmed management technique is required to overcome these problems.

To overcome these problems it is necessary to decide the suitable programme execution model for the design & development of Advanced Fighter Aircraft at the beginning of program execution. However design & development involves multiple criteria's and it is very difficult to decide about the suitable execution model.

In this paper, an effort has been made to make use of AHP tool, which is a mulit-cirteria decision analysis tool. Using this tool most preferred execution model could be selected for the design & development of advanced Fighter Aircraft by considering the multiple criteria involved in the development. Although in this paper, limited KSF and programme goals have been taken, the AHP tool can be scaled up by incorporating all the KSF's and programme goals.

## *REFERENCES*

1. *PLM as A Tool for Shortening Design Cycle Time & Cost Reduction in Military Aerospace Industry, C. Vasantharaju, Dr.B. Ashok, Dr.K.SenthilKumaran, International Conference On Trends in Product Life Cycle, Modeling, Simulation and Synthesis PLMSS-2011*
2. *SCHEDULING GUIDE FOR PROGRAM MANAGERS; Norman A. McDaniel Chair Program Management and Leadership Department, WilliamW. Bahnmaier Editor Program Management and Leadership Department*
3. *Program Management for Large Scale Engineering Programs; LAIWhitepaper Series "Lean Product Developmentfor Practitioners" Prepared by Dr.JosefOehmen, Dr.EricRebentisch, Kristian Kinscher*
4. *System Engineering & program Management, Trends & cost of guided weapon programs, David E. Stem, Michael Boito, ObaidYounossi*
5. *Application of the AHP in project management Kamal M. Al-Subhi Al-Harbi * International Journal of Project Management 19 (2001) 19±27*
6. *Ali Salh Sawadi, Analysis of Composite Material for Wing of Aircraft, International Journal of Mechanical Engineering (IJME), Volume 6, Issue 3, April-May 2017, pp. 19-26*
7. *Schuyler JR. Decision analysis in projects. Upper Darby, PA, USA: Project Management Institute, 1996.*
8. *Belton V. Multiple criteria decision analysis Ð practically the only way to choose. In: Hendry LC, EgleseRW, editors. Opera- tional research tutorial papers. 1990, pp. 53±102*

9. *Multi-Criteria Decision Analysis: A Framework for Structuring Remedial Decisions at Contaminated Sites; springer Link; Part of the Nato Science Series: IV: Earth and Environmental Sciences book series (NAIV, volume 38)*
10. *Naveen Kumar VN et al., Analysis of Foreign Object Impact on Aircraft, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Volume 6, Issue 2, March-April 2016, pp. 11-22*
11. *Naveen Kumar VN et al., Analysis of Foreign Object Impact on Aircraft, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Volume 6, Issue 2, March-April 2016, pp. 11-22*
12. *Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment, Marco Cinelli *, Stuart R. Coles, Kerry Kirwan, journal home page : www.elsevier.com/locate/ecolind*
13. *T.L. Saaty, The Analytic Hierarchy Process, McGraw- Hill, 1980*