Decision Making Tool in Aviation Industry Considering Safety and Technologies Integration

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DECISION MAKING TOOL IN AVIATION INDUSTRY CONSIDERING SAFETY AND TECHNOLOGIES INTEGRATION

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ABSTRACT

Safety, fast and regularity were and continue to be the Civil Aviation's objectives; their order invariably defines their importance. This means civil aviation firstly strives safely and after, all other objectives follow. Thus, as industry advanced toward the attainment of safety by means of aggregate improvements, demand for air transport increased, resulting in decline of cost. Successively the decline in cost, ignited the rapid course in demand for air transport, which in turn along with the increase in flights simultaneously brought about traffic congestion and flight delays.

Subsequently, technology by continuous repetitive cycles improved the flight delay problem. Improvements however, due to the new increase in demand, once more proved to be insufficient. However, technology, beside its contribution, at the same time created a new problem, concerning continuous and multiple integration, a problem, which in addition to effecting manufacturers effected decision-makers as well. This new problem emanated from the confusion to decide on the one hand of proper objectives, and on the other hand the cost effectiveness of the best alternatives. Thus and in order to help those decisions makers, in the present paper we develop a model of decision making strategy for technology matters.

Integration, Reliability, Risk, Technology

1. INTRODUCTION

In an effort to improve safely standards, civil aviation initially focused on improving the element of Hardware, thus on improving aircraft, land infrastructure and technology in general. Consecutively after realizing that improvement in technology and infrastructure did not bring about the expected results, efforts were focused on improving the "Humanware" factor that is to say to improve the human element. However, in order for the human element to coalesce with the technology factor, in an environment where precise manipulation and the absence of error is necessary, there is a call for a regulatory, procedural, instructional framework etc. the "Software", in order to specify the modus operandi of the former towards the latter.

The aforesaid improvements, which initially brought about an overall improvement in safety, gradually dragged along the decline in cost. Successively the decline in cost ignited the rapid course in demand for air transport, which in turn along with the increase in flights simultaneously brought about traffic congestion and flight delays.

In order to confront the problem industry veered toward technology, which developed rapidly as well consequently leading to an extremely fast request for its integration/completion. Rapid developments however, and the question as to which technology could integrate which other's, created confusion for decision-makers as far as the groundwork upon which they were to base their decisions regarding technology.

As a result of the above, it is apparent that a methodology is required which, will take into consideration industry's and society's objectives and the business' limitations. Its implementation by the decision makers will them to develop strategic goals which, will so much so guarantee efficiency as it will effectiveness.

2. BASIC DEFINITIONS OF RISK AND SAFETY

2.1 The concept of Risk

Safety and Reliability [1] are two closely interrelated concepts. Obviously the higher the Reliability of a system the safer the system is. However, if we want to quantify safety, we have first to quantify the possibility of the appearance of a particular danger. We must always be in position to quantify possibilities (risk assessment) in order to make choices (risk options), under the restrictions of compulsory minimum standards (regulations) and the cost involved (cost -benefit analysis) [13]. Therefore all potential dangers should be identified, measured and evaluated, starting with the design and then working through all phases of operation until a safe system of work is established. However in order to do this we must first recognize that transportation systems consist of three interacting components, which are:

- technology (the hardware);
- rules and regulations, codes of practice, operating procedures and casualty records and statistics (the software); and
- the personnel involved, both ground and air (the humanware) [15]

The probability of occurrence of an incident or accident, which is linked to the aforesaid components arising, is called risk. It is expressed as the product of the frequency of the event to its consequence. The definition of accident risk is immediately tied to the definition of financial risk, as the latter may be considered the quantitative expression of the former. The cost, which is tied to risk usually, appears in two forms, either as cost prevention, or as cost mitigation. Consequently, risk evaluation, inevitably influences the strategy of economic units overall, as far as investing resources (human and technological) are concerned, in order to face the risk[3]. Therefore, low investment in resources entails high accident risk, and this in turn entails high financial investment risk.

2.2 Formal Safety Assessment Method-FSA

The method which examines the degree of accident risk of a system and which employs risk as a measure is called Formal Safety Assessment Method-FSA. It is defined as an approach where one observes a tendency to depart from colloquial use of descriptive terms while simultaneously placing greater emphasis on the performance of the system as a whole, taking into consideration the hazards and risks which it may have to face. The following steps are utilized in this method:

a. **Identification of Hazards[1]:** objective is to create a list of all the relative accident scenarios accompanied by their potential causes as well as their probable consequences.
b. **Risk assessment:** objective is to evaluate the inborn factors of identification of hazards, in each accident scenario and by order of degree (greatest to the smallest).
c. **Risk control options:** objective is to present regulative measures in order to control and minimize the risks identified in step one. Attention is focused on greater risks, as evaluated in the previous step.
d. **Cost-Benefit Assessment:** objective is to confine the costs and benefits of implementation of each alternative risk proposition by utilizing established cost-benefit evaluation techniques.
e. **Suggestions for Decision-Making:** objective is to compile information (data) regarding hazards, the risks tied to them, the cost effectiveness of alternative scenarios for examining risk and following to forward these results to those responsible for decision-making.

Thus, FSA seems to have acquired elements [11] from human engineering, which deals with the relations between human element, procedures, machines and the environment.

3. THE GOALS OF CIVIL AVIATION AND THE FORMAL SAFETY ASSESSMENT -FSA METHOD

3.1 Civil Aviation Goals

a) Goals of Air Traffic Control

The criteria for planning Air Traffic Control [5] are the product of the principles, which need to be taken into consideration in planning and enforcing an air navigation system, economically and practically. Thus the terms 'air traffic management' and 'flow management' are used to describe the joint activities of authorities responsible for supervising, planning and organizing air space in order to bring about the most effective usage of air space and traffic flow within the area of their responsibility. Thus the goal of the air traffic flow system is to safeguard the optimum flow of traffic especially through the areas where demand for air traffic flow often exceeds the available capacity of the system. Cost effectiveness of a flow management system must be analyzed carefully and must be compared to the cost of flight delay procedures.

"Safety without accidents" is an axiom, which must be on the mind of all those responsible for managing air traffic circulation. Although, safety is the ultimate goal it cannot be examined in

[1] Hazard is an undesirable result, which may occur during the execution of an act. On the opposite Risk is the product of the apparent frequency of this undesired result to its consequences. Thus, there is a big difference between the two definitions; risk and hazard.

isolation from the need to furnish regular and efficient flow of air traffic circulation. Air traffic circulation should be administered in such a way as to provide the best possible service to all users, while simultaneously taking into consideration the difference in aircraft characteristics. The more the number of air space users increases, the more complication of managing air traffic arises. However, with the use of modern technology most obstacles may be overcome. Human and technological resources though, are costly. Thus, each new level technology suggested must reflect both established and transparent needs.

To recapitulate we can say that Air Traffic Control [14] service is provided in order to prevent collision between aircraft, between aircraft and obstructions within the maneuvering area (safety), and in order to attain regular and fast air traffic control.

The continuous objectives of air traffic control are safety, fast and regular flow of air traffic circulation.

b) Airport Goals

In order to emphasize the goals of today's civil aviation Sir John Egan, Chief Executive of BAA plc. In laying down company policy placed the issue as such "...our clients expect continuous improvements in safety, quality and cost of our airports." [12]. The ACI (Airports Council International) Safely Committee functions [6] within the same wavelength when, in a conference it organized for Chief Executives and Heads of Safety Departments it stressed "Good security is also good business"

The above mentioned objectives are obviously in sinc with those of the ICAO (International Civil Aviation Authority) and air traffic control as stated previously with safely, in both cases, being the primary objective and therefore the common goal. Quality objective on the other hand is a broader term and presupposes the existence of safety, since it cannot exist if safely does not exist. It presupposes safety as well as absence of delays and regular flight performance. This analysis indicates the relative identity between objectives, regarding air traffic control and airports which, confirms our up to now allegations and admissions.

Consequently, air traffic control objectives may as well be considered as industry's objectives in its entirety and their hierarchical order on the other hand may simultaneously depict their level of importance. Thus, firstly is aimed for the safe transport, then fast transfer of aircraft and people and finally, once these elements have been achieved, regularity. In other words increase in speed is unacceptable if safety has not been ensured beforehand.

3.2 Applying Formal Safety Assessment -FSA to Civil Aviation

Information and guidance in applying Formal Safety Assessment to Civil Aviation is described as "Accepted Good Practice" and typifies the accepted practice by which duties are attended. It presents the manner in which risks are confined and identified, and provides information on how air transport safely could be placed within the framework of a systematic and structured approach of a Safely Management System.

Within the framework of Formal Safety Assessment, the general demand to implement risk evaluation was enforced in Great Britain in 1992, with the Regulation on Management of Health and Safety [4].

This regulation in general terms states that "each employer will apply proper and sufficient risk evaluation for the health and safety of his/her employees, and others who may be effected by the employer's activities and who are exposed to them while at work." the objective being to point out all measures needed to be taken by the employer so that he/she may comply with the requirements and prohibitions imposed upon him/her by the relative provisions. Application stages are as follows:

- Policy Statement
- Organizing Human resources
- Planning and standards setting
- Measuring Performance
- Lessons learned - Control and Review

Therefore, risk assessment should be included as an operation in each program or development plan. It is essential for success that risk assessment be completely shared among all airport managers and others concerned, since, it may as well be a fast and simple estimation of all sides leading to arrival of an unerring forecast, resulting in the consolidation of safe labor practices. In contrast risk analysis is a much more compound procedure and naturally only applied to bigger development projects [12]. Where thought required for each big new project it may be necessary to pinpoint and satisfy a Target Level of Safety (TLS).

The application steps mentioned previously as well as the rationale, methodology of FSA presented in section 2.2 and the expected results confirm that we have a uniform methodology which, can be applied to every kind of industry, with, naturally, small conformance modifications.

4. EVALUATING OBJECTIVES BY USING THE COST-BENEFIT METHOD

4.1 Objectives and Potential Compromises

There is evidence which, has been produced through project research and which manifests that most passengers are prepared to pay a logical rate for improved services, while less passengers are prepared to endure delays and lack of comfort. It is a well-known fact that society exercises pressure to reduce delays, forcing the industry to seek new solutions. Any solution however, must be able to calculate risk and to take it into consideration so that it will not decrease the level of safety but rather increase it. In order to solve these issues it is necessary that the three reliability factors of the system work together (Hardware, Software, Humanware), with technology (Hardware) coming first.

Summing up we are able to say that society today, on the one hand, seeks and pressures to zero delays and on the other hand demands improvements in safely standards even, if this translates into a limited increase in transport cost. Continuous increases in demand result in traffic congestion, both ground and air. As this cycle repeats itself it creates the need for more complicated technologies and at the same lime for greater increase in cost. As delays are reduced there may be a rise in risk. Civil Aviation along with the air transport industry are driven towards improving the three reliability factors in order to confront this situation: the Hardware factor, by improving technology, the Human ware factor by improving human resources and finally the Software factor by developing systems of Air Traffic Flow Management. Such a management system for years now has been through the process of being developed and is currently being completed by the European Organization, Eurocontrol.

4.2 Cost-Benefit assessment based on Risk

In order to apply the cost-benefit approach it is necessary to compare the selected measures to a suitable diminishing risk monetary value. This approach may seem appealing since, the idea behind it is immediately understood, but its practical approach holds a number of "crisis values" which contain components such as the value of life [13]. Two popular approaches in estimating the value of life are the "human capital" and "willingness to pay" approach.

Human capital

This approach assumes that individuals may regarded as a special type of equipment whose potential output would be lost as a result of premature demise. Life is therefore equated to the value of a person's potential earnings plus a notional sum for the 'pain, grief and suffering' experienced by those affected by his or her death.

Willingness to pay

This approach was devised to overcome the admitted deficiencies of the previous approach, such as the failure to examine the preferences of those at risk. The calculation is based on the "willingness to be paid either for decrease in risk or compensation of those involved in high-level risk activities.

Thus, information regarding risk control effectiveness from stage three [3] of the Formal Safety Assessment are combined with the application cost of each alternative control of this risk, with an objective of attaining the measure of cost effectiveness for all alternative approaches.

The following relationship calculates the present clear value (NPV) of risk application control:

$$NPV = \sum_{t=0}^{n} [(B_t - C_t) - (1 + r)^{-t}]$$

where C_t = the sum for cost of period t

B_t = the sum of benefits for period t

r = interest rate

t = time, measuring evaluation starting from "0" to "n" time

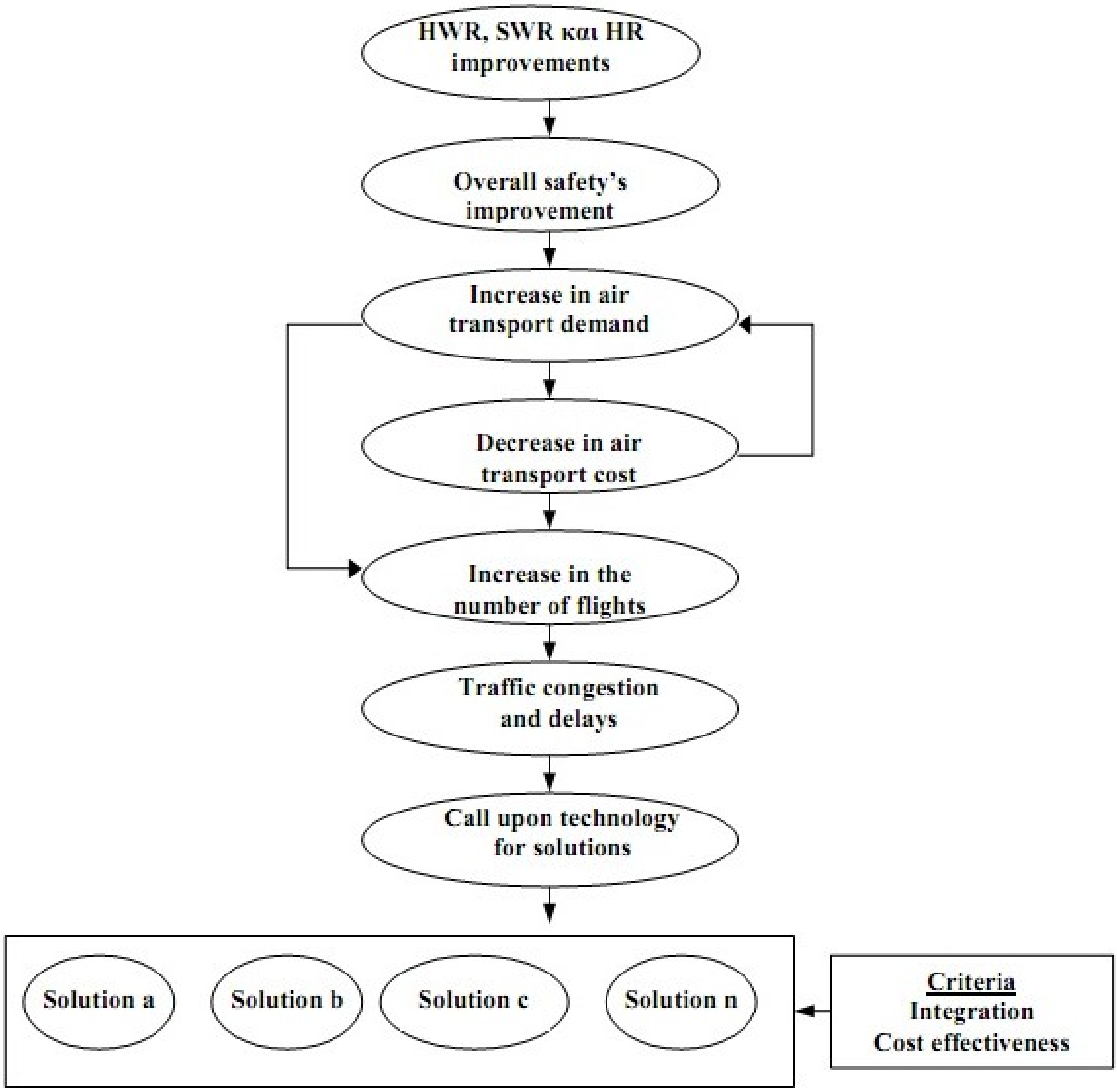
The NPV result is then used to calculate the cost per unit Risk Reduction (CURR) dividing NPV with the estimated benefit acquired from the equal reduction in the amount of deaths. CURR values may then be used to compare the measures of risk control which provide effectiveness for the measure in improving human safety.

5. SYSTEM INTEGRATION AND THE COMPLICATIONS THIS BRINGS ABOIT IN ATTAINING OBJECTIVES

5.1 The need for system integration

The continuous improvement and development of new technologies which, aims at solving problems, simultaneously at times creates new ones. Those having to do with training, as far as new technologies are valued by employees (Humanware), and also with the relation being developed with the third factor, the Software, This relation are the development and modification of proceedings under which the human element is called upon to operate the new increased Hardware possibilities.

Figure 1 : Civil aviation's evolution and its problem definition



Thus, airports are constantly becoming smarter through communication and information systems [8]. This new dimension is copiously evolving and is recognized by industry as an administrative tool, which leads to essential functional and financial returns. The effort to attain functional efficiency illustrates the strain to integrate IT systems in most airports. Therefore, today, perhaps the most necessary department of a modern airport, for it to function efficiently with safety and effectiveness, is the platform for developing IT. Airports as well as Air Traffic Control have parallel similarities. Air Traffic Control is a highly automated industry, which must maintain a close relation to the situation regarding all technological equipment, used in order to decrease the probability of accidents taking place [16]. Here as in many other industries, integration is the key to simplification and convenience in use. Integration of many systems simplifies the initial ease in installation and allows the excellent use of available space. Thus rationalizing the systems' structure reduces the initial as well as the following functional expenses, while at the same time improving returns.

5.2 The relation between systems integration and safety

Up to now, it has been presented how systems integration contribute to the efficiency and effectiveness of airports as well as air traffic control and this could be achieved through an excellent IT platform. The structure contributes as well to simplification and ease in use thus resulting, in reducing the cost of initial installation and functional expenses which, lead to high returns.

However, as mentioned, the primary goal of civil aviation is not integration but safety. Thus the decision-maker within the barrage of available technologies (which each have different costs) must not get carried away and decide based on better integration and returns, but based on safely and effectiveness. However, safety and returns are definitions which bring us back to the FSA method and its application steps which are isolating risks, evaluating them and then evaluating each risk based on cost-benefit. The situation as we understand it can be seen in Figure I.

In this figure it is presented on an aggregate manner Civil Aviation's evolution with its problem definition as we face it today. Improvement of reliability factors brought about improvement of safety which, in turn caused an increase in demand, lead to the reduction in cost. This demand then, leaded to the reduction in cost. But cost reduction brought about again an increase in demand, which created a new increase in the number of flights and thus traffic circulation congestion. Consequently, the decrease in cost brought about a new increase in demand, which created a new increase in the number of flights. Thus the increase in demand and the decrease in cost finally invoked an increase in the number of flights or put differently a boom of flights and severe traffic congestion. The call upon technology to provide solutions to problems which the decision-makers could not easily adapt to resulted in confusion and required decision-makers to request assistance from technology in dealing with the problems.

Thus within the framework of an increased level of congestion in air traffic circulation and the constant pressure for safety issues to be resolved, the demand for advanced information systems and decision-making tools which would ensure, regular, efficient and safe observation, control and management of air traffic circulation arises.

This situation leads to the demand for a fault-tolerant supervisory system where the software and hardware of information systems must be superfluous.

This observation once more leads to the theory of reliability systems and the three reliability factors and thus to FSA.

6. FORMATION OF RISK MANAGEMENT STRATEGY INDER SYSTEM INTEGRATION

6.1 Decision making based on system reliability

The operation research paves the road and demonstrates the general method, which should be used in order to arrive to a solution in developing a model for decision-making for issues involving technology and specifically issues regarding integration technology.

It has been seen that in order to deal with probable threats of any system it must:

- Utilize the factors of reliability in the best possible manner so that it may deal reliably with the probable losses, either when this concerns the airport or the air traffic control.
- Design the planning phase correctly

Thus the need for developing a model for decision-making arises, based on the system reliability theory which affects the system also during the planning phase and not only during operational. The steps of such a model for decision making take into consideration the steps of FSA methodology as well as those of the general steps of the operation research. Therefore the steps of the proposed methodology are presented below:

- *Identification and correlation of reliability factors'.* Hardware, Software. Humanware and their correlation. The result of this step is to list the risks, which connect the three factors, and then evaluating them.
- *Qualification of the Safety System:* Use of techniques to quantify interactive risk, such as fault-tree analysis of risk matrix etc. Resulting of this step in evaluating combined risk according to the order of magnitude [2].
- *Decision making for the Reliability level of the System:* Combined risks are evaluated on the basis of cost-benefit and the desired future level of reliability of the system. For this level we take into consideration: safety objectives which in turn are translated into integration choices, speed and consistency. Compromises could not may happen, those could be undertaken only in technology's integration, in the speed and traffic regularity (delays etc.).
- *Decision making for apportioning resources:* After deciding the level of System Reliability then we decide upon the level which could be achieved by combining the three reliability factors, for example intermediate system reliability may be achieved by high level reliable hardware and low reliability humanware, and the opposite.
- *Strategy formulation:* The decision for system reliability and the decision for apportioning resources have already formed part of the strategy of the firm. These decisions influence the entire company's strategy objectives and are also influenced by them.

It is apparent that in this model, all potential objectives are taken into consideration without expecting integration, congestion (lack of delays), effectiveness (cost-benefit) and efficiency (attaining objectives: safety, speed and consistency)

In figure 2 we see the development of this model which seems to continue exactly from the point of confusion of the decision-maker which was presented in the previous figure (Figure I).
Here we see that each probable solution is called safety case and is examined separately making use of the stages of the FSA method as well as the steps of the presently suggested methodology. The result is the formation of a total strategy for the organization, which contains the strategy for issues regarding technology. This strategy compensates the objectives of the organization; it leads to high quality safety, the best speed and consistency. Finally satisfying these objectives leads to high efficiency and effectiveness.

6.2 Decision-making regarding technology issues:

It is now obvious that hardware, such as is technology, is immediately influenced by cost and integration, thus we are in a position to answer to the question of confusion of the decision-maker on issues regarding integration, and in regards to which technology to choose, based on what criteria. The answer is found in the model we presented previously and which satisfies the basic goal of the industry which is safety best served by technology, while the cost of integration as well satisfies the reliability goal of the specific system. On the basis of cost-benefit a compromise is only made regarding the goal for expedience and consistency and the other two factors humanware and software are used as a regulative tool which helps achieve the total level of reliability of the system seeked. Here it is apparent that decision-making regarding matters of technology (Hardware - HWR) and issues of integration of technology are logical relationships and are as much a part of the desired level of reliability of the system (System Reliability - SR) as of the level of reliability of the two other reliability components Humanware - HR and Software - SWR [2]. The relation, which brings them together, is may be expressed as a function of System Reliability (SR) as follows:

$$SR = f(HWR, SWR, HR)$$

or

$$SR = HWR * SWR * HR$$

If we assume that f is a single multiplicative function. Then solving for HWR the relation takes the following form:

$$HWR = \frac{SR}{SWR * HR}$$

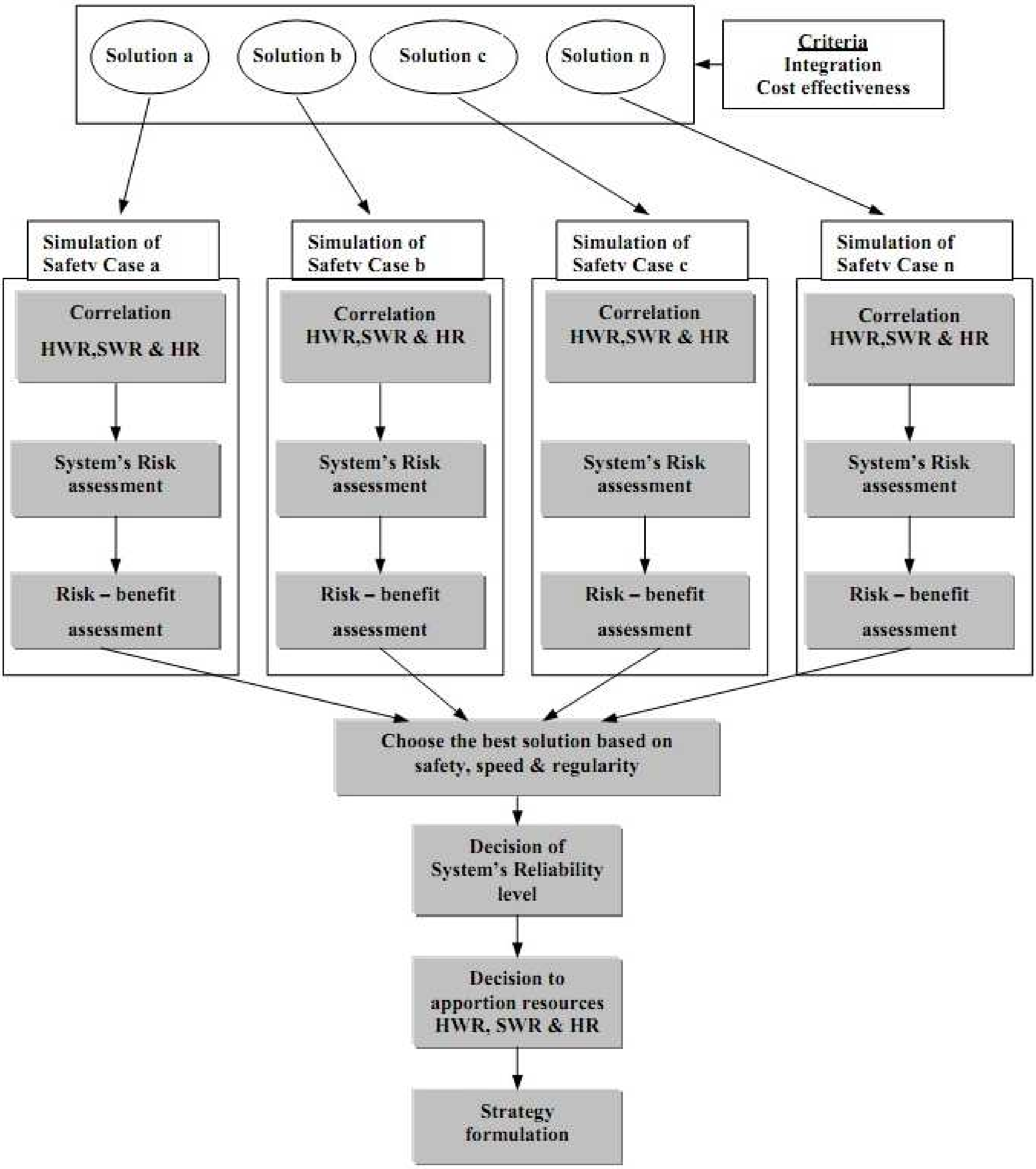
In a given level of System Reliability (SR) the Software (SWR) component may perhaps not be able to play a very important role in an environment as is that of air traffic circulation which is strictly regulative. Thus the component which can play a determining role is Humanware (HR). Control of its magnitude inversely influences Hardware (HWR). Thus it arises that decision-making for Hardware must:

- Satisfy to the fullest the objective of reliability
- May make compromises on the other two objectives, namely speed and regularity
- Must be intercompleted by Humanware

6.3 Simulation a tool for choosing alternative solutions and decision - making

The area of civil aviation has no room for error, since; any mistake may cause irreparable damage to individuals and property. Thus any decisions or alternative scenarios must be tested in advance prior to implementation and must allow for familiarization of the human factor before the entire system is set into use.

Figure 2: The problem and its solution



The way something like this could happen is by simulating safety cases which are set into function so that any errors of imperfections which may occur can be repaired and the best possible alternative solutions may be chosen by satisfying the objectives on the basis of the confines of cost-benefit. Such an example is the NASA space center. Future Flight Central which on the basis of simulation examines problems where effectiveness of technology is measured and safety is analyzed [10]. Consequently this center:

- Assess the return on technology investment and analyze safety
- Makes cost-benefit evaluation, using real traffic scenarios

From the above derives that simulation and modeling may be considered as to contributing to the correct decision-making and that they are thus a part of the decision making model which we demonstrated previously. Namely they contribute to all steps of the model from the quantification of safety to the strategy formulation.

7. EPILOGUE-CONCLUSION

Safety, fast and regularity were and continue to be the Civil Aviation's objectives; their order invariably defines their importance. In the last couple of years though, the constant improvement as well as the development of new technologies try to solve problems while simultaneously creating new ones, one of which is the constant integration of technologies.

Subsequently the problem, which we had to solve in this present paper, is the complications initiated in decision-making, the expedient integration of technologies in the air industry.

Consequently decision-making as far as obtaining integration of technology is concerned enters new dimensions, under the confine of reducing risk on the basis of cost-benefit. This problem with its limitations is a common problem of operations research whose tool is simulation. Simulation is a powerful and widely acknowledged technique for analyzing and studying complex systems [18].

Summarizing, in the framework of this study and solution to this problem we made use of the general model of operations research but also of the more specific method of analysis and risk management through FSA. On the basis of these two methods we developed a correlative model for decision-making with which decision-makers are in a position (and through them the companies) to avoid confusion as far as choosing integrated technologies. Decisions are based on system reliability, of which one of the factors is technology. In this manner integration of various choices simply is transformed to alternative solutions safety cases, which in turn are tested in combination with the other two factors of reliability, the Humanware and the Software as to how far they fit the given objectives of safe, fast and regular. Following the various choices are evaluated on the basis of cost-benefit and compromises, which are necessary to be made on the basis of cost, concern only the objectives of speed and consistency and never the objective of safely.

On the other hand the present paper showed that there are matters which need further investigation. Such matters include the examination of using other specified methods as for example BPR (Business Process Reengineering) in combination to Benchmarking, to Activity Based Costing and to Modeling. To BPR as a method directed toward the market is believed to be able to give excellent results while simultaneously maintaining high safety standards and low cost. Another issue which seems to require a more detailed analysis is the issue of the reliability factors, their interdependence and their better linkage to Human ware and Software through modeling.

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