WHICH IS THE BEST HELICOPTER?

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Abstract. *The answer to the question: "Which is the best helicopter?" is based upon considerations and tradeoffs involving several factors, both technical and economic, and it only can be answered if the helicopters present similar characteristics. The purpose of this paper is to present a methodology to show, among a group of analyzed helicopters, which helicopter is most suitable to accomplish the mission for which it is employed. The methodology involves dividing the helicopters in three groups: light, medium and heavy, so one can compare and analyze them up under the configuration and performance data.*

Keywords: *Helicopter, performance, configurations, forecast, market and models.*

1. Introduction

To start a helicopter bidding procurement process it is necessary to define the requirements and to evaluate what is the profile of a typical mission the helicopter will be involved. For instance, helicopters equipped with one engine with maximum capacity for two passengers will not carry out, with the same effectiveness, the functions of others provided with two engines, capacity for 10 passengers and capable to flying in several environmental conditions with speed of 300 km/h or more. There are several options and models available on the market today, each one of them with a profile of a typical mission, Fig.1.

Figure 1. Nowadays, helicopters are used in the several unique missions.

Currently, in the world market it is possible to find several options of models among the several manufacturers, which stand out: Sikorsky (USA), Bell (USA), Agusta (Italy) and Eurocopter (France). The increase in the use of helicopters is due to the great versatility in the accomplishment of the several particular missions, such as: passenger's transport (executive and commercial) and surveillance. With all those attractions, one had in the last decade a great increase in the number of units sold and its market became very attractive with forecasts of great commercial and strategic disputes in a very close future. Figure 2 presents the forecast of the helicopter world market for next 5 years (Aviation Week & Space Technology, 2004).

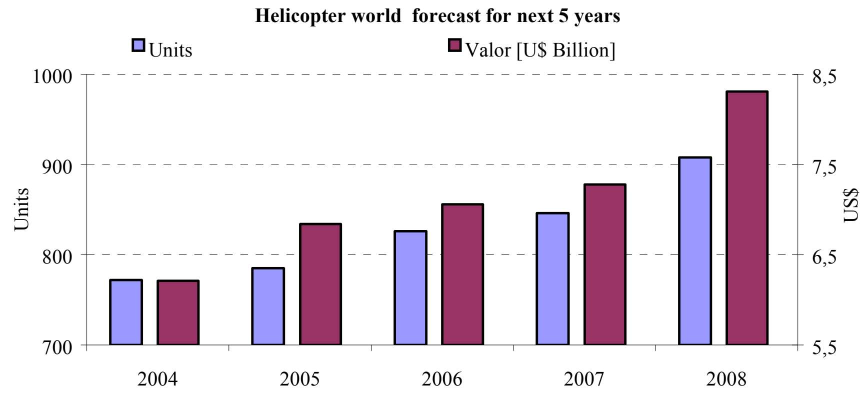

Figure 2. Helicopter world forecast for next 5 years.

The objective of this paper is to purpose a methodology to show, among a group of analyzed helicopters, which helicopter is most suitable to accomplish the mission, regarding the advantages and disadvantages of each one of the models among a set of 19 (nineteen) chosen for analysis. The methodology involves dividing the helicopters in 3 (three) groups: light, medium and heavy. Then one can compare and analyze them up under the configuration and performance data.

2. Definition of the Groups of Study

The first division of the groups is based on information peculiar to each one of the chosen models. The patterns used for analysis are configurations and performance data. Once defined the patterns, the models in the same group are subdivided in several items in order to make possible a better analyses (maximum load, number of passengers, engines etc).

2.1. Configurations

In the current market it is very important to compare the models through the maximum number of passengers that can be transported and maximum load for take-off. Figure 3 shows all the helicopters analyzed in that comparative group. According the results (red dashed lines), it becomes already clear a separation of the models by configuration.

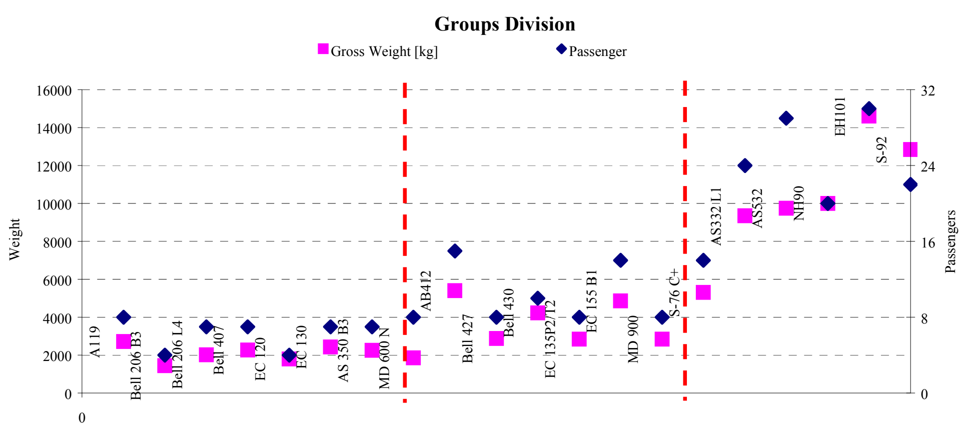

Figure 3. Distribution of the models based on maximum weight of take-off and number of passengers.

In the early 1970s the first helicopters equipped with two engines (twin engines) coupled in the axis of the rotor appeared on the market. The pioneers in that segment were the models MBB BO-105, Agusta 109 and Bell 212.

A great advantage of helicopters equipped with two engines is the reliability in case of failure of one of them, because the other engine is capable to guaranteeing a safe flight. In contrast, the single engine presents some benefits that can be very attractive and enough for the mission in which the helicopter is to be used. Table 1 shows the advantages of helicopters equipped with 1 and 2 engines (Manninghan, 1996).

Table 1. Advantages of single and twin engines helicopters

Single Engine	**Twin Engines**
Larger load capacity with respect to its empty weight	Redundancy in case of engine failure
Lower consumption of fuel (economy of 25-35%)	Larger safety in flights over great areas of water, mountains, forests and cities
Lower cost of maintenance	Possibility of instrument flight operation (IFR)
Easier to operate and with quick maneuverability	Transport of dangerous materials (explosives, biological, chemical etc)
Lower initial cost	Larger load and passengers capacity

2.2. Performance

Concerning performance characteristics, it is possible to compare and analyze helicopters that have the same value of disk loading (*DL*). This value is obtained by the ratio between the thrust required by the operating helicopter (*T*) and the main rotor disk area (*A*), Eq. (1).

$$DL \cong \frac{T}{A}. \tag{1}$$

Once again, it is possible to see the segregation of the groups. Figure 4 shows the separation according to the Disk Loading's ranges of 125, 175 and 250 [N/m^2].

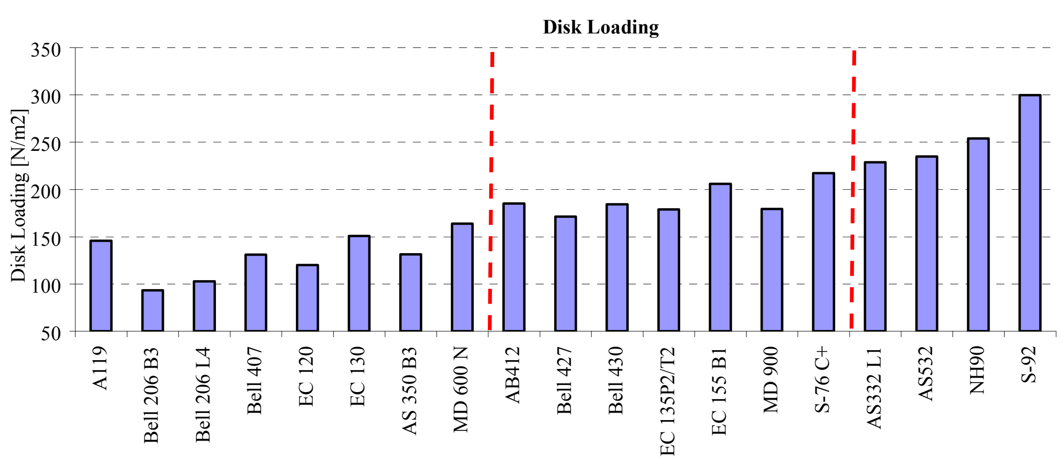

Figure 4. Distribution of the helicopters based on Disk Loading.

Using the disk loadings values it is also possible to calculate the values for the induced velocity (*u*), Eq. (2).

$$u = \sqrt{\frac{DL}{2 \times \rho}} \tag{2}$$

The induced velocity is proportional to the square root of the disc loading and inversely proportional to the squared root of the density (ρ), which is function of the flight altitude. Figure 5 represents the values of induced velocity calculated in function of the operational envelope altitude of each one of the models.

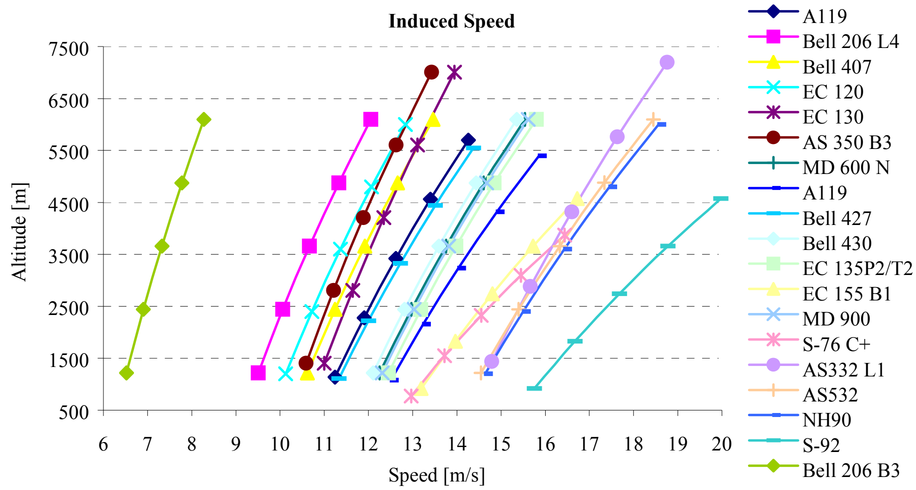

Figure 5. Calculation of induced velocities as functions of the variation of the altitude.

To analyze the efficiency of the engine during a hovering flight, the Figure of Merit is used (*FM*). By definition, the Figure of Merit is the ratio of ideal power for a rotor in hovering flight by the actual power consumed by the rotor to operate in that condition, Eq. (3).

$$FM = \frac{Ideal\ Power\ in\ Hover}{Actual\ Power\ in\ Hover}\ . \tag{3}$$

Figure of Merit is an important indicator used to choose helicopters for very specific operations (mainly when hovering is the most time consuming function of the vehicle). Models with high values of Figure of Merit have privilege over the others.

The comparison using Figure of Merit is only valid for helicopters with same or closer values of disk loading. The division of the groups is once again evident, Fig. 6.

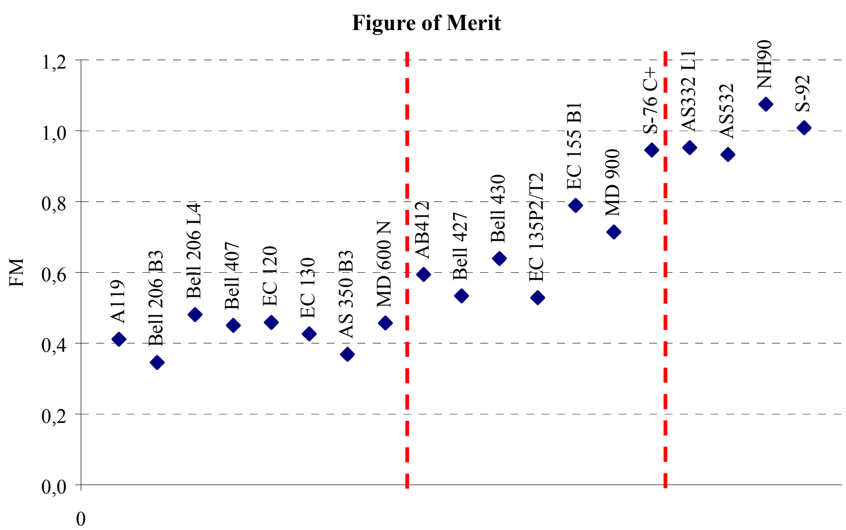

Figure 6. Distribution of the helicopters based on Figure of Merit.

The ideal power in hover (*PI*), Eq. (3), represents the power necessary to accelerate the induced flow thought the rotor disk, Eq. (4).

$$P_{IDEAL} = T \times u = T\sqrt{\frac{DL}{2 \times \rho}} \tag{4}$$

Based on all information and comparisons presented previously and using the "traditional" competitors in the market (Bower et al., 1999), the groups divisions used for the comparative study of the models are defined according to Tab. 2.

Table 2. Definition of the groups and models.

Light	**Medium**	**Heavy**
A119 (Agusta)	AB412 (Agusta)	AS332 L1 (Eurocopter)
Bell 206 B3 (Bell)	Bell 427 (Bell)	AS532 (Eurocopter)
Bell 206 L4 (Bell)	Bell 430 (Bell)	NH90 (NH industry)
Bell 407 (Bell)	EC 135P2/T2 (Eurocopter)	S-92 (Sikorsky)
EC 120 (Eurocopter)	EC 155 B1 (Eurocopter)	
EC 130 (Eurocopter)	MD 900 (MD Helicopters)	
AS 350 B3 (Eurocopter)	S-76 C+ (Sikorsky)	
MD 600 N (MD Helicopters)		

3. Results and Discussions

As a comparative criterium for the helicopter models selected, some technical and economical factors are defined.

Considering the economical point-of-view, it is very important to observe that the values of costs involved in day-by-day operation. The following are used as indicators: specific consumption of fuel, operational cost (it includes fuel, hydraulic fluid, preventive maintenances) and initial acquisition cost (Flug Revue website et al., 2004).

Considering the technical point-of-view, the following operational characteristics are taken: maximum speed, service altitude, autonomy and range. The models' technical information presented in the paper are obtained from the technical specifications supplied by the manufacturers (Agusta S.p.A. website et al., 2004).

3.1. Light Group

It contains helicopters equipped with 1 (one) engine, capacity up to 8 (eight) passengers and maximum take-off weight of approximately 2,500 kg.

There are helicopters with low initial cost that become them economically viable and attractive and allow flying with reasonable comfort with all advantage and versatilities expected from a helicopter.

Figures 7 and 8 present the characteristics related to costs: operational, initial, consumption of fuel and day-by-day operation. Figures 9 and 10 present the characteristics related with the operational envelope and limitations specified by the manufacturer.

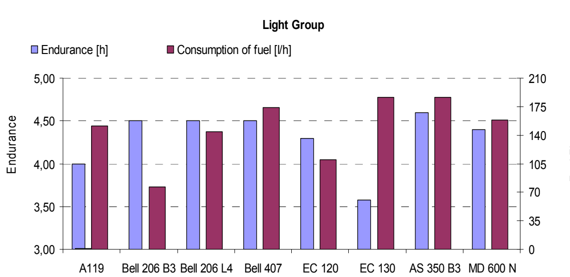

Figure 7. Light Group: models versus time of flight and consumption of fuel.

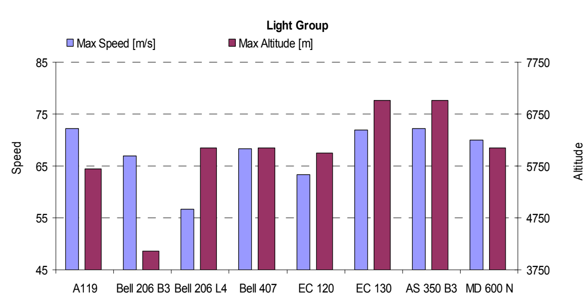

Figure 8. Light Group: models versus operational cost and price.

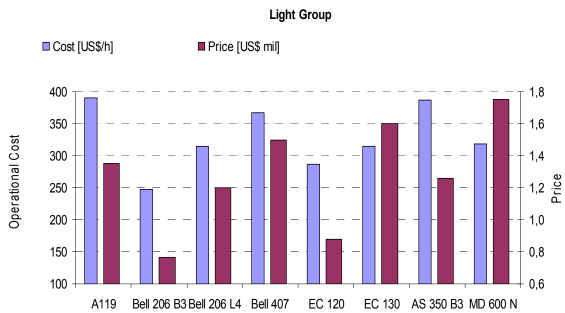

Figure 9. Light Group: models versus maximum speed and operational altitude.

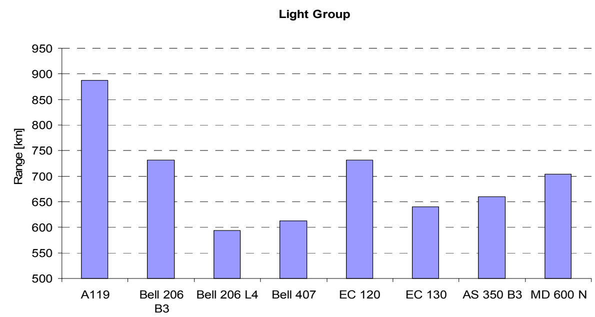

Figure 10. Light Group: models versus maximum ranges.

3.2. Medium Group

It contains helicopters equipped with 2 (two) engines, capacity up to 15 passengers and maximum take-off weight of approximately 5,000 kg.

They are larger and more powerful and robust helicopters compared to their Light Group counterparts, but they are faster, agile, comfortable and capable to flying with larger safety and comfort. They can fly in several conditions of weather, many different routes, above the center of the cities and even land on the top of buildings. Due to those characteristics, they are quite sought for executive's transport, rescue and surveillance. It is important to observe that, when the customers decide to enter into the world of twin engines helicopters, a new market appear in front of them, mainly related with options and higher costs.

Figures 11 and 12 present the characteristics related to costs: operational, initial, consumption of fuel and day-by-day operation. Figures 13 and 14 present the characteristics related to the operational envelope and limitations specified by the manufacturer.

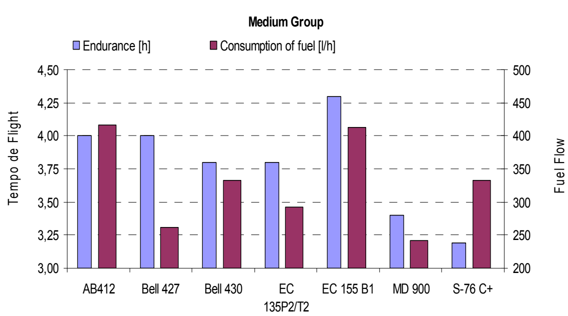

Figure 11. Medium Group: models versus time of flight and consumption of fuel.

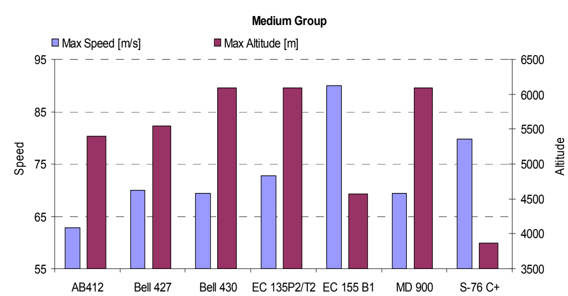

Figure 12. Medium Group: models versus operational cost and price.

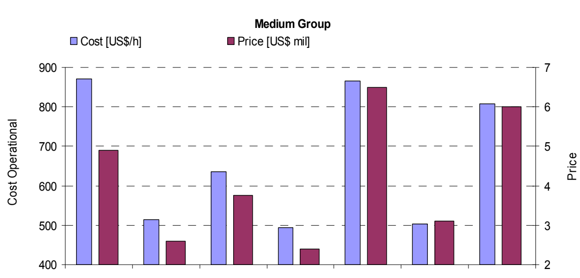

Figure 13. Medium Group: models versus maximum speed and operational altitude.

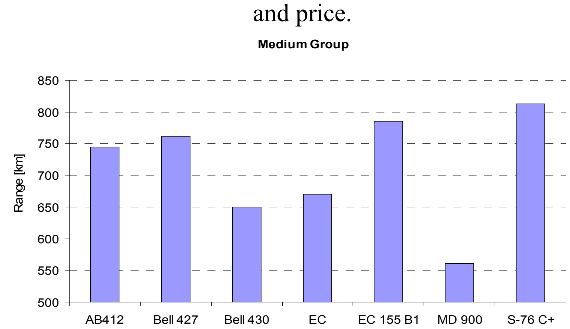

Figure 14. Medium Group: models versus maximum ranges.

3.3. Heavy Group

Similar to what is done for the medium group models, this category is defined for helicopters with twin engines, capacity up to 25 passengers and maximum take-off weight of approximately 10,000 kg. They are known as "helibuses", due to the high capacity to transport a great number of passengers. They can also be used for the transport of great and heavy loads as aerial cranes (air cranes).

Figures 15 and 16 present the characteristics related to costs: operational, initial, consumption of fuel and day-by-day operation. Figures 17 and 18 present the characteristics related to the operational envelope and limitations specified by the manufacturer. It was not possible to obtain the referring values of operational costs for models AS532 and NH90, because they are brand new models operated by the military forces and, so far, do not present reliable cost values.

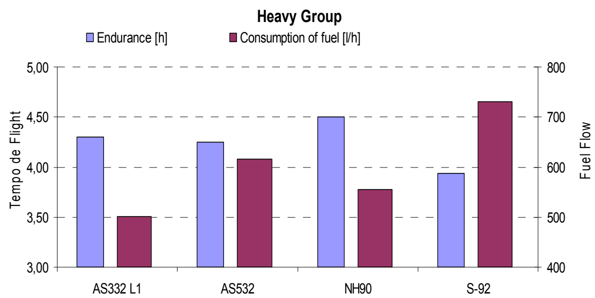

Figure 15. Heavy Group: models versus time of flight and consumption of fuel.

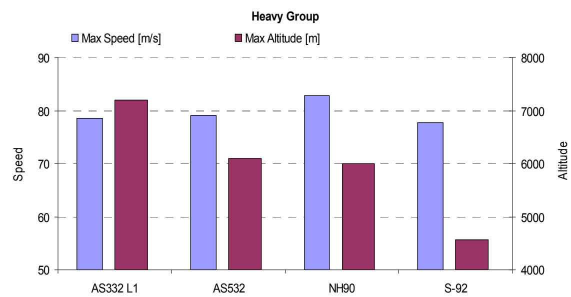

Figure 16. Heavy Group: models versus operational cost and price.

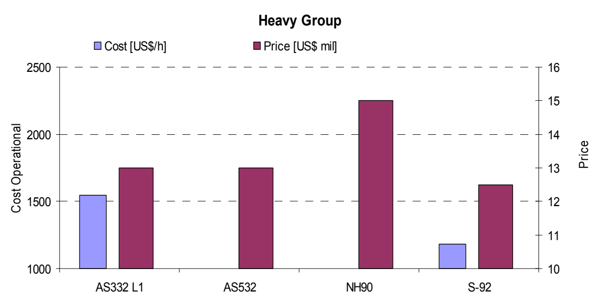

Figure 17. Heavy Group: models versus maximum speed and operational altitude.

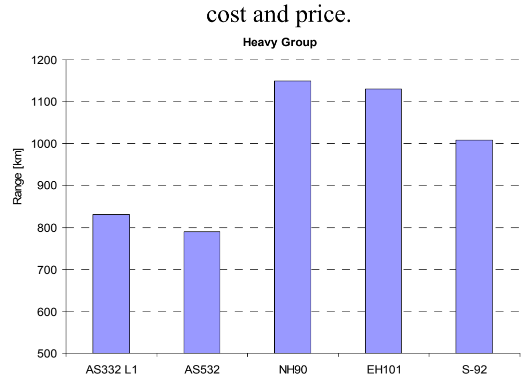

Figure 18. Heavy Group: models versus maximum ranges.

4. Final Considerations

Table 3 summarizes the items, presented on the Figures 7 thru 18, used as comparisons among the groups and models, showing the advantages and major aspects of each group. The rank used is based on customer priority and necessity that will be analyzed during the procurement.

Table 3. Advantages of the groups.

	Light	**Medium**	**Heavy**
Number of passengers	★	★★	★★★
Gross weight	★	★★	★★★
Engines	★	★★★	★★★
Figure of Merit	★	★★	★★
Maximum speed	★	★★	★
Endurance	★★	★	★★
Service altitude	★★	★★	★★
Range	★	★★	★★★
Consumption of fuel	★★★	★★	★
Operational cost	★★★	★★	★
Price	★★★	★★	★

Based on the methodologies purpose in this paper, a flowchart is presented to support the customers to evaluate the performance and configuration data to define the specific helicopter model to accomplish the mission, Fig. 19. The first step is to define and assure the helicopter group that will be analyzed, light or medium or heavy. The second step is to define the most suitable helicopter model that will be choice by the customer.

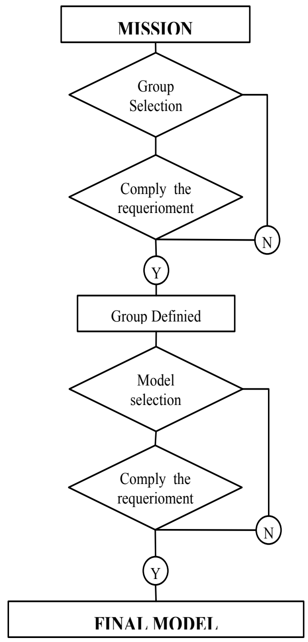

Figure 19. Flowchart proposal for helicopter model definition.

5. Conclusions

The real necessity and circumstances requested by a daily operation along with the operational costs determine which will be the most effective helicopter to choose. Any choice concerning the helicopter model should be made by means of a commitment involving size, capacity, costs (initial and operational), comfort, operational envelope (speed, maximum altitude, weight etc) and versatility. Based on all these factors, it is possible to define the helicopter suitable to accomplish the mission with the smallest possible costs; this model, thus, can be considered “the best helicopter” for the purpose of this particular mission.

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