APPLICATION OF RISK MANAGEMENT PROCESS ON WAVE PROPAGATION IN AEROSPACE MEDIUM

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ABSTRACT

APPLICATION OF RISK MANAGEMENT PROCESS ON WAVE PROPAGATION IN AEROSPACE MEDIUM

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In this thesis, risk management methods are investigated in order to integrate risk management practices into the Turkish Aerospace industry. The research presents the sequence of risk management processes as identification of risk, analysis of risk, risk planning etc. Risk analysis methods named as Risk Ranking and Analytical Hierarchy Process (AHP) are investigated in order to improve reliability and safety of the systems or processes in the aerospace industry. The main aim of using risk ranking and AHP together is to translate the knowledge in the Turkish Aviation Industry to a tangible form with a quantitative approach and to prepare a basis for probabilistic risk analysis. Instrument Landing System (ILS) has been considered only in order to facilitate a demonstration how risk management can be done in this context. This study investigates and seeks to create awareness for risk management practices within Turkish Aviation industry.

Keywords: Risk, risk assessment, risk management, AHP, Turkish Aviation Industry

ÖZ

HAVACILIKTA DALGA YAYILIMI ÜZERİNE RİSK YÖNETİMİ SÜRECİ UYGULAMASI

Konukçu, Selda
Yüksek Lisans, Havacılık ve Uzay Mühendisliği Bölümü
Tez Yöneticisi: Prof. Dr. Yurdanur Tulunay

Eylül 2006, 124 sayfa

Bu tezde, Türk Havacılık Endüstrisine risk yönetimi faaliyetlerini entegre etmek amacıyla risk yönetimi metodları incelenmiştir. Bu araştırma riskin belirlenmesi, belirlenen risklerin analizi ve risk planlaması gibi risk yönetimi sürecinin temel basamaklarını içermektedir. Havacılık Endüstrisinde yer alan sistemlerin ve işlemlerin güvenilirliğini ve güvenliğini arttırmak amacıyla, Risklerin Oranlaması ve Riskin Analizi Süreci için Analitik Hiyerarşi Süreci gibi çözümler incelenmiş ve uygulanmak üzere sunulmuştur. Buradaki temel amaç, Türk Havacılık Endüstrisindeki bilgi ve tecrübe birikimini numerik yöntemlerle somutlaştırmak ve Olasılık Analizi Yöntemleri icin temel hazırlamaktır. ILS (Instrument Landing System) isimli iniş sistemi risk yönetimi sürecinin uygulanması amacıyla seçilmiştir. Bu çalışma ile Türk Havacılık Endüstrisinde risk yönetimi faaliyetleri üzerine 'farkındalık' yaratılmaya çalışılmıştır.

Anahtar Kelimeler: Risk, risk değerlendirme, risk yönetimi, AHP, Türk Havacılık Endüstrisi

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ATCT	Airport Traffic Control Tower
CI	Consistency index
EMC	Electro Magnetic Compatibility
EMI	Electromagnetic Interference
ERMS	Engineering Risk Management Sytems
FMEA	Failure Modes and Effects Analysis
FTA	Fault Tree Analysis
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
ITU	International Telecommunications Union
MCDM	Multi-criteria decision making
MLS	Microwave Landing System
NASA	National Aeronautıcs and Space Administration
NOTAM	Notice to Airmen
PRA	Probabilistic Risk Assessment
RF	Radio Frequency
RMDB	Risk Management Database
TA	Turkish Airlines

TAF	Turkish Armed Forces
TCAA	Turkish Civil Aviation Authority
TSAA	Turkish State Airports Authority
TTA	Turkish Telecommunication Authority
UHF	Ultra High Frequency
UN	United Nations
VHF	Very High Frequency

CHAPTER 1

1 INTRODUCTION

1.1 BACKGROUND

Risk management in aerospace industry is a serious issue since the faults in aeronautical activities may be extremely dangerous, even fatal. Aerospace industry has been playing a leadership role in technological developments when compared to other industries. Everyday, new technologies are emerging, developed and tested in order to use more innovative and safe solutions in the aerospace industry. However besides these, the aerospace technology faces important challenges in meeting the criterion of the best way to manage the forthcoming technologies. It not only cares the efficient and safe use of existing technologies but also studies on how to make progress by introducing new technologies with high safety and reliability. There is always need of creating care and awareness for the negative consequences of any technologies used in the aerospace industry. In its broadest sense, 'the problems that can offset at least one of the gains from modernization and the introduction of new innovations should be discussed and analysed for safe and reliable aerospace industry' (Janic, 2000, p.43). Due to this chaotic nature of aerospace industry, risk management studies are inseparable part of all existing and new technologies of aerospace medium nowadays. Good risk management helps the industries to be able to achieve the outcomes in easier and appropriate way, to limit threat to acceptable levels and to take right decisions about exploiting opportunities (ICE, 2005). It is obvious that aerospace industry seriously needs risk management activities to increase safety and reliability.

Risk and reliability assessment studies have started in the US aerospace and missile programs since the early 1960s (Stamatelatos et. al., 2002). The risk management practices are indispensable part of all aerospace activities all over the world in 21st century. In addition to risk assessment studies conducted by the technology developers, many private enterprise and governmental bodies who are set up specifically for a safe and reliable aeronautical industry have supported such missions. As example, one may mention the EUROCONTROL in Europe, or International Civil Aviation Organization (ICAO) the specialized agency of the United Nations (UN) etc. These organizations try to develop a safe, reliable and standardized aerospace industry in terms of the perspective of all users. Among the users one may mention the technology developers, passengers, pilots, aircraft crews etc. In order to create a “one common safe and reliable sky all over the world”, the technologies employed by the aerospace medium should be investigated and interpreted in terms of their risks. There should be standardisation achieved for a safer and reliable sky throughout the world. The governmental bodies in Turkey have been working very closely with the EUROCONTROL in order to adapt the national aerospace industry to meet the ICAO standards.

To increase safety and reliability, the risk management process can be applied to various aerospace applications. However, in this thesis, due to the practical limitations and constraints, the Instrument Landing System (ILS) has been considered only in order to facilitate a demonstration how risk management can be done in this context. ILS is an essential instrument in the civil and military aviation industry. In this thesis, the ILS is studied in terms of the risks, which may disable its operation due to Electromagnetic Interference (EMI). Electromagnetic interference is the derogation of signals of any system because of an external or internal electromagnetic source. The ILS is one of the main international, ICAO approved, precision landing systems. It is a precision approach system in general, which consists of a localizer facility; a glide slope; and VHF marker beacons. ILS provides vertical and horizontal navigation information during landing. In particular, the ILS is needed for landings under poor visibility conditions such as foggy and stormy weather (DoD & DoT, 2003). In general, the ILS is a critical instrument to be owned by countries like Turkey, which has harsh climatic conditions especially at North and East parts. When the rapid development in Turkish aviation industry in recent years is taken into consideration, it can be concluded that the air traffic will become much more chaotic in a few years time. When the harsh climatic conditions and crowded air traffic are considered together, the need for a more reliable ILS operation becomes inevitable. Having such a critical mission, it is concluded that to handle the risk management process of ILS, will be an important study for Turkish Aviation industry, which have some severe problems on ILS operations. ILS is presently satisfying but 'has limitations in sitting, frequency allocation, and performance' (DoD & DoT, 2003, p.91). In this thesis, the problematic areas that cause EM interference of ILS were studied and discussed. Risks were identified and analyzed by the help of experts in Turkish State Airports Authority (TSAA), Turkish Armed Forces (TAF), Turkish Airforce and Turkish Airlines (TA). Risk mitigation scenarios were developed to prevent the negative effects of the risks identified.

Summarizing, it is considered to be timely to take initiative in pursuing some research on how to identify the probable risks on an ILS system employed in Turkey and how to deal with such risks systematically.

1.2 AIMS AND OBJECTIVES

1.2.1 The Aims

The following aims are proposed:

1. To understand the risk management processes.
2. To apply risk management process on an RF based system in aerospace medium.
3. To understand the limitations of risk management processes in Turkish Aviation Industry.

4. To bring some awareness on the risk management among the Turkish Aviation Units.

1.2.2 The Objectives

The followings are the objectives of this research

1. To investigate statistical and historical ILS data kept in Turkish Aviation Industry.

2. To identify and evaluate the ILS risks by appropriate risk analysis methods.

3. To specify ILS risk mitigation scenarios.

4. To make recommendations for risk management studies in aerospace medium.

1.3 OUTLINE OF THE DISSERTATION

This thesis is based on five chapters and three appendices chapters. The 1st Chapter consists of a brief introduction to the main aims and objectives of this research. The 2nd Chapter is a philosophical interpretation of the research methods and styles in the literature, and presents adopted styles and methods, and their justification, which are considered to meet the objectives of this thesis. In the 3rd Chapter, a literature review, which is based on the recently published books, articles, white papers, and web sites, is presented. Chapter 3 involves general overview of risk management methods, and the detailed description of the adapted risk management methods in this work. In Chapter 4, risk management application concerning the ILS wave propagation is performed. In this chapter, risk identification study on the ILS due to EM interference is presented. A risk analysis on the identified ILS risks is performed in the light of the literature review and the methods selected to apply in the previous chapter. Following the analysis, risk planning study to mitigate the analysed risks is presented. Then, the suggestions for risk tracking control and documentation is carried out. In Chapter 5, all the findings and the results are discussed. A general conclusion is drawn by taking into consideration the aims and objectives of this thesis. In Appendix A, brief information on Probabilistic Risk Assessment (PRA) methods is presented. Appendix B involves details of interviews and analysis performed in order to carry out the ILS risk assessment. In the Appendix C, an RF based system Instrument Landing System (ILS) is introduced. In this chapter the ILS system is described briefly.

CHAPTER 2

2 RESEARCH METHODS

2.1 INTRODUCTION

The main objective of this chapter is to present a detailed methodology to show the appropriateness of the techniques and methodological approaches to gather data for this research (Hart, 1998). However, to present a detailed methodology first the meaning of ‘research’, and the need to do research should be understood well. Following the definition of research, the research styles and methods in the literature are described briefly. To define available research methods helped to identify the adapted methods for this thesis in a more accurate way. The method of this dissertation is heavily based on literature review, expert interviews and a questionnaire. The methods chosen to apply in this thesis is described with their justifications.

2.2 DEFINITION OF THE MEANING OF ‘RESEARCH’

Chambers English Directory defines research as (quoted by Fellows & Liu, 2003, p.3): ‘a careful search, investigation, systemic investigation towards increasing the sum of knowledge’. Research can be defined as a ‘voyage of discovery`, whether anything discovered or not. Depth of discovery depends on search techniques, knowledge and abilities of researchers, location and subject of material (Fellows & Liu, 2003). The Concise Oxford Dictionary explains research as (quoted by Fellows &Liu, 2003, p.4): ‘the systematic investigation into and study of materials, sources etc. in order to establish facts and reach new conclusions'. According to Phillips and Burbules, quoted by Creswell (2003, p.12), 'research is the process of making claims and then refining or abandoning some of them for other claims more strongly warranted'. The practice of research is much more than philosophical assumptions. In order to perform research in an appropriate way, theoretical ideas should be combined to research strategies and methods (Creswell, 2003). According to Crotty, quoted by Creswell (2003), during the design of a research proposal the following questions should be asked:

- Which methodology (strategy or action plan) will be used to connect methods to results? (e.g. experimental research, survey research, etc.)
- Which methods (techniques and procedures) will be adopted? (e.g. questionnaire, interview, etc.)

Since the questions asked by Crotty serves as a map to do research in a proper way, the applied research styles and methods in the literature are investigated and the proper ones for our research are selected.

2.3 RESEARCH STYLES AND METHODS

The Research Styles suggested by Bell (1993) are, quoted by Fellows & Liu (2003) as: Action, Ethnographic, Surveys, Case Study and Experimental.

- **Action Research:** Researcher actively participates in the process in problem identification and evaluation. Action research suggests and tests solutions to particular problems. Change/innovation is the main consideration of the research and coordination between researcher and participants is very important (Fellows & Liu, 2003). According to Myers et al.(1999), quoted by Gittins, 'To make academic research relevant, researchers should try out their theories with practitioners in real situations and real organizations' (Gittins, 1999, p.3)

- **Case Studies Research:** In this type of research, 'deeper investigation of particular areas within the research subject and employs various data collection methods' (Fellows & Liu, 2003, pp.26).

- **Survey Research:** Surveys are based on statistical sampling which can be obtained from structured questionnaire or unstructured interviews. The main aim of surveys is to collect information from various numbers of respondents. Most important criteria, which identify quality of survey, can be counted as response rate, number of responses, and identification of survey sample (Fellows & Liu, 2003).

- **Experimental Research:** This type of research is best suited to `bounded` problems or issues in which variables involved are known or hypothesized. Generally, 'experiments are carried out in laboratories and aimed to test relationships between the defined variables' (Fellows & Liu, 2003, pp.26-27).

- **Ethnographic Research:** Ethnographic research basically includes study of races and cultures and has its foundation in anthropology. In this type of research a group of researchers observe subjects` details in order to gain insights into how, what and why people's behavior occurs. (Fellows &Liu, 2003, Gittins 1999).

According to the five above research styles mentioned above, this thesis is composed of Action Research; Survey Research and Case Studies Research styles. It is an Action Research style since it suggests risk management solutions to Instrument Landing System (ILS). The solutions are developed in the light of the knowledge gathered from the various organizations of Turkish Aviation Industry. It is a Survey Research style since some information is gathered by interviews and questionnaires. It is a Case Study Research style since the aim of this research is the risk management study on an RF based system and the ILS is chosen as a case study.

The Research methods are commonly classified as; Qualitative, Quantitative and Mixed (Triangulation) approach (Creswell, 2003).

- Quantitative methods basically use post positivist claims for developing knowledge (i.e. cause and effect thinking, reduction to specific variables and hypotheses, use of measurement and observation and testing of theories), selects strategies of inquiry such as experiments and surveys and accesses to numerical data (Creswell, 2003; Fellows & Liu, 2003).

- Qualitative approach, on the other hand, is based on 'constructivist perspectives (i.e. multiple meanings of individual experiences, meanings socially and historically constructed, etc.) or advocacy/participatory perspective (i.e. political, issue-oriented, collaborative or change oriented)' (Creswell, 2003, pp18). According to Holloway, quoted by Gittins, (1994 p.4) qualitative research is "a form of social inquiry that focuses on the way people interpret and make sense of their experiences and the world in which they live." In qualitative research, the research subject is undertaken without past formulations. The aim is to collect information and data for the proposed theories. Therefore, qualitative research is the first step before quantitative research and the data gathered may be unstructured. Analysis of qualitative data is much more difficult than quantitative data (Fellows & Liu, 2003).

- Mixed method (triangulation) uses the strategy of collecting data by using both numeric (e.g. on instruments, surveys) and textual data (interviews) collection techniques. Triangulation is very helpful to achieve results and to assist in making inferences and in drawing conclusions (Fellows & Liu, 2003). In Figure 2-1 the triangulation approach is presented.

In the light of information mentioned above about the research methods, this thesis is based on triangulation method. Both the qualitative and quantitative approaches are assumed to reach the aim and objectives of this research. It is based on the interviews and a quantitative analysis of questionnaires.

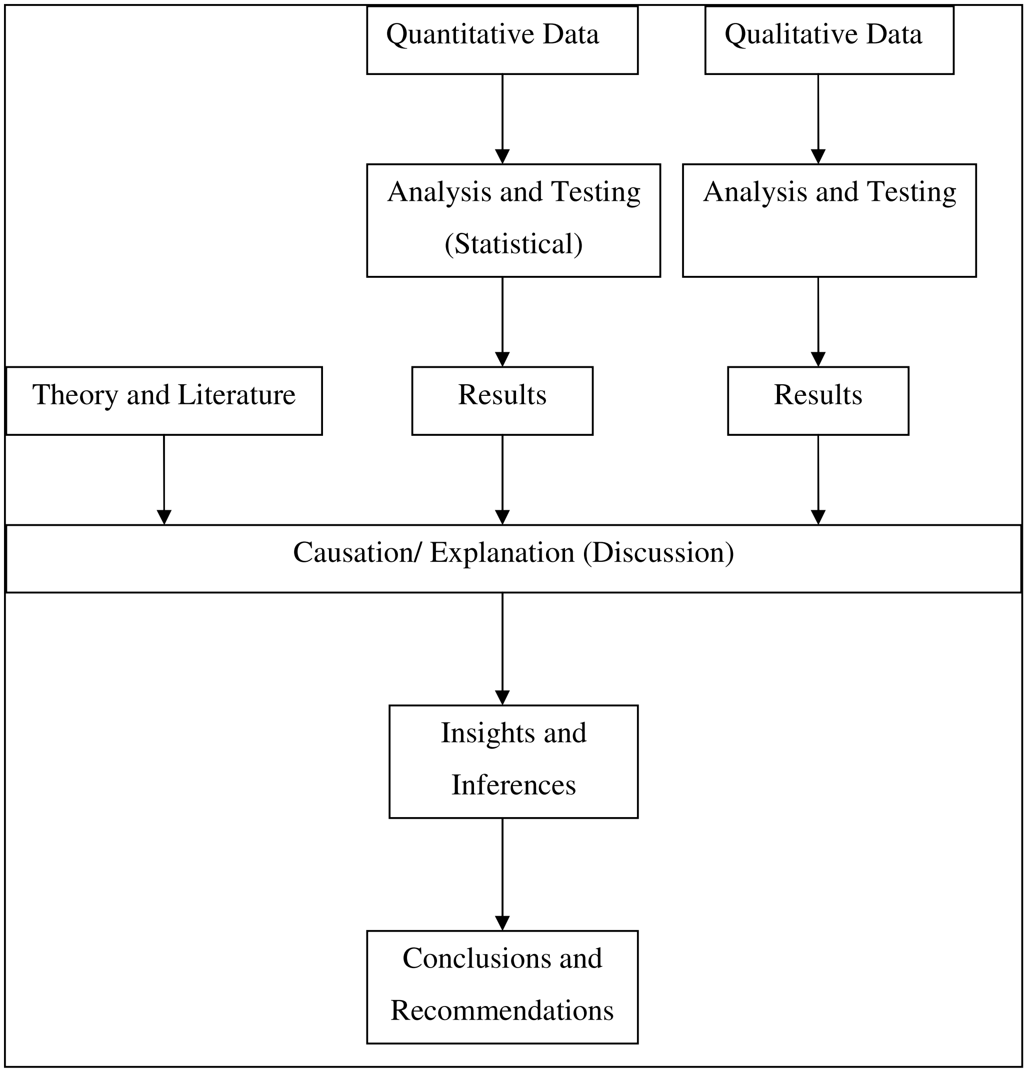

Figure 2-1 Triangulation Approach (Fellows & Liu, 2003)

2.4 ADAPTED METHODOLOGIES AND JUSTIFICATION

The following methodologies are adapted in this thesis. The general overview of these methods and their justification are defined in the following sections.

2.4.1 Literature Review

Literature review is ‘the study on the selection of available documents, which contain information, ideas, data and evidence from a particular standpoint to achieve predefined aims and objectives’ (Hart, 1998 p.13). According to Saunders (2000), the critical literature review is a basis on which research is built. The main starting point of the research is the literature review which is often called ‘desk research’ and its aim is to identify what has been done before and to justify the research. Literature review is a continuous process. It begins before the finalization of the research problem and continues until the research is completed. The literature review brings clarity and supports the methodology. A literature review for a proposal or a research study means finding and summarizing the previous or existing studies about the research topic (Creswell, 2003). The research process is concerned with collecting data and processing it into information (Moore, 2000). The main sources for the literature review are published books, journal articles, and recent conference papers and published theses (Kumar, 1999; Creswell, 2003). Nowadays, Internet and databases are essential repositories for accessing various magazines, e-journals, etc.

As Kumar and Creswell defined the possible sources, the recently published electronic and print journal articles, books and the Internet sources were mainly used in this thesis. Journal articles were mainly accessed from the databases such as Scirus, Science Direct, etc. The relevance and usefulness of such articles were searched by defined terms or key words. Also, web search engines such as Google and Google Scholar were used for retrieving some relevant information for the other information needs of this thesis. Lists of precise references, which can be seen in the bibliography, were cited for those items referred to directly in the text and for those which were used for further reading. The referencing style is based on Harvard Style (Central Queensland University, 2006).

2.4.2 Data Collection

The next step in research process is data collection. There are different types of collecting data for research. Figure 2-2 shows the main methods of data collection.

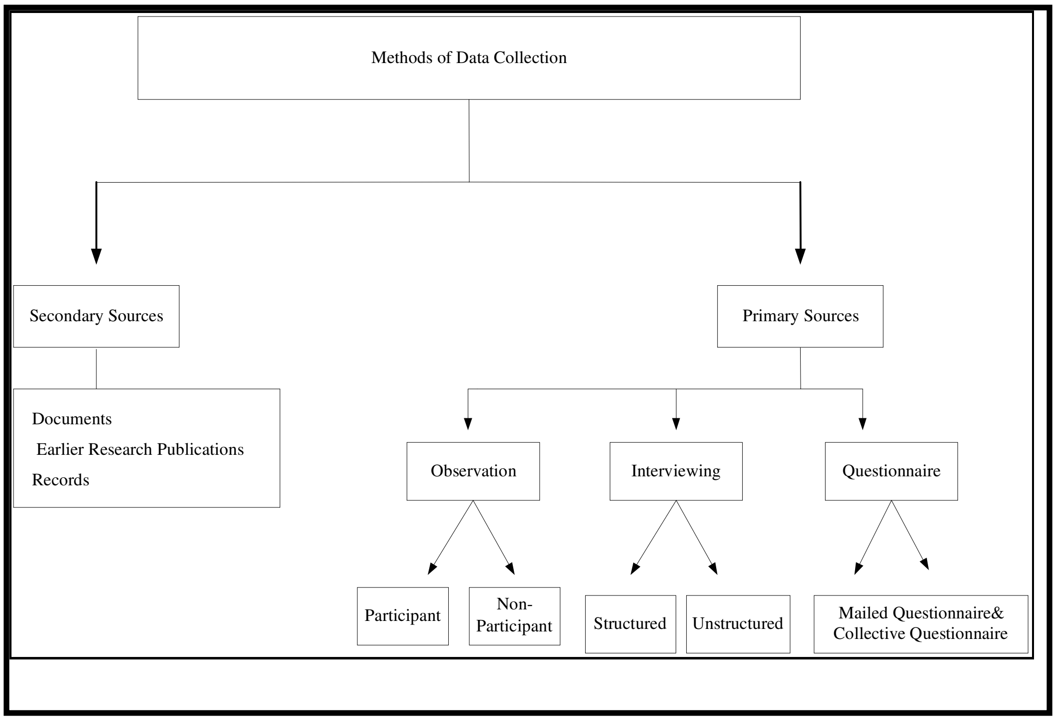

Figure 2-2 Methods of data collection (Adapted from Kumar, 1999)

Data collection methods are divided into two categories as primary sources and secondary sources. Primary sources can be gathered from observation, interviews and questionnaires.

- Observation is a systematic and selective way of watching and listening to an interaction or any activity (Kumar, 1999).

- Interviewing is a commonly used method of collecting information from people. Interviews are classified according to the degree of flexibility; unstructured and structured. A structured interview is prepared before the meeting with the respondent and it provides uniform information (Kumar, 1999; Lang& Heiss, 1985). Structured interviews are built around a questionnaire. Semi-structured interviews provide much more scope for the discussion and recording of respondents` opinions and views (Moore, 1983). Interview surveys have a great deal in common with questionnaire surveys (Moore, 1983). Interview techniques are more appropriate to collect in-depth information and can cover a wider area of application than questionnaires (Kumar, 1999). The main advantage of interviews is that they provide more opportunity to obtain qualified answers (Moore, 1983).

- Questionnaire surveys are the most commonly used research method and can be used to gather information on any topic from large or small numbers of people. It is a written list of questions and the answers recorded by respondents. The main advantages of questionnaires are in the ease of completion, analysis, access to dispersed respondents and accuracy (Kumar, 1999; Moore, 1983; Rothwell, 1993). In questionnaires, questions have to be clear and easy to understand because there is no one to explain the meaning of questions. However, in interview there is a chance to explain questions in detail. Questionnaires are an inexpensive way to obtain information from the respondents and sometimes increase the likelihood of obtaining accurate information for sensitive questions. On the other hand, main disadvantages of questionnaires are low response rate and some delay in getting results (Kumar, 1999; Rothwell, 1993).

In this thesis, interviewing and questionnaire methods are used to gather data. Semi-structured interviews were conducted to have a flexible but logical information gathering. Interviews were very helpful to understand the Turkish Aviation industry and its position in risk management applications. By the help of experts and the relevant literature review, the risk identification process was performed successfully. Then the questionnaires were performed with the participation of ILS experts from Turkish State Airports Authority (TSAA), some civil and military pilots from

Turkish Armed Forces (TAF), Turkish Air-force and Turkish Airlines (TA). The questionnaire survey was an essential part of risk analysis and the results of the questionnaire were used as an input for the risk analysis process. Using questionnaire method and interviewing together created a platform to identify and analyse the risks in a more structured way.

The secondary sources for data collection were also used in this research. Since it has been very difficult to access the proper fault and failure data, the secondary data collection period was a bit time consuming and full of troubles. Therefore, a statistical risk analysis could not be performed. Instead, other methods of risk analysis are assumed.

CHAPTER 3

3 RISK MANAGEMENT

3.1 INTRODUCTION

Risk is 'the combination of the probability that any program or any project will experience an undesired event and the consequences, consequence, or severity of undesired event' (Conrow, 2003, p.21) There are many risk management definitions in literature. But it can be summarized as an 'organized systematic decision-making process that efficiently identifies risks, assesses or analyses risks, and effectively reduces or eliminates risks to achieve the goals of the program' (Greenfield, 1998, p.7). Risk management activities can be concluded as identifying, quantifying and responding to programme risks. At the end of a successful risk management programme, the results of positive events should be maximized and the consequences of adverse events should be minimised. It is obvious that this result may only occur when a successful risk identification process is made at the beginning. But it should be stated that risk management is an iterative process initiated at start of the programme and continues throughout the life cycle. (EUROCONTROL, 2001) It is stated that success depends on identifying, understanding, and controlling risk in all that we do (Greenfield, 2001 p.7) Being the key to success, risk management process is an important responsibility for all professionals working for the aerospace industry. The major risk drivers of aerospace industry can be concluded as specific environmental conditions, need for high level performance, high cost, associated difficulties to test things in operating conditions and limited maintainability during operation (Gonzales, 2000). Having such a chaotic environment risk management studies should be the essential part of most aerospace projects.

There are six major steps in risk management process (Fairly, 1994);

- Risk identification
- Risk Analysis
- Risk Planning
- Risk Tracking
- Risk Control
- Documenting and Communicating Risk

For successful risk management plan, the steps given should be completed with all of its duties as it is seen in Fig 3-1. Each step defined in the Figure 3-1 will be described briefly in the following parts.

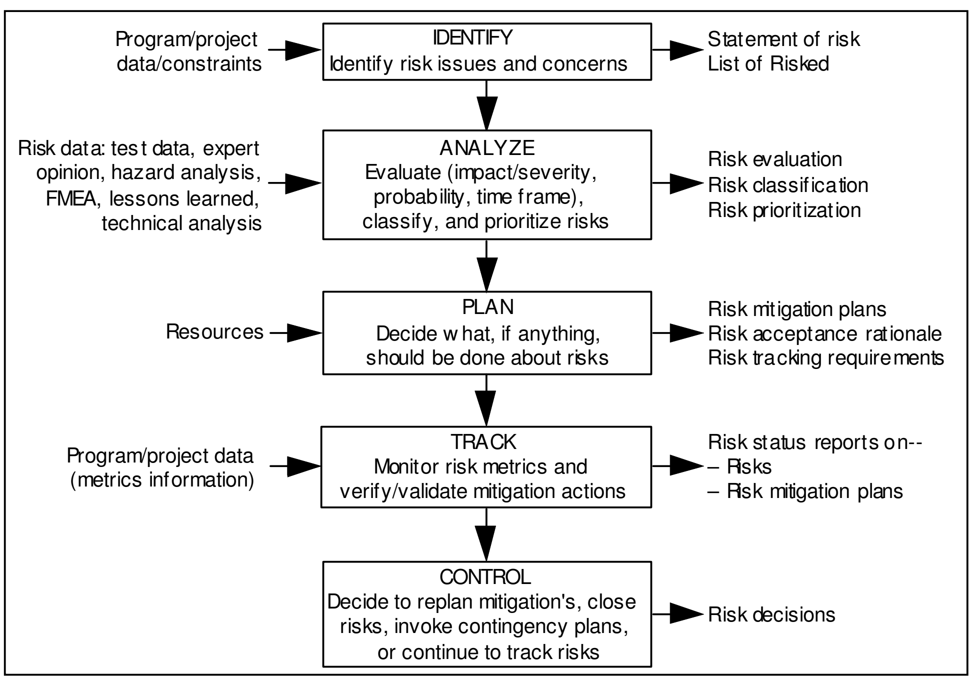

Figure 3-1 Risk management process (Greenfield, 1998)

Although in Fig 3-1 it is shown that risk management process starts with risk identification and ends with control, it should be noted that risk management is an iterative process. As it is shown in Fig 3-2, it has no end and it goes on as long as the projects go on.

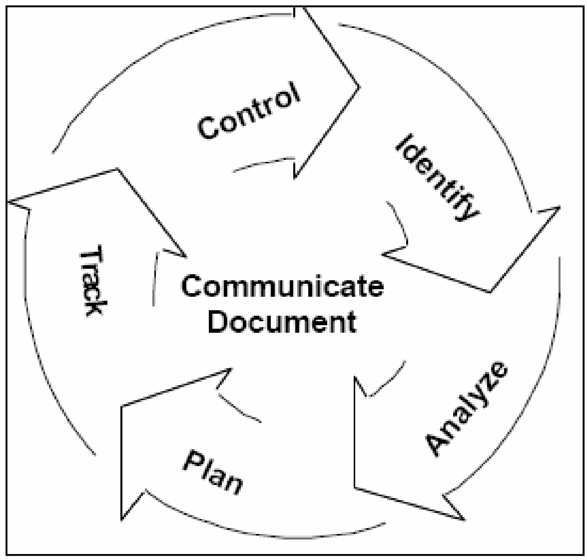

Figure 3-2 Risk Management Life Cycle (Adapted from Greenfield, 2001)

3.2 RISK MANAGEMENT PROCESS

3.2.1 Risk Identification

Risk identification involves discussing and deciding which risks are likely to affect the project and determining the characteristics of each. (EUROCONTROL, 2001) Risk identification is an important stage for further evaluation and management steps, and it is the most time consuming process. Risk identification can be carried out by using various methods such as (Carter et al., 1996; Tweeds, 1996):

- Use of experienced management
- Use of experts in departments
- Standard questionnaires and checklists
- Structured or semi-structured interviews
- Brainstorming sessions

During risk identification process each risk should be identified in terms of both the undesirable event that the risk presents and the consequences of that risk. The primary inputs of risk identification process are previous analysis, historical data, expert interviews, test data, analysis of work breakdown structure, analysis of resources etc. The primary output of risk identification process is a definition of each risk (NASA, 2002). Risk identification process needs to be an up to date approach and it should last to the end of the project. This approach will help to develop more realistic result at the end of projects.

3.2.2 Risk Analysis

Risk analysis 'involves estimating the likelihood and the consequences of each risk and timeframe in which action must be taken on an identified risk to avoid dangerous positions' (NASA, 2002, p. 3). The main purpose of risk analysis is to minimize the expected loss. Risk analysis creates a platform to make risk management decisions (Suh & Han, 2002). Risk analysis methods are based on two main approaches; quantitative and qualitative. The quantitative methods develop a level of risk for each hazard. The probability of each level can be evaluated by many techniques generally known as Probabilistic Risk Analysis methods. Qualitative methods explain risks in terms of descriptive variables based on knowledge and judgement of decision makers. They include scenario analysis, risk ranking, questionnaires etc (Suh & Han, 2002).

Quantitative methods and qualitative methods have different strengths and weaknesses as presented in Table 3-1. These advantages and disadvantages should be known whether a quantitative or qualitative method is applied.

Table 3-1 Advantages and Disadvantages of Quantitative & Qualitative Risk Methods (Adapted from Suh & Han, 2002)

	Quantitative methods	**Qualitative methods**
Advantages	Applicability to all assets	Simple Risk Calculation
	Mathematical Foundation	Usefulness when asset value is unknowable
		Less Time Consuming
Disadvantages	Time consuming	Subjective Results
	Inappropriateness of general statistics	Coarse granularity

The choice of risk analysis technique generally depends on the size, type and general nature of the identified problem, 'the amount and reliability of available data' and 'the nature of the required output' (Raftery, 1994, p.72).

In analysing risks, the main questions that have to be asked are;

- How likely is it for this risk to occur?
- How soon do we need to act on this risk?
- How does this risk compare with other risks?

3.2.2.1 Risk Ranking

It does not matter whether some input come from a probabilistic risk analysis methods or any other qualitative approach, each type of identified risks must be ranked in order to estimate the severity of the risk. In other words, any risk analysis should involve the estimation of the likelihood and the consequences of each risk and timeframe in which action must be taken on an identified risk to avoid dangerous positions. Likelihood is the probability that an identified risk event will occur. Likelihood categories can be classified as likely to occur (very high), probably will occur (high), may occur (moderate), unlikely to occur (low), or improbable (very low). Consequence of a risk is an assessment of the worst credible potential result of that risk. Consequences can be assessed with respect to its technical, schedule and cost consequences (NASA, 2002).

In Figure 3-3, the classification to define the level of each risk's likelihood is given. As it is seen there are five levels to define the likelihood/ probability for each risk identified; Very Low, High, Moderate, High and Very High.

What is the Likelihood of This Risk?		
LEVEL	**PROBABILITY**	**DESCRIPTION**
5	VERY HIGH	Continously Experienced (Frequent)
4	HIGH	Will Occur Frequently (Probable)
3	MODERATE	Will Occur Several Times (Occasional)
2	LOW	Unlikely, But Can Reasonably Expected To Occur (Remote)
1	VERY LOW	Unlikely To Occur, But Possible (Improbable)

Figure 3-3 Likelihood of the risk (Adapted From Greenfield, 2001)

In Figure 3-4 the classification to define the magnitude of each risk's impact/ consequence is given. This consequence can be determined by taking into consideration three criteria; technical, schedule, and cost. This classification depends on the type of risks. It is not obligatory to determine the level of consequence by evaluating all three criteria. It is possible to evaluate it with respect to at least one criterion. The specifications for schedule and cost should be defined with respect to each project. However, the specifications for technical evaluation can be used for every project.

What is the Magnitude of Impact of This Risk?					
LEVEL	**1**	**2**	**3**	**4**	**5**
OPERATIONAL/ TECHNICAL	Minimal or No Impact	Mod. Reduction Same Approach Retained	Mod. Reduction but Workaround e Available	Maj Reduction but Workaround e Available	Unaceptable/ No Alternatives Exist
SCHEDULE	Minimal or No Impact	Additional Activities Required	Milestone Slip of <1 month	Critical Milestone Slip of >1 month	Can Not Acieve Milestone
COST	Minimal or No Impact	Budget Increase Between xxx	Budget Increase Between xxx	Budget Increase Between xxx	Budget Increase Between xxx

Figure 3-4 Magnitude of Impact/Consequence (Adapted From Greenfield, 2001)

To rank the risks, the results of the probability/ likelihood of an event occurring and the consequences/ consequences of the event should be taken into consideration. Risk matrix is a practical solution to evaluate risk ranking. As it is seen in Fig. 3-5, it is used to rank the risk by taking into account the likelihood and consequences of the risk. Risk matrix ends with a qualitative result such as High, Medium and Low Risk. The primary input of risk matrix may come from expert opinions, lessons learned data, test data, technical analysis, PRA, etc. The primary outputs of risk analysis are 'clear estimations of the consequences of the risk and the likelihood of the risk's occurrence' (NASA, 2002, p. 8). As it is seen there are three different colour codes to identify the severity of each risk. They can be classified as Low Risk, Medium Risk, and High Risk. As qualified by Greenfield;

Low Risk 'has little or no potential for decrease in performance, increase in cost or change in schedule'.

Medium Risk 'may cause some decrease in performance, increase in cost or change in schedule'. But this can be handled by additional action.

High Risk may cause 'major reduction in performance, increase in cost and change in schedule'. Significant action will be needed to handle risk. (Greenfield, 2001 p.60)

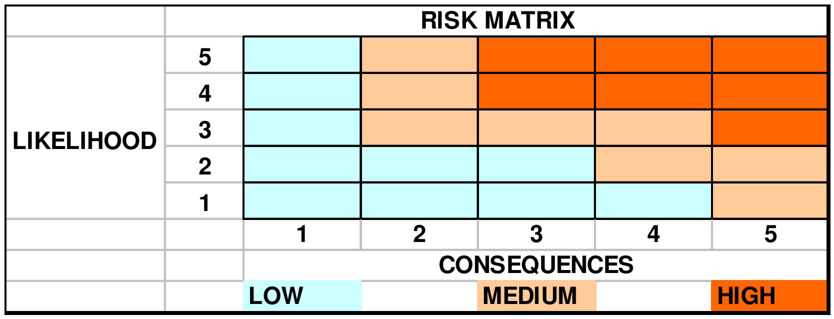

Figure 3-5 Risk matrix (Adapted From Grienfield, 2001)

If a more detailed risk matrix is needed, then the classification may be presented in a more detailed manner as seen at Figure 3-6.

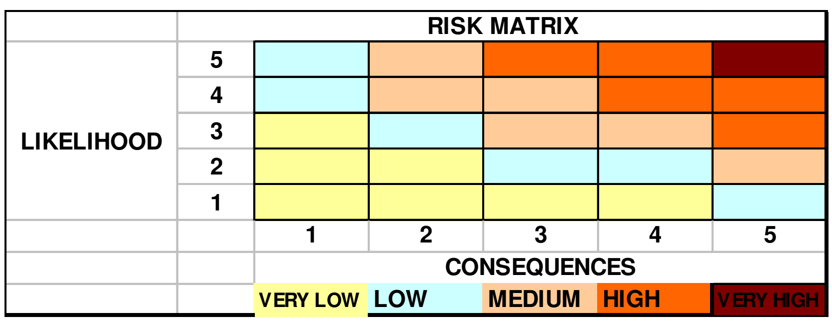

Figure 3-6 Risk matrix (The Aerospace Institute, 2003)

The findings of the risk matrix are to be evaluated within the flow chart presented in Figure 3-7. That is, at this stage, it is seen that for each risk ranked by the risk matrix, a question can be asked; if this risk is acceptable or not? The answer to this question is very important for the risk management process. If the risk is High Level or somewhere between High and Medium Level, then it would mean that the risk is unacceptable and in this case a different approach is required. Risk mitigation, avoidance or transfer plans should be prepared. Naturally the risk levels should be evaluated once more with the new position of each critical risk. If the risk is Low Level or somewhere between Medium and Low Level then sometimes this risk item may be accepted. The acceptance depends on the risk likelihood or severity of consequence and the possible mitigation scenarios. Sometimes it may be better in terms of schedule and cost to operate with the risk instead of preparing risk mitigations scenarios and planning and tracking activities. That is, it means that there will be no further investigation on this risk item any more.

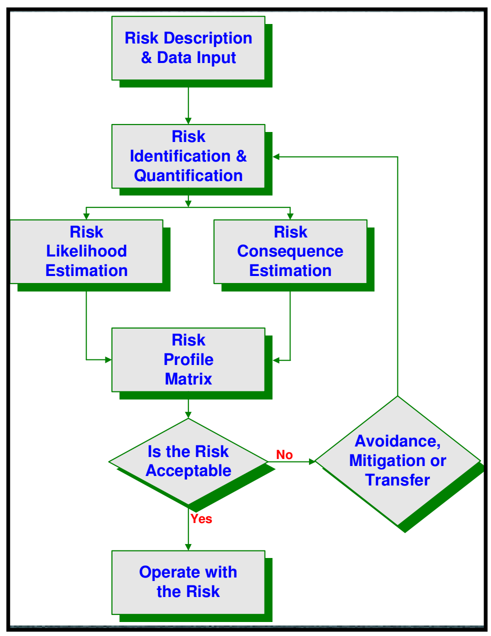

Figure 3-7 Risk Assessment Process (De Giorgio, 2002)

3.2.2.2 Probabilistic Risk Analysis Methods

As it is stated, method of analysing risk may include qualitative approaches such as individual or expert judgment, or if possible quantitative approaches as probabilistic risk analysis methods. Probabilistic risk analysis methods evaluate the failure scenarios in a probabilistic way, identifying the risks and ranking the individual contributors. Probabilistic risk analysis methods ‘examine complex systems to assess the probabilities and consequences of different failure modes, with particular attention to the risk of catastrophic failure’ (Henley & Kumamoto, 1981 p.15). Probabilistic risk analysis can be performed to assure that an existing system is 'safe enough', to set priorities among a set of possible risk management options, or to validate a proposed engineering system design (Cornel & Regal, 1997 p. 160). These probabilistic methods can be counted as Probabilistic Risk Assessment (PRA), Fault Tree Analysis (FTA), Failure Modes and Effects Analysis (FMEA) or Reliability Block Diagram etc.

Since it was not possible to obtain statistical and historical data, in practice the statistical analysis could not be performed. However, risk assessment does not have to be based on probabilistic analysis. The experiences, knowledge, judgement shared by the experts are at least valuable as the historical and statistical data itself (Heller, 2006). Therefore a qualitative but systematic approach on risk assessment can be performed by the help of other techniques in the literature.

However, to serve as reference for the follow up work, a concise summary of PRA methods are presented in Appendix A. It will be a basis for further studies.

3.2.2.3 Multi-criteria decision making (MCDM)

Multi-Criteria Decision Making (MCDM) is an important technique, which makes the experts’ knowledge more clear and makes it more concrete. This strengthens the risk management process for the purpose of making critical risk decisions. Decision making techniques are ideal for use in the early stages of risk assessment process. It creates a platform to determine the need for more insensitive scientific risk analysis (Heller, 2006).

Analytic Hierarchy Process (AHP) is one of the most important multi-criteria decision technique developed by Thomas Saaty, and has been widely used for over 20 years. This technique is very helpful to assess risks when the historical and statistical data are not available (Macharis et. al., 2004).

3.2.2.3.1 Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is a very helpful aid in risk analysis process since it provides easier decision making in multi-criteria and multi-factor analysis environment. It enables to organize the problems in hierarchical structures which allow thinking about them one or two at a time. By this way, it avoids the possible biases that come out when the analyst 'compares data sets which may be related subject wise but not situational' (Heller, 2006, p.59).

AHP is a problem-solving framework, which organizes the basic rationality by breaking down a problem into its smaller parts and then calls for only simple comparison judgements to develop priorities in each hierarchy. AHP is very useful when number of people participate in judgement of a problem (Saaty, 1986). AHP combines qualitative and quantitative factors in the overall evaluation of alternatives (Student Peer Evaluations, 1995). This section provides an introduction to AHP with an emphasis on the presentation of the general methodology.

AHP is based on three principles; construction of hierarchy, priority setting, and consistency check (Macharis et. al., 2004).

- **Construction of the hierarchy** is mainly achieved by 'working downward from the main goal in the top level criteria bearing on the goal in the second level and followed by sub-criteria in the third level and may go on until the most particular and definite level is achieved' (Saaty, 1986, p.841). The design of the hierarchy phase is based on the knowledge and experience of the participants.

In Figure 3-8, a simple hierarchy model is given. As it is seen on the top of the hierarchy, at Level 1, the overall main objective or goal of the multifactor problem is defined. Then the selection criteria to evaluate the problem are identified at Level 2. At the third level, the decision alternatives from which the choice is made are presented. Although 3 Level Hierarchy is shown in Fig 3-8, the number of levels in the hierarchy depends on the complexity of the problem.

In Fig 3-9 the same logic is developed for risk assessment with AHP. The main aim can be defined as risk assessment or risk ranking. As it is seen in the figure, the criteria to reach the aim can be defined as likelihood/probability and the impact/ consequence of the risk. The alternatives can be considered as several risks defined at the end of risk identification process. This hierarchy creates a platform to compare the (n) number of risks with respect to C1 Likelihood, and C2 Consequence/Impact respectively.

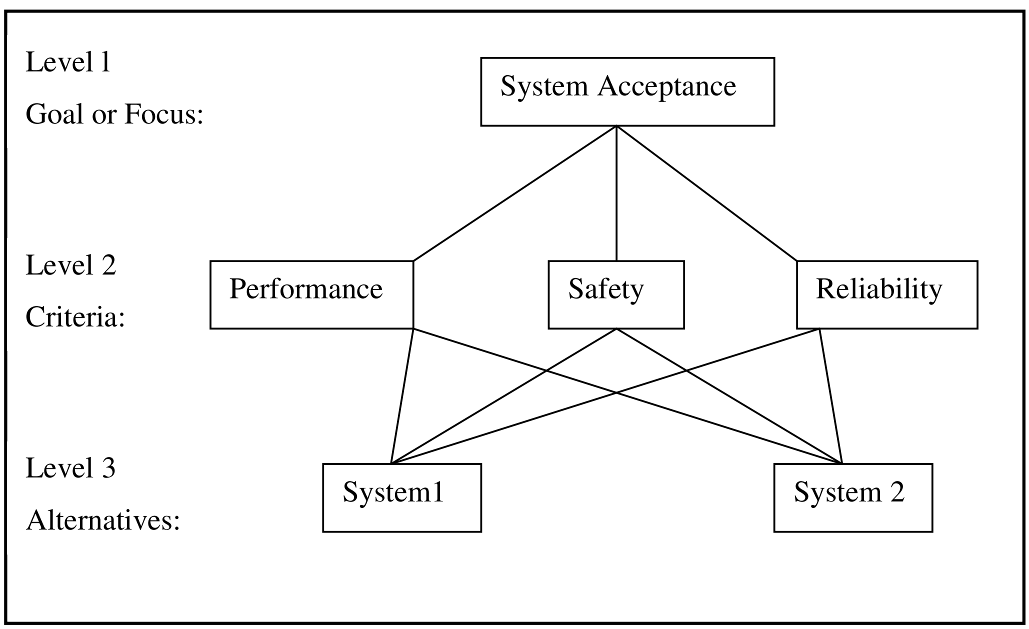

Figure 3-8 Hierarchy for AHP (Adapted from Saaty, 1986)

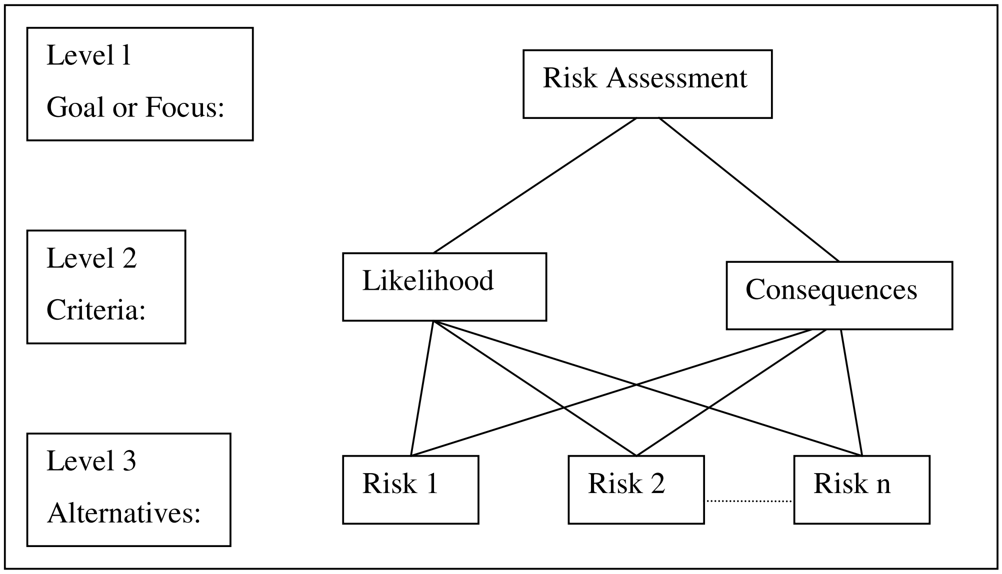

Figure 3-9 Hierarchy for risk assessment process with AHP

- **Priority Setting:** 'The relative priority given to each element in the hierarchy is determined by comparing pair-wise the contribution of each element at a lower level in terms of the criteria (or elements) with which a causal relationship exists' (Macharis et. al., 2004 p.309). In other words, in this phase the relative importance of each alternative with respect to the criterion in the level above it is determined (Heller, 2006).

The evaluation phase starts after designing all the hierarchy. In this phase, each alternative is compared with all other alternatives by the help of ranking score system at Table 3-2. In this table, as it is seen, intensity of relative importance has a score from 1 to 9 and each value has different importance. By this scale participant can decide which alternative is more important and by how much.

As an example, in Table 3-3, the logic of this evaluation process is given for the hierarchy at Fig 3-9. This process is repeated for all combinations of alternatives in the hierarchy. This results in a risk matrix as shown at Table 3-4, AHP Pair-wise Comparison Matrix.

Table 3-2 Scale of Relative Importance (Saaty, 1986)

Intensity of Relative Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective.
3	Moderate importance of one over another	Experience and judgment slightly favor one activity over another.
5	Essential or strong importance	Experience and judgment strongly favor one activity over another.
7	Demonstrated importance	An activity is strongly favored and its dominance is demonstrated in practice.
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation.
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed.
Reciprocals of above nonzero numbers	If an activity has one of the above numbers assigned to it when compared with a second activity, then the second activity has the reciprocal value when compared to the first.	
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining *n* numerical values to span the matrix.

Table 3-3 Intensity of Relative Importance for Fig 3-2

SCORE	DESCRIPTION
1	R1 has equal importance with R2 with respect to C1.
3	R1 has slightly more importance than R2 with respect to C1.
5	R1 has essentially more importance than R2 with respect to C1.
7	R1 has a lot more importance than R2 with respect to C1.
9	R1 has extreme importance and totally dominates R2 with respect to C1.
1/3	R2 has slightly more importance than R1 with respect to C1.
1/5	R2 has essentially more importance than R1 with respect to C1.
1/7	R2 has a lot more importance than R1 with respect to C1.
1/9	R2 totally dominates R1 with respect to C1.

Each element r_{iL} in the upper triangular matrix expresses the importance of intensity of an alternative r_i with respect to alternative r_L. Consequently, each element in the lower triangle of the matrix is the reciprocal of the upper triangle. ($r_{iL} = 1/ r_{Li}$) The value of each element should be assigned on expert opinion and judgement. The elements r_{iL} should be updated when better information becomes available through hard data or new expert judgement (Sadiq et al. 2004).

Table 3-4 Pair-wise Comparison of Elements in the AHP (Adapted from Macharis et. al., 2004)

C_i	r_1		r_L		r_n
r_1	1				
		[1]			
r_i			$Pc(r_i, r_L)$		
				[1]	
r_n					1

To calculate 'the relative weights for each alternatives in relation to the characteristic on which they are compared, eigenvector technique is used' (Gupta & Dey 2001 p.56). Formally, the relative priorities (or ''weight'') are given by the right eigenvector (W) corresponding to the highest eigenvalue (λ_{max}). The pair-wise comparison matrix is represented by the letter R. The standard element, 'Pc (r_i, r_L), represents the intensity of the preference with respect to a specific criterion of the row element (r_i) over the column element (r_L)' (Macharis et. al., 2004 p.309).

$$\mathbf{W= (w_1, w_2, ..., w_n)} \qquad \textbf{(3-1)}$$

$$\mathbf{R . W = \lambda_{max} . W} \qquad \textbf{(3-2)}$$

In case the pair-wise comparisons are completely consistent, the matrix R has rank 1 and $\mathbf{\lambda_{max} = n}$. In that case, weights can be obtained by normalizing any of the rows or columns of R. This process starts at the top of the hierarchy. The relative importance of each element in the hierarchy with respect to the criterion in the level above it is determined. This is achieved by averaging over normalized columns in the matrix. The results are then prioritised throughout the model using a weighting and adding process. As a result, the overall relative priority of the lowest level elements is obtained. The overall relative priority represents a synthesis of the local priorities and reflects the perspectives of the various people involved in evaluation (Macharis et. al., 2004; Heller, 2006).

When the number of the criteria and the alternatives increases, the complexity level of the evaluations also increases. Under these circumstances, some software tool can be used to make the calculations simpler. Expert Choice is one of these programs that aids in the evaluation of the overall priority of the alternatives. It is a decision making program which can be used for risk management as well as strategic planning, resource allocation, vendor selection etc. The Trial Version of Expert Choice can be accessed from its web site and downloaded for 15 days when it is necessary (Expert Choice, 2005).

Summarizing, the AHP process is given as a flow diagram at Figure 3-10. As described, the design phase is followed by the evaluation phase. The output of the evaluation phase is the ranking of each alternative with respect to several criteria adapted. When it is used in risk assessment process, the output will be the ranking of each risk from the most severe one to the least severe.

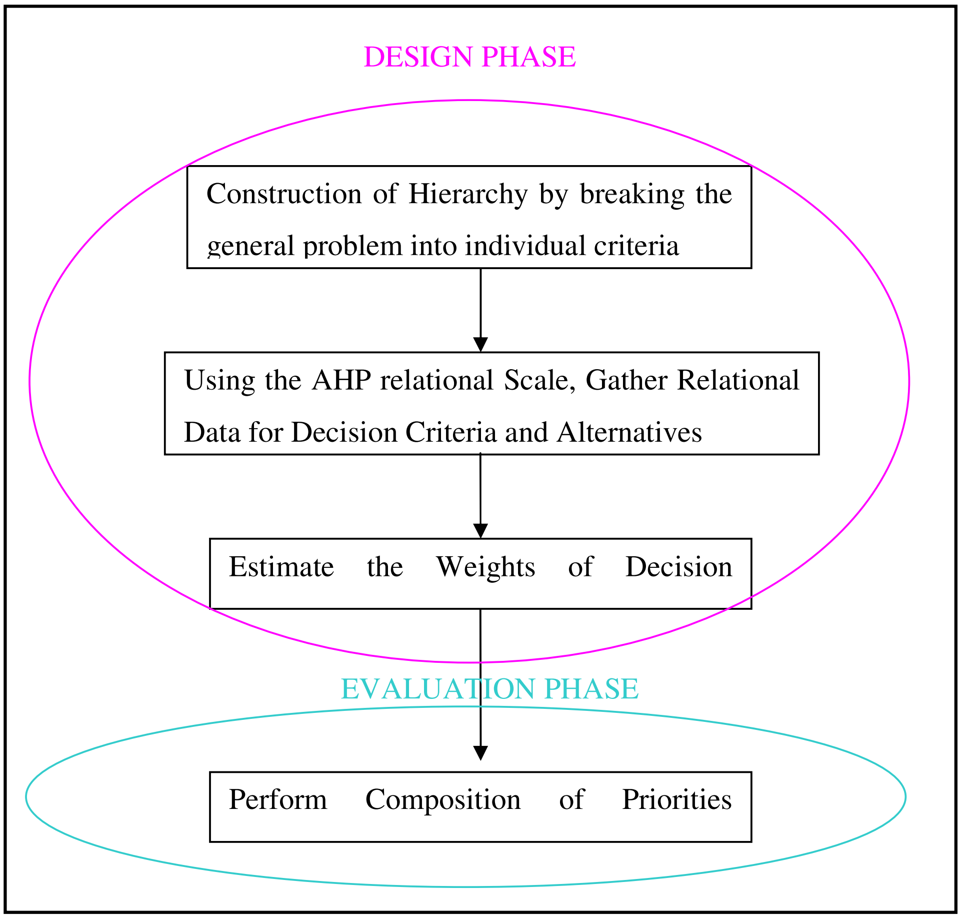

Figure 3-10 Flow Diagram of AHP Process

- **Consistency Check:** When the comparison is made by the decision maker, a number of comparisons can be redundant. Comparisons can be inconsistent in the sense that if Alternative 1 (A1) is considered more important than Alternative 2

(A2), and Alternative 2 (A2) is more important than Alternative 3 (A3), then A1 should be more important than A3. If, however, the decision maker rates A3 as more important than A1, the comparisons are inconsistent and the user should redo the comparison matrix (Finnie &Wittig, 1999). Therefore, in case there is inconsistency in the pair-wise comparison matrices λmax is no more equal to n. The deviation, (λ_{max} - n), is used as a measure for inconsistency. Consistency index (CI) is calculated as in Equation 3-3.

CI= (λ_{max} – n) / (n-1) **(3-3)**

The random Consistency Index (C1*) corresponds to the degree of consistency that automatically arises when completing at random reciprocal matrices (as shown in Table 3-5) with the values on the 1–9 scale.

Table 3-5 Random Consistency Indices (Saaty, 1988)

r	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
C1*	**0.00**	**0.00**	**0.58**	**0.90**	**1.12**	**1.24**	**1.32**	**1.41**	**1.45**	**1.49**

Consistency ratio, is calculated as the ratio of the consistency index (CI) and the random consistency index (C1*)

CR= CI / C1* **(3-4)**

According to Saaty, AHP has some tolerance for inconsistency and small consistency ratios less than 0.1 do not drastically affect the ratings. The user has the option of revisiting the comparison matrix if desired (Student Peer Evaluations, 1995).

When the hierarchy is too complex and there are too many participants this inconsistency calculation will be trouble for the decision maker. However, as long as the answers given by the participants are checked in a general sense, the more detailed inconsistency calculation can be made by the software tools, as Expert Choice. If the consistency ratio is more than 0.1, then the participants should revisit the matrix.

The results with inconsistencies less than 0.1 are a great aid for the decision makers, since the output is the ranking of alternatives from the most important ones to the less important ones with respect to the criteria defined. Summarizing, decision making in multi-criteria and multi-factor analysis environment can be enabled by the help of AHP method.

3.2.3 Risk Planning

Risk planning is the process of developing and documenting organized, comprehensive and interactive strategy and methods for the assessed risks. Risk planning concept includes the following questions;

- For which risk should the preventive actions be taken first?
- What can we do to prevent it from going wrong or at least reduce the probability or severity of the consequences?
- Who should be assigned to take these preventive actions?

Risk planning concept should involve mitigation scenarios, or if some risks are acceptable, it should define the accept criteria which should be documented, tested. Besides these, a successful plan should include to track survey or watch trends and behaviour of risk indicators over time. The basic inputs of risk planning come from the risk identification and risk analysis processes (NASA, 2002).

3.2.4 Risk Tracking

Risk tracking is an important process to measure the progress of the risk management program. Risk tracking consist of collecting, updating, compiling, organizing and analysing risk data and reporting risk trends. This will help to determine whether particular risks are diminishing, staying the same or increasing over time.

Risk tracking concept includes the following questions;

- Are risk mitigation actions effectively mitigating the risks?
- Is the overall risk for the program increasing or decreasing? If it is decreasing is it decreasing to the maximum practicable extend?

Tracking of a particular risk requires knowledge of its data elements, applicable mitigation plan, resources of available for mitigation etc. The major output of risk tracking are risk status reports. (NASA, 2002)

3.2.5 Risk Control

Risk control asks questions for the overall condition of each risk identified during the project. It should include the assessment of risk mitigations and their results, the reached point of each risk, the accepted risks and the accept criteria, the closed risks etc. During this process the following questions should be asked (NASA, 2002);

- Which risks still need research?
- Which risk mitigation scenarios still need research?
- Which risks can be accepted and formally closed?

3.2.6 Documenting and Communicating Risk

The knowledge created during the risk management process is extremely valuable. It involves a long process, which is full of experience. Making this knowledge open, clear, and accessible can only be handled by a systematic documentation and communication approach. Moreover any knowledge developed without sharing with all related people will not be valuable enough; therefore it has to be shared by all related people. Successful risk communication allows information to be exchanged within and between all related project levels. By this way, all risks and the mitigation plans will be understood by project members. Moreover, today every organization should understand and implement “Lessons Learned Approach” in every project. Lessons learned from the previous risk management applications will be a great input for the success of future projects. This approach should be developed for every risk management study in aerospace industry. This can be achieved by effective documentation and communication.

The documentation of risk management process should be standardized, in a logical format, which will lead to an easy and effective risk management process. Moreover it will enable the project members to examine the previous projects’ risk management plans in a more structured way.

CHAPTER 4

4 APPLICATION OF RISK MANAGEMENT PROCESS IN INSTRUMENT LANDING SYSTEM (ILS) RADIO WAVE PROPAGATION

4.1 AN OVERVIEW TO INSTRUMENT LANDING SYSTEM

Instrument Landing System (ILS) was an impact in aviation industry searching ways to deal with foggy and stormy weather. The ILS is one of the main international, ICAO approved, precision landing system, which consists of a localizer facility; a glide slope; and VHF (Very High Frequency) marker beacons. ILS provides vertical and horizontal navigation information during landing. In particular, the ILS is needed for landings under poor visibility conditions such as foggy and stormy weather (DoD & DoT, 2003).

ILS ground station includes two transmitters called Localizer and Glide Path and three markers. Localizer operates between 108.11- 111.95 MHz (VHF) frequency band. It shows weather the plane is right or left to the imaginary lateral centre line. Glide path shows weather the plane is above or below the imaginary glide slope. Glide path operates between 329.15- 335 (Ultra High Frequency (UHF)) MHz frequency band. Three markers inform the pilot about the distance of the plane to the beginning to of the landing runway. They are, the outer marker located at 4-7 NM from the beginning of the runway, the middle marker located at 3500 feet distance from the beginning of the runway and the inner marker located at the 50 ft from the beginning of the runway. They both operate on 75MHz frequency (TSAA Department of Navigation, 2003).

ILS receiver in the airplane uses the received ILS signal to help the pilot to make a perfect landing in poor visibility conditions due to foggy and stormy weather. It provides landing guidance through a display unit as shown in Fig 4-1. The display shows how far the craft deviates from the vertical glide path and imaginary lateral centre line to the runway touch down point (Tang, 2005, p.7).

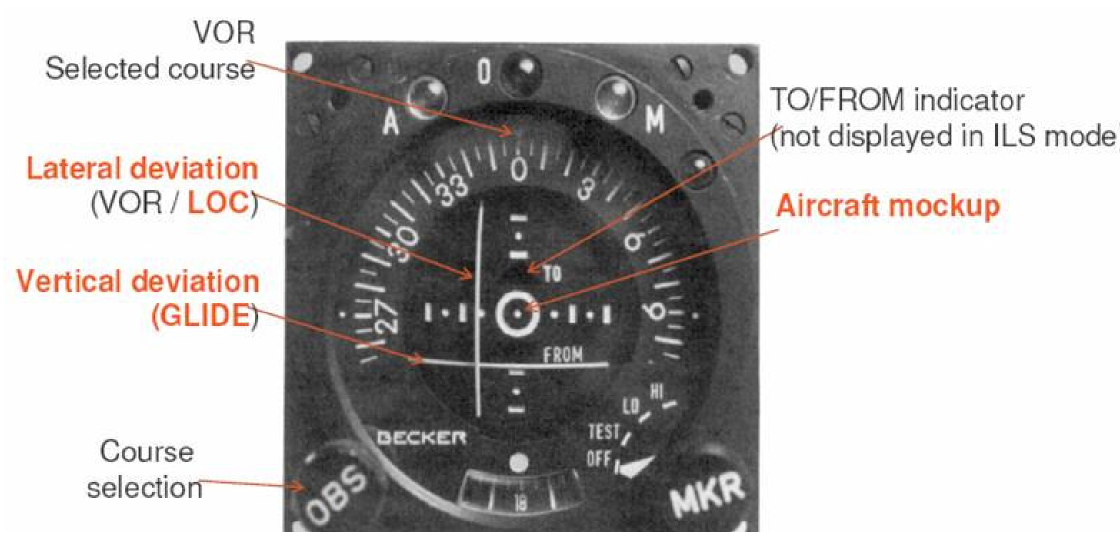

Figure 4-1 ILS CDI Display (Turkish Armed Forces (TAF), [n.d.])

More detailed information on the historical development of ILS and its operating principles are given in Appendix B.

4.2 INSTRUMENT LANDING SYSTEM RISK ASSESMENT RESULTS

4.2.1 Identification of ILS Risks

Although ILS was a boon to aviation world, with the huge increase in air traffic since the 1960s its weaknesses became more severe. This weakness creates problems in aviation safety in Turkey as well as the whole world.

Risk identification process was started with the interviews conducted with members from various divisions of Turkish Aviation Industry. A number of professionals from Turkish Civil Aviation Authority (TCAA), Turkish State Airports Authority (TSAA) and Turkish Armed Forces (TAF) were interviewed. The details of the interviewees are presented in Appendix C. Moreover, some formal data acquisition letters, which aimed to capture available fault data related to ILS were sent to TSAA. It was a great opportunity to investigate some ILS fault documents at Electronics Div., TSAA. Some historical data was accessed while performing the documentation survey. Although the quantity of the data was not enough to make a statistical risk analysis, it was such an important clue for the risk identification process. Risk identification is based on the results of interviews, investigations of checklists of problems occurred in the past, other case studies, technical papers and other key documents. The main questions asked to identify the ILS risks during the interviews are as follows:

- What can be the reasons that cause ILS RF communication go wrong?
- Is there any statistical or historical data kept or analysis done about these problems?
- What can be the main consequences of these derogation or interruption in ILS signal?

Based on the data and knowledge gained from experts, documentation survey and literature survey most common ILS risks are identified.

The most common source of interference comes from the effect of the utilization of frequency bands, adjacent to aeronautical bands, where radio systems are in operation using relatively high-power signals. An example is the use of the band 100-108 MHz by the FM broadcasting service, which may cause interference to ILS (Howde, 2000; Witzen, 2001). Today, increased demands of commercial users on the radio spectrum threaten levels of interference that cause serious problems in Turkish Aviation Industry. According to the historical data obtained from TSAA, there are some RF interferences due to FM radio stations in the past. These events forced the pilots to land without the help of ILS. It is obvious that they were lucky enough to land the aircraft safely, but it can be very serious when this occurs under low visibility conditions such as a very stormy weather. In Turkey it is stated that the main reason of such interference is the unfiltered transmitters of FM radio stations (Arslan M, 2006). When the radio interference takes place, the localizer receiver is not able to receive the right information but instead, sometimes pilots hear FM radio broadcast.

Another risky situation may be the interference caused by the machines operating in the factories located around the airports. It is stated that especially at the airports close to industrial estates, this event may occur. Although there is not any statistical data kept, theoretically this can be considered as a potential dangerous situation for the ILS signal interference. It is stated that the reasons of some of the interferences could not be found and operating machines around airports may be the possible reason of such interferences (Kinali C., 2006).

Multi-path interference may impose limitations upon the use of the ILS signal. Special consideration must be taken of terrain factors and dynamic factors such as taxiing aircraft that can cause multi-path interference (DoD & DoT, 2003). The derogation of the signal due to multi-path such as reflection of the signal by large objects (large hangars, terminals and even the tails of passenger jets on the ground) reflective to radio signals in the vicinity of the ILS is an important problem (Tang, 2005 p.7). There had been some signal derogations one of which was the signal derogation due to multi-path such as reflection of the signal by a buoy near Ataturk

Airport. Following the investigation of the environment around the airport was removed from that place; there was no more signal derogation (Arslan M., 2006).

It is said that the change of permeability of the ground can effect the electromagnetic wave propagation and cause ILS signal derogation. It is stated that changes in permeability of the ground due to conditions as the tracks, snow, and grass on the ground, etc. may create signal derogation. It is stated that the last ILS signal derogation happened because of the marsh around the Mus Airport (Arslan M., 2006).

Another factor is the introduction of new aeronautical systems that make use of the RF spectrum for communications, navigation and tactical operations. This requires that special consideration should be taken into by aviation experts to 'avoid mutual interference between aeronautical systems on board' (Witzen R., 2001, p.4). According to Yzb. Ozkaya A., the RF based systems that creates interference on ILS can be separated into two; first one is the systems that use the adjacent frequencies with the ILS such as the aircraft radio instrument, and the second is extremely powerful RF systems that suppress the signal of the ILS. It is declared that the most problematic area in the systems that use the same frequency band is the aircraft radio instrument. Aircraft radio instrument is operated in 118-137 MHz radio frequency band. Since it is stated that the ILS localizer operates in between 108.11- 111.95 MHz frequency band, and due to closer frequencies, there may be signal derogation. The powerful RF systems like RF jammer, are another risk item especially in military air vehicles. It is said that it is impossible to use ILS landing when RF jammer is in operation. It is declared that digital ILS display may disappear suddenly or the analogue ILS displays may become unstable when the RF jammer is operated. (Ozkaya A., 2006)

An interesting study made by Rakov & Uman, (2003) indicates that lightning have adverse affects on the ILS system. It is stated that there are indirect effects produced by deleterious voltages and currents induced within the aircraft by the lightning electric and magnetic fields. These include upset or damage to many aircraft electronic systems. According to statistics from 1971-1984, 20 percent of 851 reported strikes resulted in indirect effects and 6 of which were ILS interferences. Moreover from 1948 to 1974, 40 % of 245 recorded strikes have indirect effects on electronic instruments of aircraft in South Africa (Rakov & Uman, 2003). Although there is not any statistics or data for lightning effects on ILS at Turkish authorities, strike effects on ILS can be also counted as ILS RF risk.

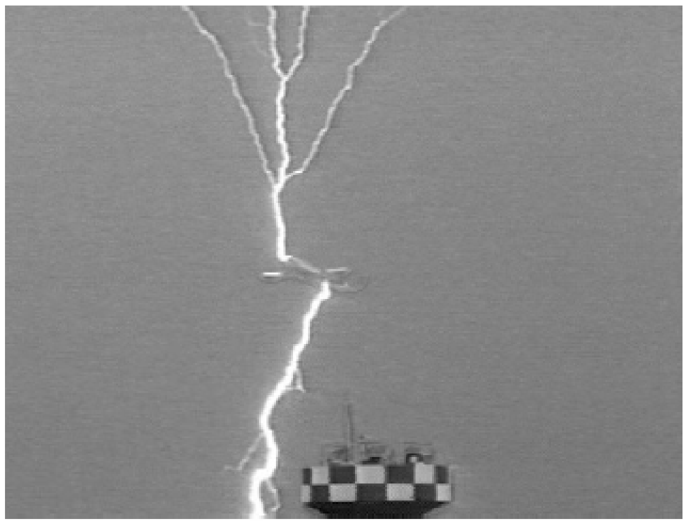

Figure 4-2 Video frame of a lightning strike to an aircraft (Rakov and Uman, 2003)

The systems on aircraft that operates within the similar RF band can be another risk item for the operation of ILS.

Summarizing, the following risk items were identified in light of these inputs;

1. EM Interference due to FM radio stations.
2. EM Interference due to machines operating at factories etc. around the airports
3. EM Interference due to multi-path such as reflection of the signal by large objects (large hangars, terminals and even the tails of passenger taxiing jets on the ground)

4. Derogation of the ILS signal due to the change of permeability of ground (by the tracks, the snow, grass on the ground)

5. EM Interference due to powerful systems on aircraft like RF jammer

6. EM Interference due to the other systems operating on adjacent RFs on the aircraft such as the aircraft radio instrument

7. Derogation of the ILS signal due to lightning during flight

4.2.2 Analysis of Identified ILS Risks

4.2.2.1 Risk Ranking

In this section each risk identified in previous section are qualitatively analysed with the aid of quantitative approach, named as risk ranking. In standard applications risk severity can be evaluated from reliability data obtained in previous and well-known similar applications. In this study, there is a lack of statistical or historical data, due to the missing experience in dealing with risk management activities in aerospace industry. Because of the lack in knowledge management activities the historical fault and failure data kept is not adequate for a detailed statistical analysis. However, instead of using historical data, there is 'knowledge' in Turkish Aviation Industry. The main idea is to translate this knowledge in to more concrete and tangible format by the help of risk management techniques in literature. This lack can be overcome by using expert experience from various organizations within Turkish Aviation Industry and some practical engineering considerations.

In this stage, qualitative assessment is performed by taking into account the likelihood of the identified risks and the magnitude of their consequences. Since the best way for assessing the severity of risks is to use matrices, the analysis were achieved with the use of risk matrix described in the Chapter 3 (Dallas, 2006). This analysis is completed with the participation of nine people from different divisions of Turkish Aviation Industry. The participants are selected with respect to their ILS relevance. They all have different backgrounds, different occupations and therefore different experience. Since the user perspective is as important as the technical experts' perspective, pilots having avionic systems experience were participated in this analysis. The detailed information about participants is presented in Table 4-1. The main questions asked in this analysis are;

- How likely does this risk occur?
- What will be the consequences if this risk occurs?

The participants were asked to think about the above questions for each risk and determine the level of each risk for its consequence and likelihood. The detailed information about this questionnaire-based analysis is presented in Appendix B. The answers of the participants for each risk event are presented in the tables, in the following section. The likelihood answers and the consequences answers were averaged and the result is presented on the risk matrix for each risk event.

Table 4-1 Properties of Participants

PARTICIPANTS	**OCUPATION**	**BACKGROUND**
PARTICIPANT 1	Director Of Flight Aids Division, TSAA	Electric Electronics Eng.
PARTICIPANT 2	ILS Systems Chief, Esenboga Airport, TSAA	Electronics Technician
PARTICIPANT 3	Director Of Avionics Department Helicopter 5th Maintenance Centre, Turkish Armed Forces (TAF)	Electric Electronics Eng.
PARTICIPANT 4	TUBITAK	Helicopter Pilot-Avionics
PARTICIPANT 5	Turkish Airlines (TA), A/C Pilot	A/C Pilot - Avionics

Table 4-1 Continuing

PARTICIPANT 6	TA, A/C Pilot	Helicopter Pilot, Flight Instructor
PARTICIPANT 7	TAF, Helicopter Pilot	Helicopter Pilot-Avionics- Cockpit Instrument Chief
PARTICIPANT 8	TAF, Helicopter Pilot	Helicopter Pilot, Flight Safety Officer
PARTICIPANT 9	Turkish Airforce, A/C Pilot	A/C Pilot

4.2.2.1.1 Risk Ranking Results

The first risk item; EM interference due to the signals of FM radio stations is analysed in Table 4-2. This event may be prevented, but strict control on FM radio stations is required. It is known that although there is regulation on FM radio stations, pilots still have problems with FM radio interference. It is obvious that when there is invisible flight condition and the only landing way is the ILS landing, any interference in the ILS signals may create trouble. Sometimes aircrews in aircraft equipped with receivers are unlikely to know the information displayed by their flight instruments is inaccurate (Wood, 2000). However, generally when such interference occurs, pilot hears FM radio broadcast. If this is the situation and there is inaccuracy, an alternative way for landing should be searched for with the aid of ATCT (Airport Traffic Control Tower). As it is seen in Figure 4-3, the FM radio interference is a *Medium Level Risk*.

Table 4-2 Risk Ranking for Risk Event 1

FM RADIO INTERFERENCE	LIKELIHOOD	CONSEQUENCES
PARTICIPANT 1	4	4
PARTICIPANT 2	3	3
PARTICIPANT 3	3	4
PARTICIPANT 4	2	4
PARTICIPANT 5	2	2
PARTICIPANT 6	4	3
PARTICIPANT 7	3	2
PARTICIPANT 8	4	3
PARTICIPANT 9	4	2
AVERAGE	3.22	3

RISK EVENT 1		EM interference due to FM radio stations				
LIKELIHOOD	5					
	4			L3.2, C3		
	3					
	2					
	1					
		1	2	3	4	5
		CONSEQUENCES				
		VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

Figure 4-3 Risk Matrix for Risk Event 1

The second risk item; RF interference due to machines around the airports is analysed in Table 4-2. The airports around industrial estates are under effect of this risk. Because the factories are dynamic environments, new machinery can be installed in these plants and when they are in operation, they can create electromagnetic field, which may cause interference in the ILS signal. Sometimes crews are unlikely to know the information displayed by their flight instruments is inaccurate. However, when this risk event occurs, generally there is noise on the system that they can hear, when this kind of interference happens. Again under this condition, pilot should check the accuracy of the ILS, and choose a plan with respect to this accuracy. This risk event is *Medium Level Risk* as it is seen at Figure 4-4.

Table 4-3 Risk Ranking for Risk Event 2

INTERFERENCE Due to MACHINES	**LIKELIHOOD**	**CONSEQUENCES**
PARTICIPANT 1	2	3
PARTICIPANT 2	2	3
PARTICIPANT 3	3	3
PARTICIPANT 4	3	3
PARTICIPANT 5	2	2
PARTICIPANT 6	3	2
PARTICIPANT 7	2	2
PARTICIPANT 8	2	2
PARTICIPANT 9	2	2
AVERAGE	2,333	2.555

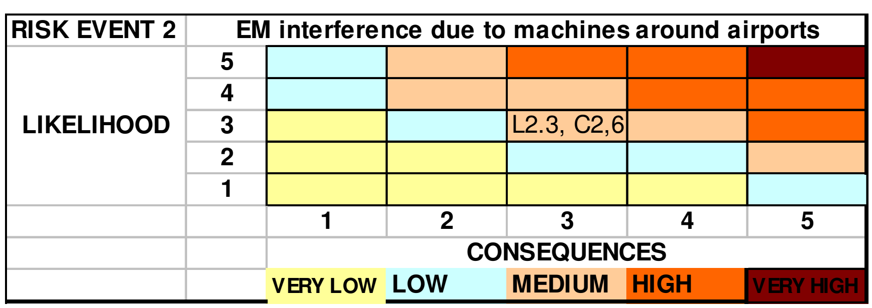

Figure 4-4 Risk matrix for Risk Event 2

The third risk item; RF interference due to multi-path such as reflection of the signal by large objects (large hangars, terminals and even the tails of passenger jets on the ground) is an important risk. This risk event has likelihood higher than mid level and high level consequence. The consequence of this risk may be very dangerous, because there is not any alert in the system like a noise or sound like in the other interference situations as the FM radio stations or effects of machines at factories create on ILS. Therefore the crews are unlikely to realize the information displayed by their flight instruments is inaccurate and therefore they will try to land with this inaccurate information. Therefore as it seen in Figure 4-5, it is *High Level* Risk.

Table 4-4 Risk Ranking for Risk Event 3

INTERFERENCE Due to MULTIPATH	**LIKELIHOOD**	**CONSEQUENCES**
PARTICIPANT 1	3	5
PARTICIPANT 2	4	4
PARTICIPANT 3	4	5
PARTICIPANT 4	2	4
PARTICIPANT 5	4	4
PARTICIPANT 6	4	4
PARTICIPANT 7	3	4
PARTICIPANT 8	2	4
PARTICIPANT 9	4	3
AVERAGE	3.333	4.111

RISK EVENT 3		EM interference due to multipath				
LIKELIHOOD	5					
	4					L3.3, C4,1
	3					
	2					
	1					
		1	2	3	4	5
		CONSEQUENCES				
		VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

Figure 4-5 Risk matrix for Risk Event 3

The fourth risk item RF interference due to change of permeability of earth is an interesting risk event. The permeability of the ground changes due to the natural effects like snow, or grass or even with the change on the shape as tracks of vehicles. The likelihood of this risk is ranked as 'very low' by the participants; however like the third risk event, this risk may create catastrophic results. Again when this risk event occurs, the crew will not be aware of any abnormal signs, alerts in the ILS and may again try to land with inaccurate information. Therefore as it is seen in Figure 4-6, this risk event is a Medium *Level Risk*.

Table 4-5 Risk Ranking for Risk Event 4

INTERFERENCE Due to CHANGE OF PERMEABILITY	**LIKELIHOOD**	**CONSEQUENCES**
PARTICIPANT 1	2	5
PARTICIPANT 2	3	5
PARTICIPANT 3	2	4
PARTICIPANT 4	1	4
PARTICIPANT 5	1	4
PARTICIPANT 6	1	4
PARTICIPANT 7	1	5
PARTICIPANT 8	2	5

Table 4-5 Continuing

PARTICIPANT 9	1	4
SUMMARY	1,566	4.444

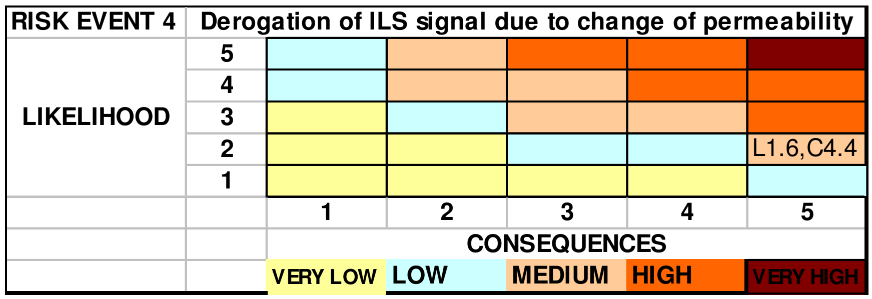

Figure 4-6 Risk matrix for Risk Event 4

Powerful RF based systems such as RF jammer is a critical risk event especially on military operations. When a powerful RF based system like RF jammer is needed there is no alternative approach to do, to prevent ILS from going out of order. According to Atinc M., when RF jammer is used the ILS display directly goes out of order. When this happens the consequence is extremely catastrophic. It is unacceptable and there is no alternative to do (Atinc M., 2006). However, the probability of using RF jammer and ILS together is extremely low. Therefore, as it is seen in Figure 4-7, this risk is a *Low Level Risk*.

Table 4-6 Risk Ranking for Risk Event 5

INTERFERENCE Due to POWERFUL SYSTEMS	LIKELIHOOD	CONSEQUENCES
PARTICIPANT 1	1	4
PARTICIPANT 2	1	3
PARTICIPANT 3	1	4

Table 4-6 Continuing

PARTICIPANT 4	1	4
PARTICIPANT 5	2	3
PARTICIPANT 6	1	3
PARTICIPANT 7	2	4
PARTICIPANT 8	1	4
PARTICIPANT 9	1	4
SUMMARY	1.222	3.667

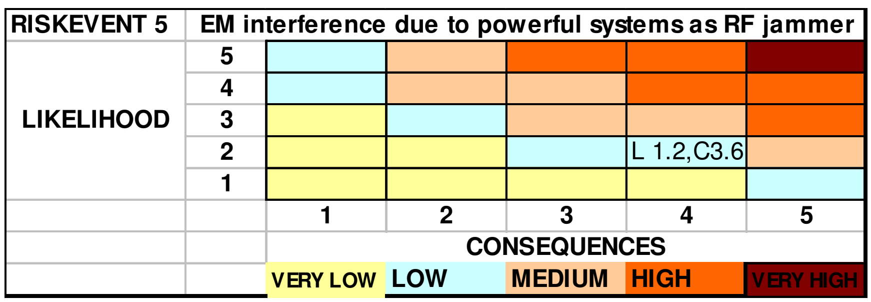

Figure 4-7 Risk matrix for Risk Event 5

It is concluded that, especially radio communication with control tower and pilot may cerate a direct effect on ILS in some airports. The main reason for this is the adjacent frequencies used for ILS and radio communication. Although there is alternative frequencies set for radio communication, Yzb. Ozkaya A. stated that generally the tower does not prefer to let the pilot to convert to this frequency because of the crowded air traffic. When the development of Turkish Aviation is taken in to consideration, it seems that it will be a more chaotic problem if frequency management is not studied for Turkish airports. Moreover there are many avionic systems that operate on aircrafts within adjacent frequencies, and they sometimes create interference problems. Although the EMI/EMC (Electromagnetic Interference/ Electromagnetic Compatibility) tests are performed for these avionic equipments, the pilots state that these problems are not eliminated. This risk is a Medium Level Risk as it is seen in Figure 4-8.

Table 4-7 Risk Ranking for Risk Event 6

INTERFERENCE Due to SYSTEMS operating at adjacent RFs	**LIKELIHOOD**	**CONSEQUENCES**
PARTICIPANT 1	2	2
PARTICIPANT 2	2	2
PARTICIPANT 3	4	2
PARTICIPANT 4	3	2
PARTICIPANT 5	4	3
PARTICIPANT 6	3	3
PARTICIPANT 7	4	2
PARTICIPANT 8	4	2
PARTICIPANT 9	2	4
SUMMARY	3.111	2.444

RISK EVENT 6	**Interference due to systems operating at adjacent RFs**					
LIKELIHOOD	**5**					
	4			L3.1, C2,4		
	3					
	2					
	1					
		1	**2**	**3**	**4**	**5**
		CONSEQUENCES				
		VERY LOW	**LOW**	**MEDIUM**	**HIGH**	**VERY HIGH**

Figure 4-8 Risk matrix for Risk Event 6

As it is stated, lightning on aircrafts has direct and indirect effects. The direct effects can be concluded as structural damages. The indirect effects are caused by deleterious voltages and currents induced within the aircraft by the lightning electric and magnetic fields. There is not any statistical study made for lightning effect in the Turkish literature. However, when the studies made by Rakov & Uman (2003) are taken into account, the 6 ILS interference events in the period between the years 1971-1984 caused by indirect lightning events tell that this has a mid level probability. But when the EMI/EMC procedures applied and the absence of any events are taken in to account the level of likelihood is low. However, it is obvious that the consequence of this risk may be extremely catastrophic. Therefore this risk is a *Medium Level Risk*.

Table 4-8 Risk Ranking for Risk Event 7

INTERFERENCE Due to LIGHTNING	**LIKELIHOOD**	**CONSEQUENCES**
PARTICIPANT 1	1	4
PARTICIPANT 2	1	5
PARTICIPANT 3	2	4
PARTICIPANT 4	1	4
PARTICIPANT 5	1	4
PARTICIPANT 6	1	4
PARTICIPANT 7	1	4
PARTICIPANT 8	1	4
PARTICIPANT 9	1	5
AVERAGE	1,111	4.222

RISK EVENT 7	Derogation of the ILS signal due to lightning					
LIKELIHOOD	5					
	4					
	3					
	2					L1.6,C4.4
	1					
		1	2	3	4	5
		CONSEQUENCES				
		VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

Figure 4-9 Risk matrix for Risk Event 7

Table 4-9 Overall Risk Ranking Matrix

RISK NO	RISK EVENTS	LIKELIHOOD	CONSEQUENCES	RISK LEVEL
1	EM interference due to FM radio stations	3.2	3	MEDIUM
2	EM interference due to machines	2.4	2.6	MEDIUM
3	EM interference due to multipath	3.3	4.1	HIGH
4	Derogation of ILS due to change of permeability	1.4	4.3	MEDIUM
5	EM interference due to RF jammer	1.2	3.6	LOW
6	EM interference due to systems with same RF band	3.1	2.4	MEDIUM
7	Derogation of the ILS signal due to lightning	1.1	4.2	MEDIUM

As it is seen in Table 4-9, reflection of the signals by large objects (large hangars, terminals and even the tails of passenger jets on the ground), in other words multi-path of ILS signals has High Risk level. Electromagnetic interference due to RF jammer has the low risk level. The other risks are determined as medium level by the participants. This phase of risk analysis revealed the general tendency of experts in ILS risk assessment process. However as it is stated, risk analysis is done to determine the levels of risk and to determine which risks needs an urgent action plan. At the end of the risk ranking process, the overall tendency is drawn; however a more detailed analysis is required to determine the importance of each risk. To determine the priority of each risk, a second analysis is performed with the help of Analytic Hierarchy Process (AHP) method. In the following section, the priorities of each risk are determined by the same participants.

4.2.2.2 Application of AHP

Following the development of the risk matrix, next step is a detailed study with the experts to make valuable contribution for a brainstorming session to review and evaluate previously qualitatively analyzed risks and to flush out the importance of each risk with respect to each other in a quantitative manner. This comparison study is very important since it is argued that, ‘relative judgements tend to be more accurate than absolute judgements’ (Forman & Gass, 2001 p.471). However before making a relative judgement, an absolute judgement process should be performed as done in this study. By this absolute study each risk factor were identified in terms of probability and consequences separately. After understanding each risk factor in terms of its probability and consequence separately, it is possible to compare two risks one at a time, and perform this for all possible combinations. As described in Chapter 3, AHP is a great method to obtain relative weights of each risk.

At first the hierarchy for the ILS case was developed. As it is known, the main objective is to find out the highest risk. The criteria to select the highest risk come from the definition of risk. As Conrow stated that, risk has two components such as ‘the probability of failing to achieve a particular outcome and the consequence of failing to achieve that outcome’ (Conrow, 2003, p.21). It is obvious that likelihood and consequences are two main criteria to select the more severe risks. Therefore two main criteria, Likelihood and Consequences, are defined in the second level of the hierarchy. The identified risks are constructed in the third level of the hierarchy as alternatives in order to select the highest risk.

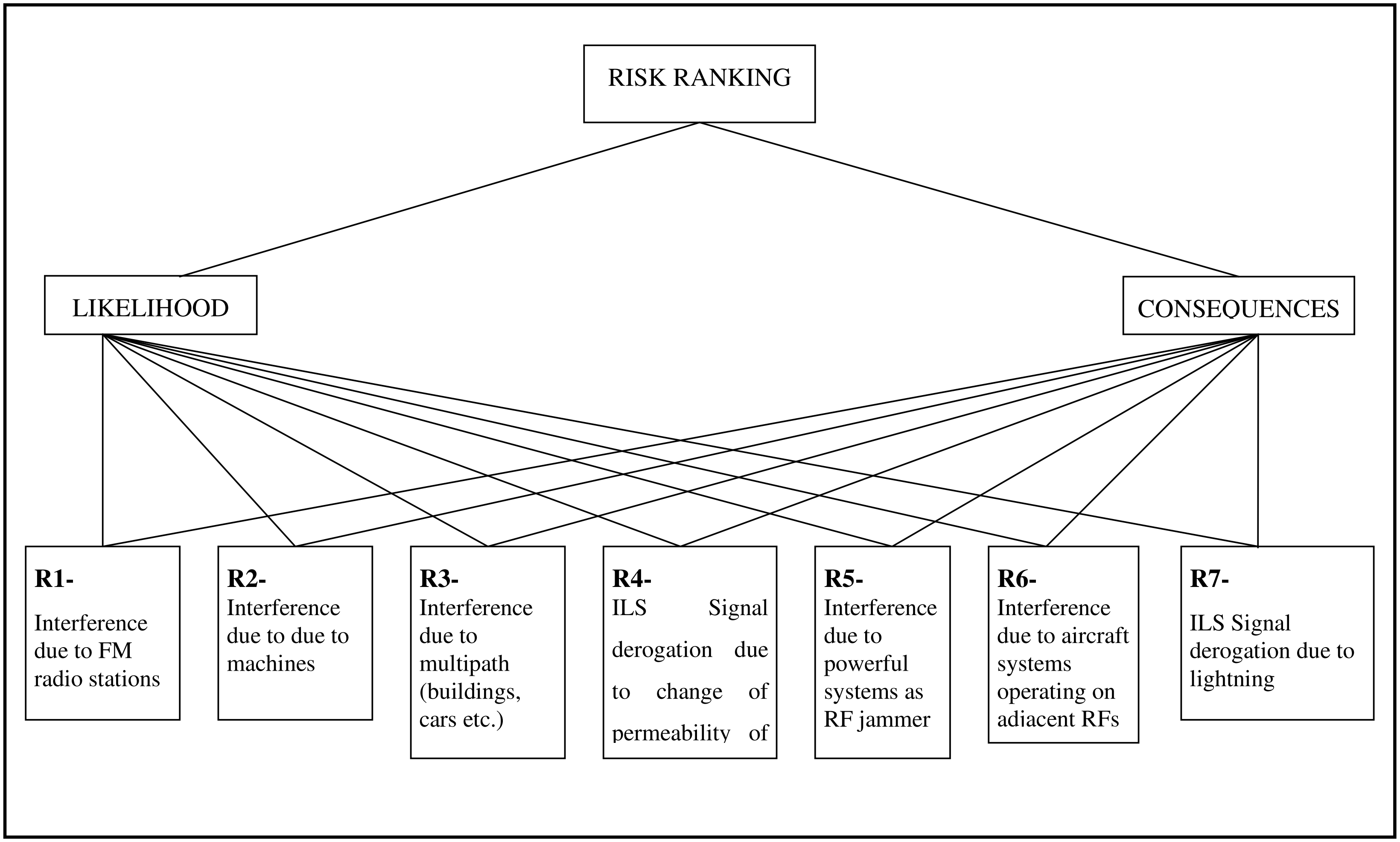

Figure 4-10 AHP Hierarchy for ILS RF Based Risk Analysis Approach

With the aid of the Table 3-2, Scale of the Relative Importance, the alternatives in other words, identified risks were compared by 9 participants from different organizations of Turkish Aviation Industry. The main criteria in participant selection are the relation of their occupation and background to ILS. As it is remembered, the properties of each participant are given in Table 4-1. The answers were resulted in 18 risk matrices corresponding to 9 participants. The matrices developed by each participant are checked in terms of any remarkable inconsistency. If there is, then the participant revisited the risk comparison matrix and considered the risks again. Each matrix developed by the answers of the participants is presented in the following sections.

After establishing the matrices without any remarkable inconsistency, the priorities of each risk with respect to likelihood and consequences are evaluated. Since the likelihood and consequences are the two main criteria that define risk, the weighting of likelihood and consequences are assumed as equal. Therefore, the overall priority is calculated by adding the results of each criterion. This evaluation is performed by the help of a professional decision making tool, Expert Choice Trial Version, which is based on the AHP method. The 2 risk matrices developed by each participant and the local (likelihood and consequences) and the overall priorities of each risk factor for these 2 matrices are obtained and presented separately for each participant in the following section. Moreover, the inconsistencies of the participants' answers are presented with the priority graphs. As it will be seen, the inconsistencies are less than 0.1 which is acceptable.

4.2.2.2.1 The AHP Results of the Participants

PARTICIPANT 1

Table 4-10 Participant 1 Relative Comparison Chart with Respect to Likelihood

Likelihood	R1	R2	R3	R4	R5	R6	R7
R1	1	3	2	6	9	7	8
R2	1/3	1	1/2	3	8	6	7
R3	1/2	2	1	4	9	7	8
R4	1/6	1/3	1/4	1	5	3	4
R5	1/9	1/8	1/9	1/5	1	1/4	1/2
R6	1/7	1/6	1/7	1/3	4	1	3
R7	1/8	1/7	1/8	1/4	1/2	2	1/3

Table 4-11 Participant 1 Relative Comparison Chart with respect to Consequences

Consequences	R1	R2	R3	R4	R5	R6	R7
R1	1	2	1/6	1/6	1/4	3	1/4
R2	1/2	1	1/7	1/7	1/5	2	1/5
R3	6	7	1	1	3	7	3
R4	6	7	1	1	3	7	3
R5	4	5	1/3	1/3	1	5	1
R6	1/3	1/2	1/7	1/7	1/5	1	1/5
R7	4	5	1/3	1/3	1	5	1

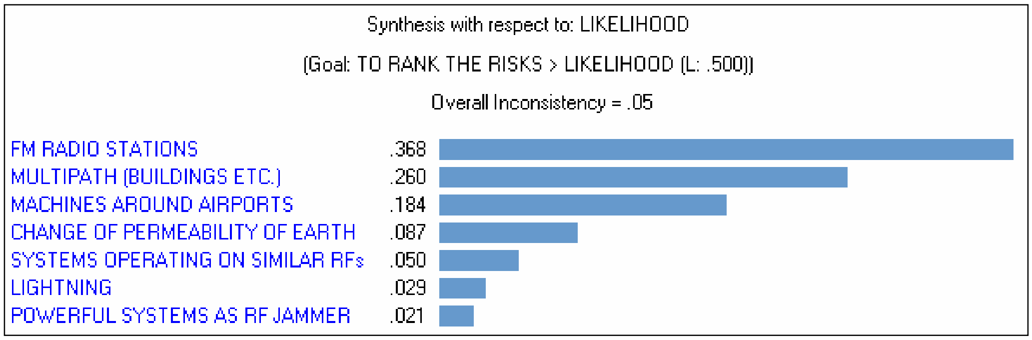

Figure 4-11 Participant 1 Risk Priority (Likelihood)

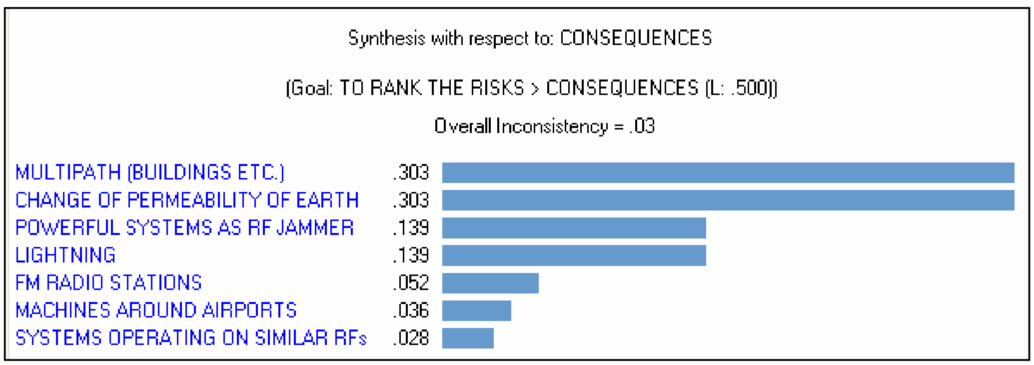

Figure 4-12 Participant 1 Risk Priority (Consequences)

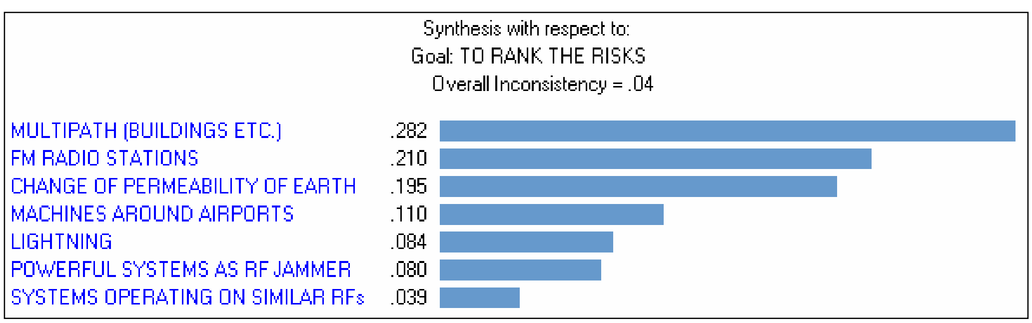

Figure 4-13 Participant 1 Overall Risk Priority

PARTICIPANT 2

Table 4-12 Participant 2 Relative Comparison Chart with Respect to Likelihood

Likelihood	R1	R2	R3	R4	R5	R6	R7
R1	1	2	1/2	5	7	5	6
R2	1/2	1	1/3	3	6	3	5
R3	2	3	1	6	9	6	8
R4	1/5	1/3	1/6	1	4	2	3
R5	1/7	1/6	1/9	1/4	1	1/4	1/2
R6	1/5	1/3	1/6	1/2	4	1	3
R7	1/6	1/5	1/8	1/3	2	1/3	1

Table 4-13 Participant 2 Relative Comparison Chart with respect to Consequences

Consequences	R1	R2	R3	R4	R5	R6	R7
R1	1	1	1/5	1/5	1/2	2	1/6
R2	1	1	1/5	1/5	1/2	2	1/6
R3	5	5	1	1	4	6	1/2
R4	5	5	1	1	4	6	1/2
R5	2	2	1/4	1/4	1	4	1/5
R6	1/2	1/2	1/6	1/6	1/4	1	1/7
R7	6	6	2	2	5	7	1

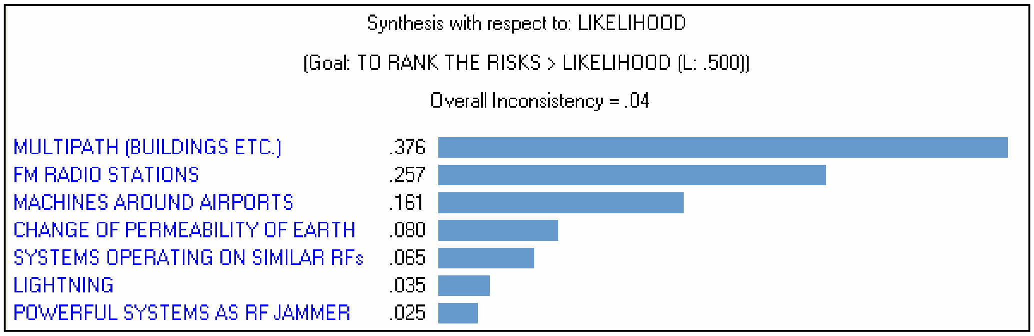

Figure 4-14 Participant 2 Risk Priority (Likelihood)

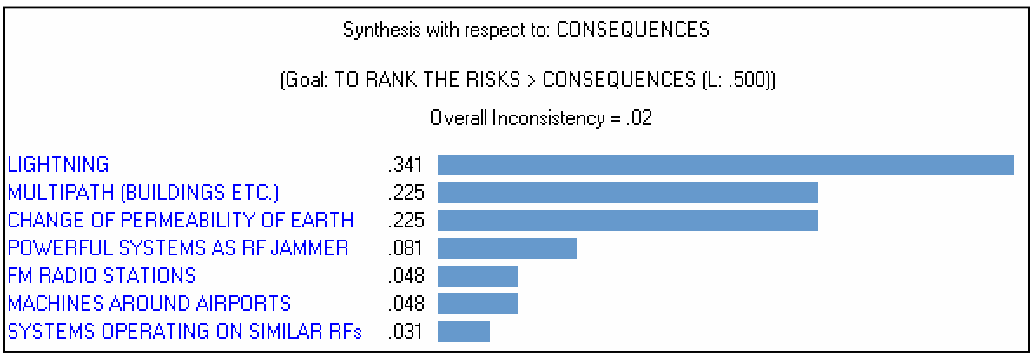

Figure 4-15 Participant 2 Risk Priority (Consequences)

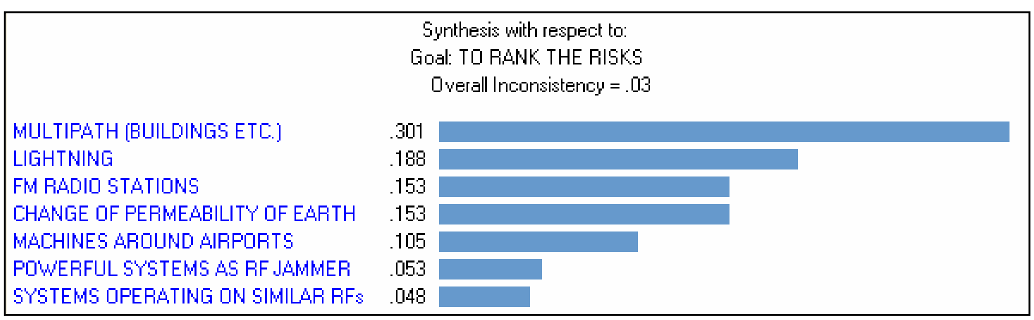

Figure 4-16 Participant 2 Overall Risk Priority

PARTICIPANT 3

Table 4-14 Participant 3 Relative Comparison Chart with Respect to Likelihood

Likelihood	R1	R2	R3	R4	R5	R6	R7
R1	1	1	1/2	4	8	1/2	7
R2	1	1	1/3	4	8	1/3	7
R3	2	3	1	6	9	1	8
R4	1/4	1/4	1/6	1	5	1/6	3
R5	1/8	1/8	1/9	1/5	1	1/9	1/2
R6	2	3	1	6	9	1	8
R7	1/7	1/7	1/8	1/3	2	1/8	1

Table 4-15 Participant 3 Relative Comparison Chart with respect to Consequences

Consequences	R1	R2	R3	R4	R5	R6	R7
R1	1	2	1/6	1/5	1/3	1	1/4
R2	1/2	1	1/6	1/6	1/4	1	1/4
R3	6	6	1	2	5	6	4
R4	5	6	1/2	1	4	5	3
R5	3	4	1/5	1/4	1	4	1/2
R6	1	1	1/6	1/5	1/4	1	1/5
R7	4	4	1/4	1/3	2	5	1

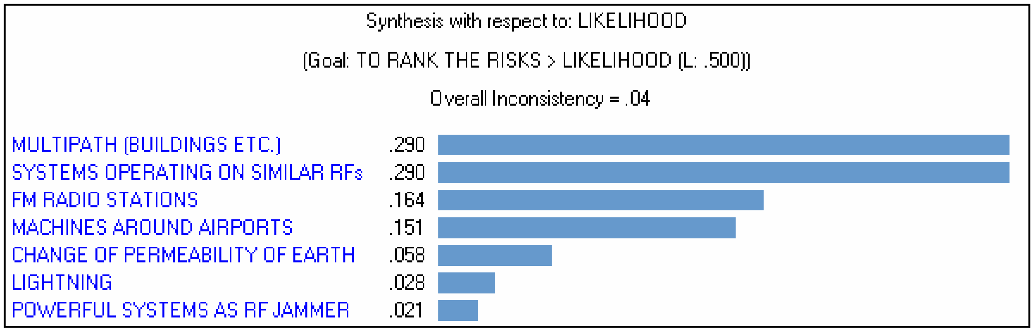

Figure 4-17 Participant 3 Risk Priority (Likelihood)

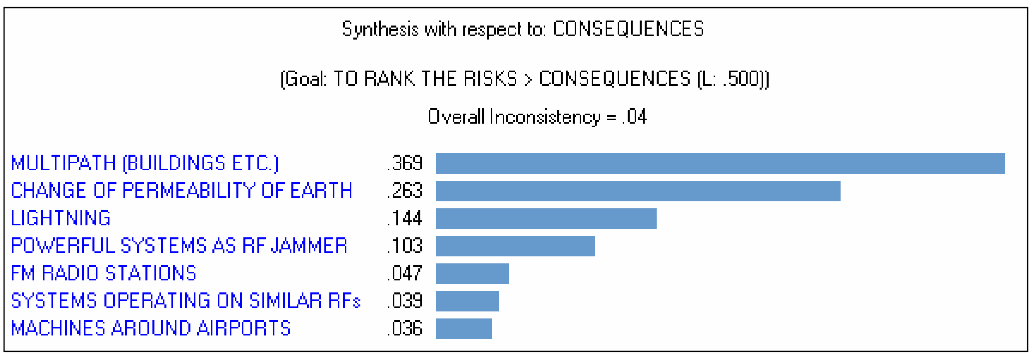

Figure 4-18 Participant 3 Risk Priority (Consequences)

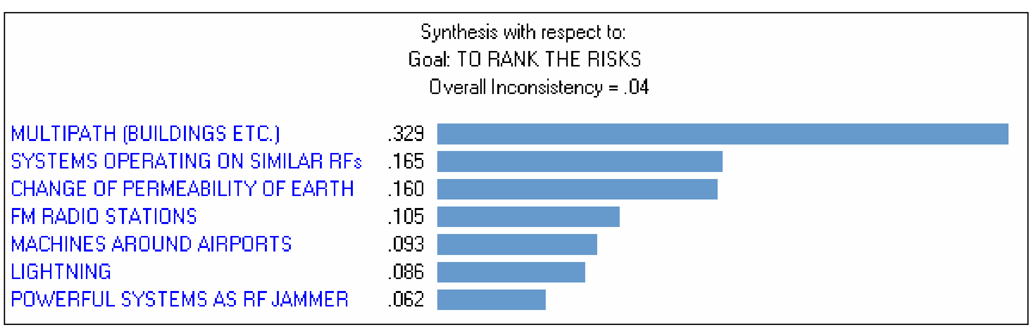

Figure 4-19 Participant 3 Overall Risk Priority

PARTICIPANT 4

Table 4-16 Participant 4 Relative Comparison Chart with Respect to Likelihood

Likelihood	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**
R1	1	1/3	3	4	6	½	5
R2	3	1	4	5	8	2	8
R3	1/3	¼	1	3	6	1/3	5
R4	¼	1/5	1/3	1	4	¼	3
R5	1/6	1/8	1/6	¼	1	1/7	½
R6	2	½	3	4	7	1	5
R7	1/5	1/8	1/5	1/3	2	1/5	1

Table 4-17 Participant 4 Relative Comparison Chart with respect to Consequences

Consequences	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**
R1	1	1	1/3	1/4	1/2	3	1/5
R2	1	1	1/3	1/4	1/2	3	1/5
R3	3	3	1	1/2	3	5	1/3
R4	4	4	2	1	4	6	1/2
R5	2	2	1/3	1/4	1	4	1/4
R6	1/3	3	1/5	1/6	1/3	1	1/8
R7	5	5	3	2	5	7	1

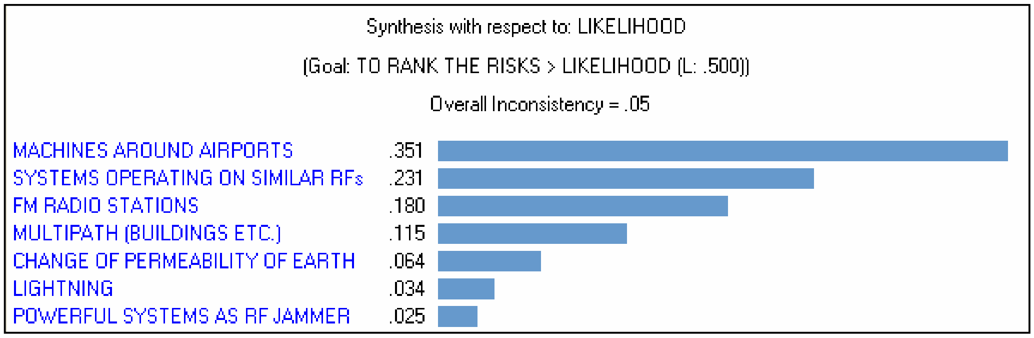

Figure 4-20 Participant 4 Risk Priority (Likelihood)

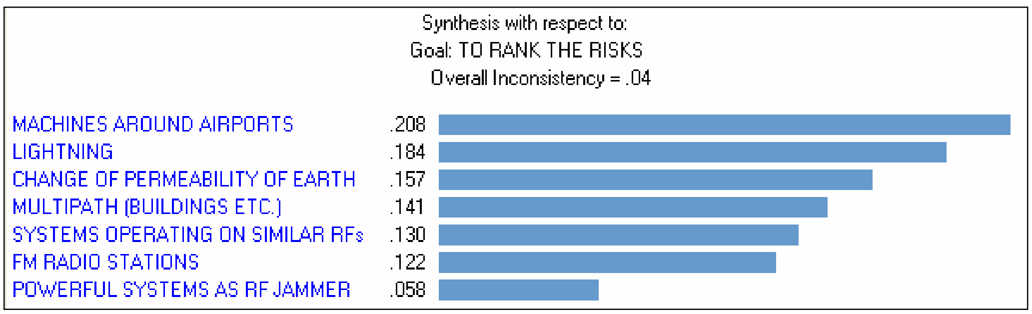

Figure 4-21 Participant 4 Risk Priority (Consequences)

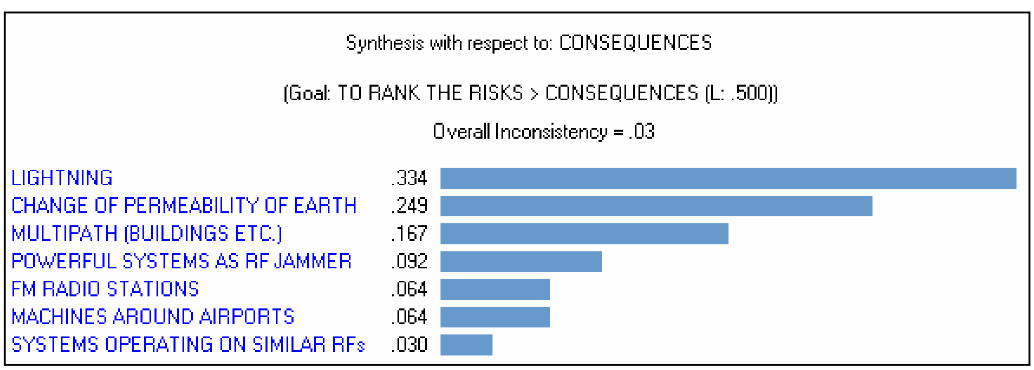

Figure 4-22 Participant 4 Overall Risk Priority

PARTICIPANT 5

Table 4-18 Participant 5 Relative Comparison Chart with Respect to Likelihood

Likelihood	R1	R2	R3	R4	R5	R6	R7
R1	1	2	1/2	5	6	1/3	7
R2	1/2	1	1/3	4	5	1/4	6
R3	2	3	1	6	7	1/2	8
R4	1/5	1/4	1/6	1	3	1/7	4
R5	1/6	1/5	1/7	1/3	1	1/8	3
R6	3	4	2	7	8	1	9
R7	1/7	1/6	1/8	1/4	1/3	1/9	1

Table 4-19 Participant 5 Relative Comparison Chart with respect to Consequences

Consequences	R1	R2	R3	R4	R5	R6	R7
R1	1	2	1/4	1/5	1/3	1	1/7
R2	1/2	1	1/5	1/6	1/4	1/2	1/8
R3	4	5	1	1/2	2	4	1/3
R4	5	6	2	1	3	4	1/2
R5	3	4	1/2	1/3	1	2	1/3
R6	1	2	1/4	1/4	1/2	1	1/5
R7	7	8	3	2	3	5	1

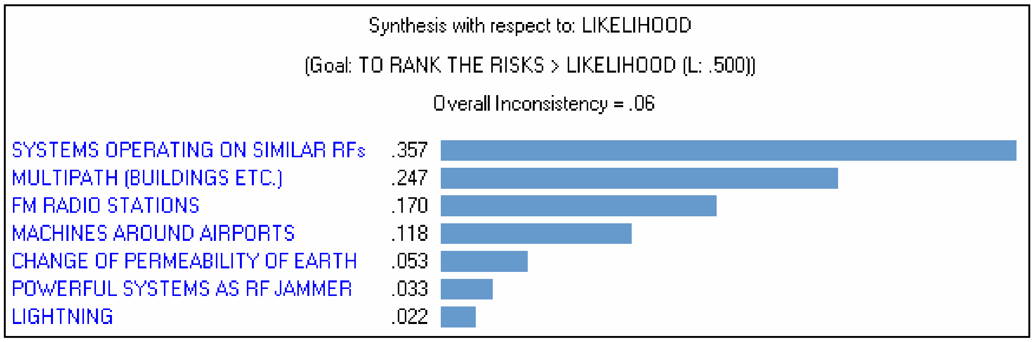

Figure 4-23 Participant 5 Risk Priority (Likelihood)

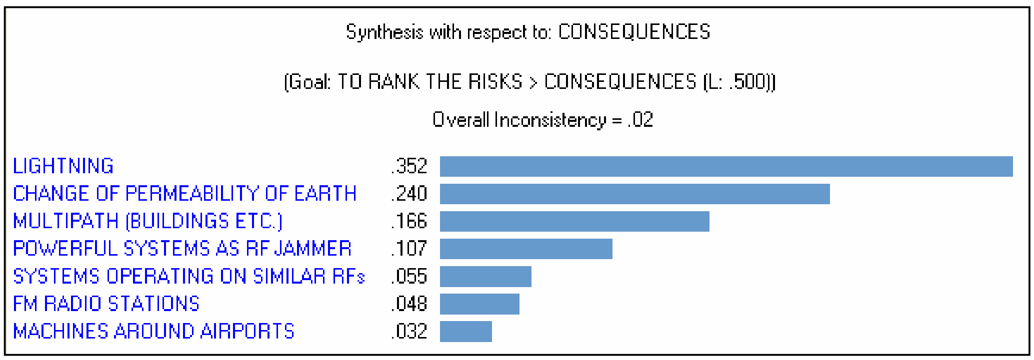

Figure 4-24 Participant 5 Risk Priority (Consequence)

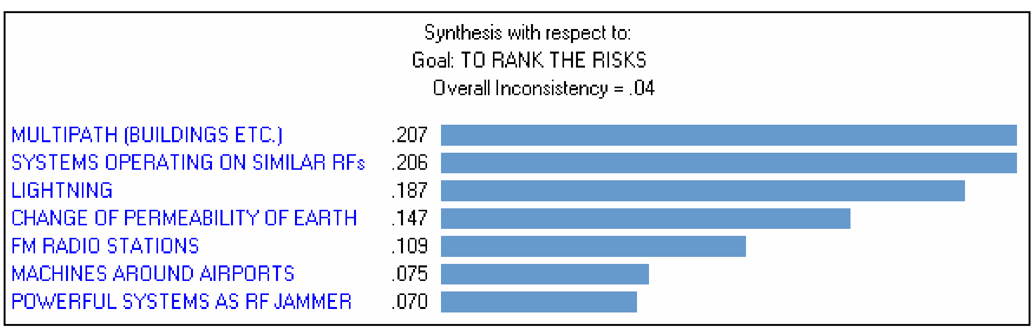

Figure 4-25 Participant 5 Overall Risk Priority

PARTICIPANT 6

Table 4-20 Participant 6 Relative Comparison Chart with Respect to Likelihood

Likelihood	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**
R1	1	4	2	5	7	3	6
R2	1/4	1	1/3	3	5	1/3	4
R3	1/2	3	1	4	6	2	5
R4	1/5	1/3	1/4	1	4	1/5	2
R5	1/7	1/5	1/6	1/4	1	1/7	1/3
R6	1/3	3	1/2	5	7	1	6
R7	1/6	1/4	1/5	1/2	3	1/6	1

Table 4-21 Participant 6 Relative Comparison Chart with respect to Consequences

Consequences	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**
R1	1	1/3	1/6	1/6	1/5	1/4	1/5
R2	3	1	1/5	1/5	1/4	1/3	1/4
R3	6	7	1	1	3	3	3
R4	6	7	1	1	3	3	3
R5	5	4	1/5	1/3	1	2	1
R6	4	3	1/3	1/3	1/2	1	1/2
R7	5	4	1/3	1/3	1	2	1

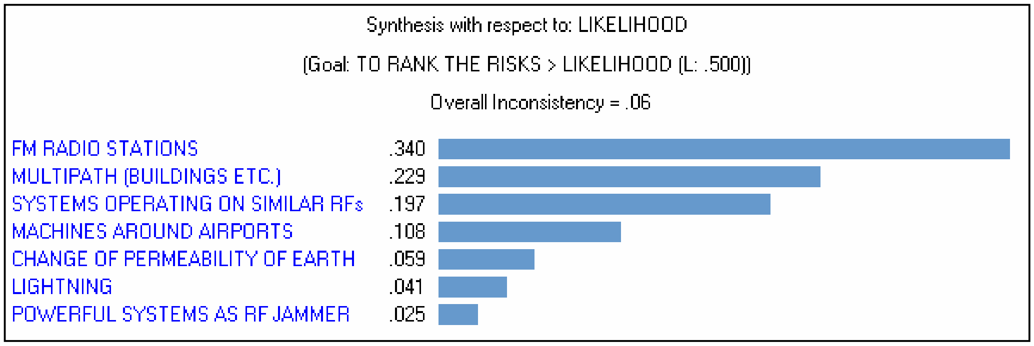

Figure 4-26 Participant 6 Risk Priority (Likelihood)

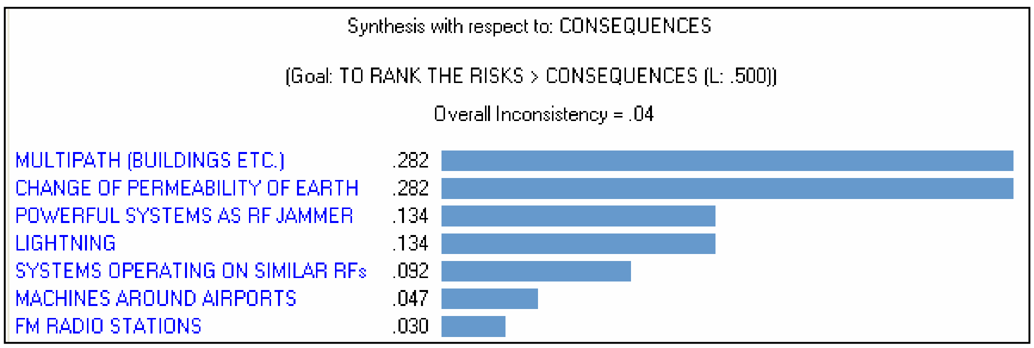

Figure 4-27 Participant 6 Risk Priority (Consequences)

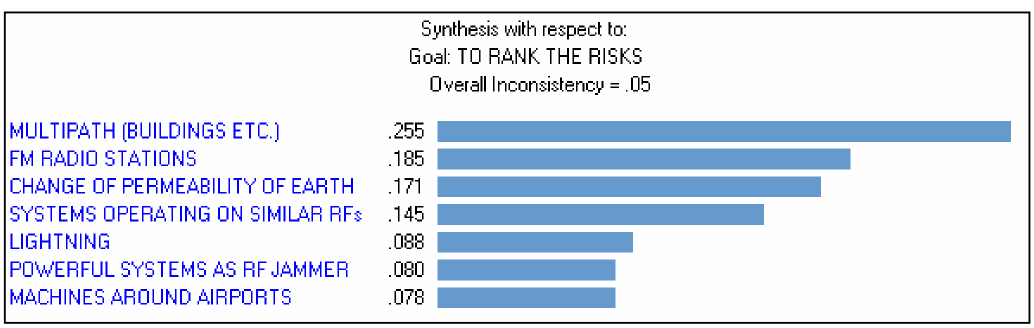

Figure 4-28 Participant 6 Risk Overall Risk Priority

PARTICIPANT 7

Table 4-22 Participant 7 Relative Comparison Chart with Respect to Likelihood

Likelihood	R1	R2	R3	R4	R5	R6	R7
R1	1	3	3	5	7	3	9
R2	1/3	1	1	3	4	1/2	7
R3	1/3	1	1	3	4	1/2	7
R4	1/5	1/3	1/3	1	3	1/4	4
R5	1/7	1/4	1/4	1/3	1	1/5	2
R6	1/3	2	2	4	5	1	8
R7	1/9	1/7	1/7	1/4	1/2	1/8	1

Table 4-23 Participant 7 Relative Comparison Chart with respect to Consequences

Consequences	R1	R2	R3	R4	R5	R6	R7
R1	1	2	1/6	1/6	1/3	1/3	1/4
R2	1/2	1	1/7	1/7	1/4	1/7	1/5
R3	6	7	1	1	5	2	4
R4	6	7	1	1	5	2	5
R5	3	4	1/5	1/5	1	1/5	1/2
R6	3	7	1/2	1/2	5	1	3
R7	4	5	1/4	1/5	2	1/3	1

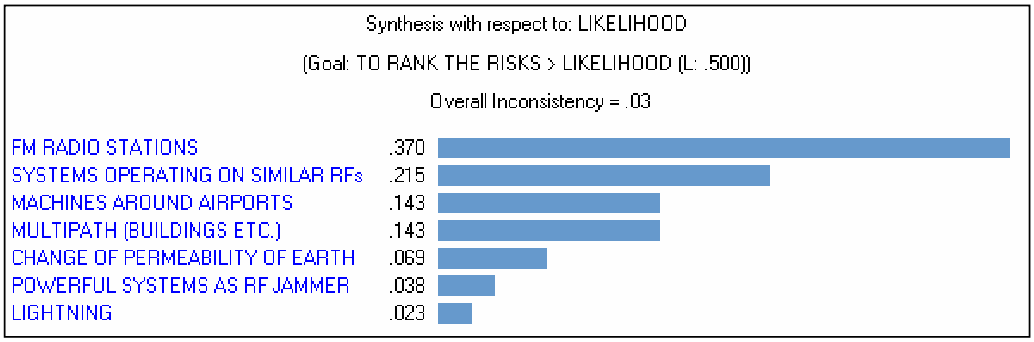

Figure 4-29 Participant 7 Risk Priority (Likelihood)

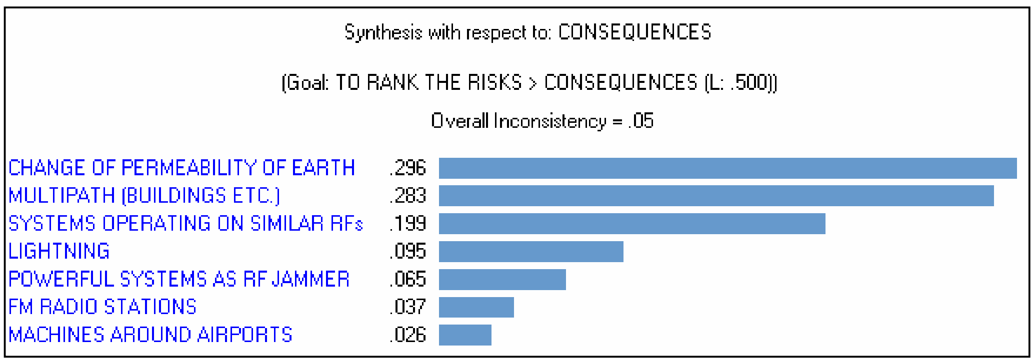

Figure 4-30 Participant 7 Risk Priority (Consequences)

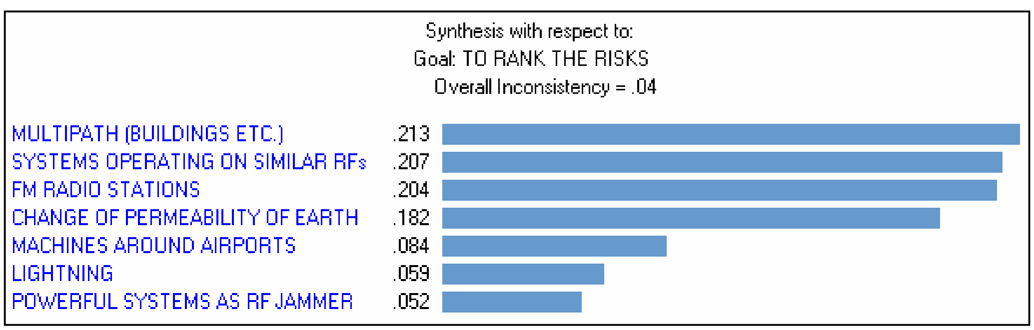

Figure 4-31 Participant 7 Overall Risk Priority

PARTICIPANT 8

Table 4-24 Participant 8 Relative Comparison Chart with Respect to Likelihood

Likelihood	R1	R2	R3	R4	R5	R6	R7
R1	1	2	2	7	7	2	9
R2	1/2	1	1	5	7	1/2	8
R3	1/2	1	1	5	7	1/2	8
R4	1/7	1/5	1/5	1	2	1/5	3
R5	1/7	1/7	1/7	1/2	1	1/7	2
R6	1/2	2	2	5	7	1	9
R7	1/9	1/8	1/8	1/3	1/2	1/9	1

Table 4-25 Participant 8 Relative Comparison Chart with respect to Consequences

Consequences	R1	R2	R3	R4	R5	R6	R7
R1	1	2	1/5	1/5	1/3	3	1/4
R2	1/2	1	1/6	1/6	1/4	2	1/5
R3	5	6	1	1	4	6	3
R4	5	6	1	1	4	7	3
R5	3	4	1/4	1/4	1	5	1/2
R6	1/3	1/2	1/6	1/7	1/5	1	1/6
R7	4	5	1/3	1/3	2	6	1

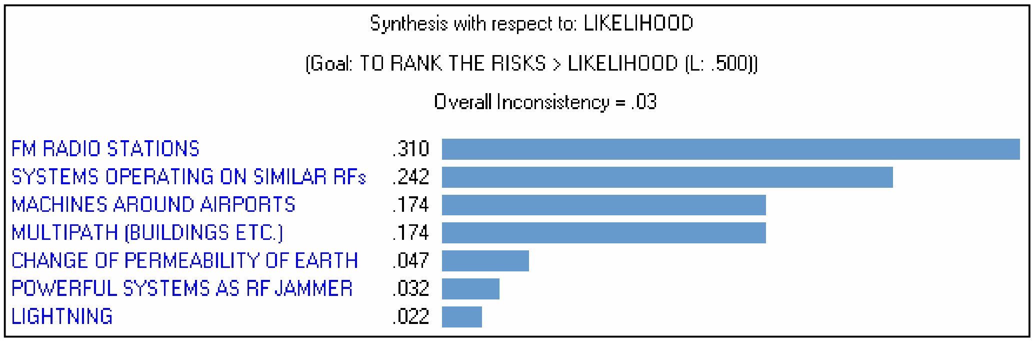

Figure 4-32 Participant 8 Risk Priority (Likelihood)

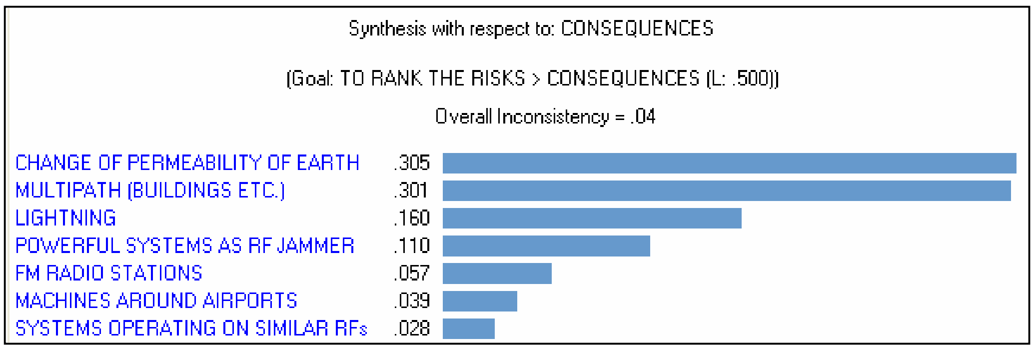

Figure 4-33 Participant 8 Risk Priority (Consequences)

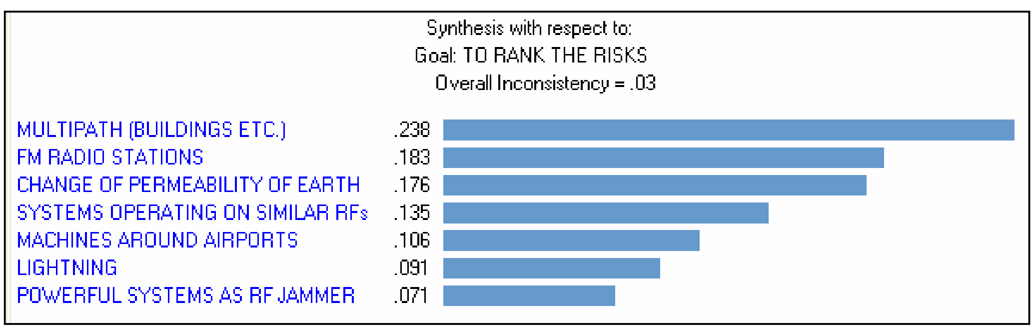

Figure 4-34 Participant 8 Overall Risk Priority

PARTICIPANT 9

Table 4-26 Participant 9 Relative Comparison Chart with Respect to Likelihood

Likelihood	R1	R2	R3	R4	R5	R6	R7
R1	1	3	2	7	8	4	7
R2	1/3	1	1/2	6	7	3	6
R3	1/2	2	1	6	7	4	6
R4	1/7	1/6	1/6	1	3	1/4	1/2
R5	1/8	1/7	1/7	1/3	1	1/5	1/3
R6	1/4	1/3	1/4	4	5	1	4
R7	1/7	1/6	1/6	2	3	1/4	1

Table 4-27 Participant 9 Relative Comparison Chart with respect to Consequences

Consequences	R1	R2	R3	R4	R5	R6	R7
R1	1	2	1/5	1/5	1/4	1/6	1/7
R2	1/2	1	1/6	1/6	1/5	1/7	1/7
R3	5	6	1	1	3	1/2	1/3
R4	5	6	1	1	3	1/2	1/3
R5	4	5	1/3	1/3	1	1/3	1/4
R6	6	7	2	2	3	1	1/2
R7	4	7	3	3	4	2	1

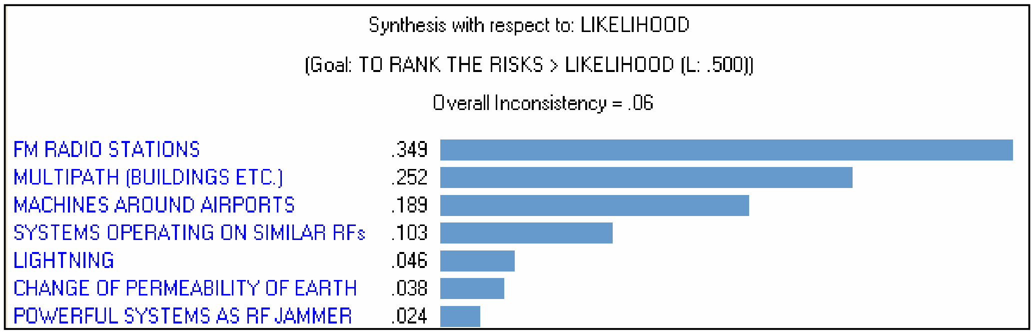

Figure 4-35 Participant 9 Risk Priority (Likelihood)

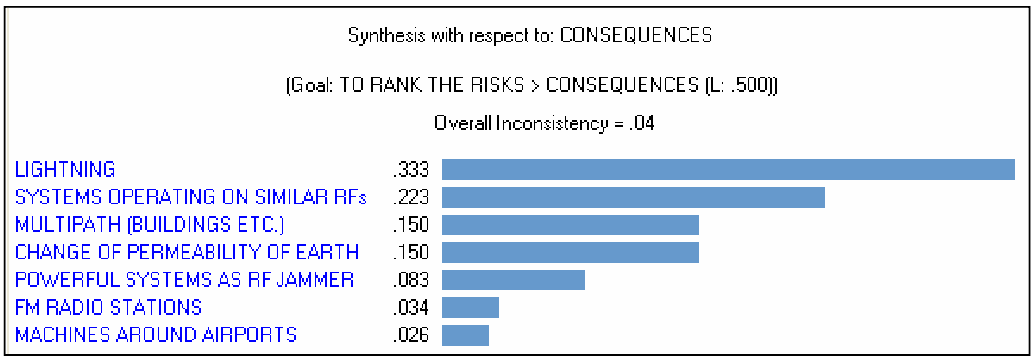

Figure 4-36 Participant 9 Risk Priority (Consequences)

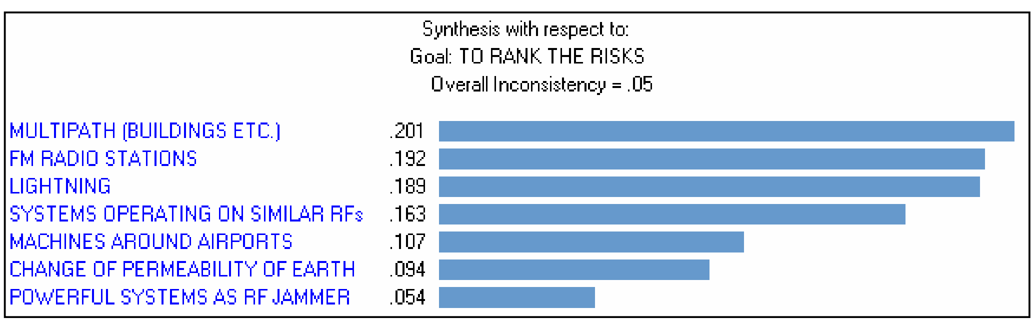

Figure 4-37 Participant 9 Overall Risk Priority

This is the end of the results of 9 participants. In the following section the results of each participant will be summarized and the overall priority of each risk will be obtained.

4.2.2.2.2 The Overall AHP Results

The Expert Choice program evaluates the "priorities" with respect to many numbers of criteria and many numbers of participants. However, in this thesis, the trial version is used for the evaluations, which allows only three people's decisions as input of the program. Since this analysis is based on 9 people, the overall priority is evaluated without the program but with the same logic. In Table 4-28, the likelihood priorities corresponding to each participant is presented. These values are added and presented at the *Total* row of the Table 4-28, as shown. Then the total values corresponding to each risk event are prioritised by dividing each value to the sum of the row. Then the risk priorities with respect to likelihood are obtained. The total sum of the Priority row is equal to 1. The same procedure is applied for Consequences priorities and the overall priorities.

Table 4-28 Risk Priorities with respect to Likelihood

PARTICIPANTS LIKELIHOOD	RISK 1	RISK 2	RISK 3	RISK 4	RISK 5	RISK 6	RISK 7
PARTICIPANT 1	0.368	0.184	0.26	0.087	0.021	0.05	0.029
PARTICIPANT 2	0.257	0.161	0.376	0.08	0.025	0.161	0.035
PARTICIPANT 3	0.164	0.151	0.29	0.058	0.021	0.29	0.028
PARTICIPANT 4	0.18	0.351	0.115	0.064	0.025	0.231	0.034
PARTICIPANT 5	0.17	0.118	0.247	0.053	0.033	0.357	0.022
PARTICIPANT 6	0.34	0.108	0.229	0.059	0.025	0.197	0.025
PARTICIPANT 7	0.37	0.143	0.143	0.069	0.038	0.215	0.023
PARTICIPANT 8	0.31	0.174	0.174	0.047	0.032	0.242	0.022
PARTICIPANT 9	0.349	0.189	0.252	0.038	0.024	0.103	0.046
TOTAL	2.508	1.579	2.086	0.555	0.244	1.846	0.264
PRIORITY	**0.276**	**0.174**	**0.230**	**0.061**	**0.027**	**0.203**	**0.029**

In Table 4-28, the risk ranking with respect to likelihood by 9 participants is presented. As it is seen the likelihood of interference by FM radio stations is the highest. The second highest score is the interference due to signal reflection by large objects in airports. The interference caused by systems operate on adjacent frequencies on the aircraft has the third likelihood score. The interference due to machines around airports has the fourth likelihood score. The last three risk events have lower scores with respect to the first four risk events. The likelihood of signal derogation due to the change of permeability of the ground has the third lowest score. The likelihood of signal derogation with respect to lightning has the second lowest score. The lowest likelihood score is the interference due to powerful systems as RF jammer. This result is compatible with the first risk ranking analysis.

In Table 4-29, the overall risk priorities with respect to consequences are presented. According to the comparison made by 9 participants, the consequence of interference due to signal reflection by large objects in airports and the change in the permeability of the ground have the highest priorities. The consequence of signal derogation due to lightning has the third highest score. R5, the consequences of the interference due to the use of powerful systems as RF jammer, has the fourth highest risk priority. R6, interference due to the systems operating on adjacent RFs on aircraft has the fifth consequence priority score. The interference due to FM radio stations, R1, and the interference due to the machines operating at factories around airports, R2, has the lowest priority score respectively.

Table 4-29 Risk Priorities with respect to Consequences

PARTICIPANTS CONSEQUENCES	RISK 1	RISK 2	RISK 3	RISK 4	RISK 5	RISK 6	RISK 7
PARTICIPANT 1	0.052	0.036	0.303	0.303	0.139	0.028	0.139
PARTICIPANT 2	0.048	0.048	0.225	0.225	0.081	0.048	0.341
PARTICIPANT 3	0.047	0.036	0.369	0.263	0.103	0.039	0.144
PARTICIPANT 4	0.064	0.064	0.167	0.249	0.092	0.03	0.334
PARTICIPANT 5	0.048	0.032	0.166	0.24	0.107	0.055	0.352
PARTICIPANT 6	0.03	0.047	0.282	0.282	0.134	0.047	0.134
PARTICIPANT 7	0.037	0.026	0.283	0.296	0.065	0.199	0.095
PARTICIPANT 8	0.057	0.039	0.301	0.305	0.11	0.039	0.16
PARTICIPANT 9	0.034	0.026	0.15	0.15	0.223	0.223	0.333
TOTAL	0.417	0.354	2.246	2.313	1.054	0.708	2.032
PRIORITY	**0.046**	**0.039**	**0.246**	**0.254**	**0.116**	**0.078**	**0.223**

Table 4-30 Overall Risk Priorities

PARTICIPANTS (OVERALL RISK PRIOITY)	RISK 1	RISK 2	RISK 3	RISK 4	RISK 5	RISK 6	RISK 7
PARTICIPANT 1	0.21	0.11	0.282	0.195	0.08	0.039	0.084
PARTICIPANT 2	0.153	0.105	0.301	0.153	0.053	0.048	0.188
PARTICIPANT 3	0.105	0.093	0.329	0.16	0.062	0.165	0.086
PARTICIPANT 4	0.122	0.208	0.141	0.157	0.058	0.13	0.184
PARTICIPANT 5	0.109	0.075	0.207	0.147	0.07	0.206	0.187
PARTICIPANT 6	0.185	0.078	0.255	0.171	0.08	0.145	0.088
PARTICIPANT 7	0.204	0.084	0.213	0.182	0.052	0.207	0.059
PARTICIPANT 8	0.183	0.106	0.238	0.176	0.071	0.135	0.091
PARTICIPANT 9	0.192	0.107	0.201	0.094	0.054	0.163	0.189
TOTAL	1.463	0.966	2.167	1.435	0.58	1.238	1.156
PRIORITY	**0.162**	**0.107**	**0.241**	**0.159**	**0.064**	**0.137**	**0.128**

According to Table 4-30, the highest risk is R3, interference due to signal reflection by large objects (large hangars, terminals and even the tails of passenger jets on the ground), in other words multi-path of ILS signals. This result is quiet compatible with the risk ranking result that was presented in Table 4.9, Overall Risk Ranking Matrix. As it is remembered, this risk event was ranked as *High Risk Level*. This is not a surprise result since as it is seen in Table 2-28 and 4-29, R3 has second highest likelihood and consequence score. The lowest score corresponds to R5. Although the consequence of this risk has not a low priority, since the probability of occurrence is too low, then this risk has the lowest priority. Again this is quite compatible with the first risk ranking study. The other risks have priority scores as R1> R4> R6> R7> R2. These four risk events were determined as *Medium Level Risks* in the risk ranking analysis. At the end of this analysis, with the help of comparison approach of AHP, these risks could be ranked and priority of each is determined. This method tells more than the risk ranking analysis about the risks. However, risk ranking was assumed the introductory step of this risk analysis process. The compatibility of the results is a sign telling that the selected participants are qualified enough and their concentrations on the risks are well. However, it should be noted that, there are some small differences between the results of risk ranking when the comparison is made in likelihood and consequences levels. Since the differences are small enough this is not an important point. This is because of the relative judgments of AHP method orient the participants better than the absolute judgement of risk ranking. The overall risk ranking scores and the results of the risk matrix are presented in Table 4-31.

Table 4-31 Risk Ranking & AHP Scores

RISK NO	RISK EVENTS	RISK LEVEL	OVERALL RISK PRIORITY
1	RF interference due to FM radio stations	MEDIUM	0.162
2	RF interference due to machines	MEDIUM	0.107
3	RF interference due to multipath	HIGH	0.241
4	Derogation of ILS signal due to change of permeability	MEDIUM	0.159
5	RF interference due to RF jammer	LOW	0.064
6	RF interference due to systems with same RF band	MEDIUM	0.137
7	Derogation of the ILS signal due to lightning	MEDIUM	0.128

4.3 INSTRUMENT LANDING SYSTEM RISK PLANNING

The main aim of the risk analysis is to identify the risks with higher likelihood and consequences. This identification should be made to define risks, which need urgent planning and solutions. At this section, a brief overview of risk planning for critical risks is presented. As it is presented at Table 4-31, the most critical risks are the R3, R1, and R4 respectively. This means that, the preventive actions for these three risks should be taken first. The risk planning section seeks for the preventive actions that can be applied to reduce the likelihood or severity of the consequences.

R3, EMI due to signal reflection on ILS is an important risk which threatens the airports all over the world. The buildings around airports, the taxiing aircrafts, and the vehicles in the airports may create EMI on ILS. There are two main ways to prevent this risk, one is based on the administrative and regulative actions and the other is based on technical solutions. The administrative and regulative actions include the airport planning issues, as checking the structuring inside and nearby the airports. These issues are under control of TSAA, and are applied as a solution for the signal reflection due to buildings. However, the taxiing aircrafts, and vehicles need a more detailed technical solutions. There are interesting studies performed in the US and Europe. Simulation of EM environment on airports is an interesting study to understand the danger caused by EMI due to signal reflection by the objects. The airport EM environment is composed of the aeronautic radio systems for navigation communication with the aircraft and surveillance of the airfield and the non-aeronautic emitters for broadcast and other services. An EM environment simulation that includes database of airport infrastructures (buildings, vehicles), trajectory for landing aircrafts, and the database of EM equipments on airports will be a helpful aid in determination of potential threats for ILS communication. An interesting study is performed to model the interactions between EM waves and the structures surround the airport. This study is mainly based on ILS and some other similar system as MLS and GNS. Within this study, establishing some scenarios, EM environment is simulated and the level of interference due to signal reflection originated from airport infrastructures and vehicles is obtained (The Sirena Consortium, [n.d.]). Another similar study in Europe seeks the solution for the problem of ILS signal interference due to proximity of large vehicles and taxiing aircraft to ILS antennas by concentrating on electromagnetic field modelling software. This study was a two-year Specific Targeted Research Project under the European Union's Sixth Framework programme which ended in December, 2006. With eight partners, including the European Commission and Airbus, the project's total cost was €1.9 million (Flight International, 2006). In Turkey, although there is not such a study for EMI on airports yet, there is a potential and capability, to carry out such of research. ISYAM Communications and Spectrum Management Centre, established at 1994, is one of the first centres to study on frequency management issues in Turkey. The centre is mainly working on various software issues for Telecommunication Authority and Radio Television Supreme Council. However, there is not an EMI study for Aviation Authorities yet. In the light of this research, the need and potential for this kind of work should be noted. The centre has the capabilities of interference analysis, wave propagation modelling etc. A collaborative research on airport EMI modelling can be a very important action to prevent the potential risk events on airports. With the development of these kinds of centres, and collaborative working environment including TSAA, research centres and universities can be an important step to prevent the hazardous results of multi-path risks.

R1, the FM interference is the other critical risk event as obtained from the risk analysis. The frequency band just above 108 MHz is allocated to aeronautical services. In particular, the band 108–112 MHz is used by the ILS. As it is observed from the risk analysis results, ILS is vulnerable to interference from broadcast transmissions. There are some critical preventive actions that should be applied to decrease the likelihood of this event. These can be stated as administrative and regulative actions and technical preventive actions. Today, in the world, the aviation authorities as ICAO have close relationships with International Telecommunications Union (ITU). Since the Turkish Aviation industry has to be consistent with the international authorities, the same culture is also developing in Turkey. Turkish FM Radio stations are under the control of Turkish Telecommunications Authority (TTA). These stations have to broadcast from the frequency which they are allowed to and they should make their filtrations not to create any interference with other RF systems. Despite of this fact, the interference of FM broadcasting is not unusual. These stations sometimes make broadcast from different frequencies or, the filtration of their transmitters is not performed well to diminish harmonics that may cause interference in the ILS signal. When there is an interference investigated, TTA has the authority to stop the broadcasting, however this takes time and does not prevent passing of crews through the interference areas in the mean time. In UK, there is an agreement between the Aviation Authorities and the Telecommunication Authorities that 9 month notice should be given before any new broadcast station is brought into service. This gives time for areas likely causing interference. Moreover, according to ICAO standards, the ILS receivers at aircrafts should meet the FM immunity requirements to be prevented from broadcast interference (Safety Regulation Group, 1998). However, the FM immunity adaptation of ILS receivers at aircrafts still remains as a question mark for the airlines operating in Turkey. The best approach in FM interference seems to be "action before event approach". Most countries are using analysis to locate problem areas then they collect the locations and signal strengths of known commercial FM stations and dump them into a computer model that identifies possible areas of interference. When they discover commercial interference areas, a collaborative work is performed with the civil broadcast authorities to find solutions to eliminate the problem (Wood, 2000). Generally in Turkey, the problem is first encountered by aircrews, and then it is reported to TSAA, and TSAA informs TTA, then the solution is developed by TTA. However this is not an adequate preventive action. Turkish Aviation Authorities should act before the FM interference takes place. The potential and capability for these kinds of studies are available in Turkey. The ISYAM Communications and Spectrum Management Centre developed a Broadcasting tool which allows specifying the frequency, coordinates, antenna height above ground level and ERP (Effective Radiated Power) for ILS/VOR systems. This tool takes into consideration the existing FM radio stations within the investigated area. However, the new or proposed FM radio stations which do not exist in the frequency assignment database can also be added to this analysis (ISYAM, 2006). This tool was developed for Turkish Telecommunication Authority (TTA) in 1998; however it has not been used in any airport for the verification or validation purposes yet, unfortunately. This tool can be used in collaboration with TSAA and TTA to check weather the existing FM stations may create interference. Moreover its' technical specifications can be improved and upgraded to get just in time information about ILS interference from broadcasting at airports. In Figure 4-38, the broadcasting program for interference analysis is presented.

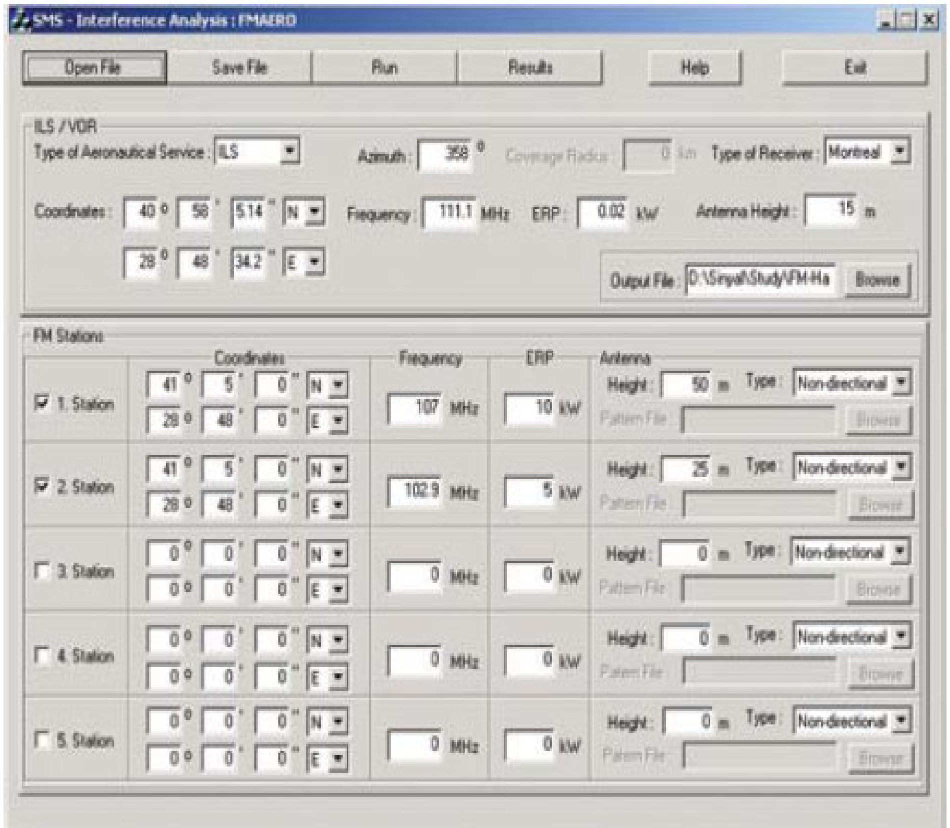

Figure 4-38 Compatibility Analysis between FM Radio Broadcasting and ILS (ISYAM, 2006)

Derogation of ILS signal due to the change of permeability of the ground has a low likelihood but it is known that it has severe consequences. The preventive action may be similar to the preventive actions of interference due to signal reflection, R1. Electromagnetic environment simulation of airports may include different scenarios with snowy ground etc. According to the results of the interference analysis, the use of ILS system at that airport can be restricted until the possibility of ILS interference becomes negligible. This action is called as NOTAM (Notice to Airmen) in aviation; NOTAM means that the system is out of order for a defined period. The main point here is; the ILS system, which has NOTAM status, should be informed to the aircrews. However to define the preventive actions for this risk better, some theoretical studies should be done in collaboration of universities and research centres about the effect of permeability on wave propagation.

The other risks, R6 (due to systems operating at adjacent RFs), R2 (due to machines around airports), and R5 (due to powerful systems as RF jammer) have smaller priorities with respect to the R3, R1, and R4. Therefore, the priority sequence for of the application of risk mitigation plans for these risks comes after the first three risks. However it should be noted that, to mitigate from these risks similar actions can be applied. The EM simulation is the only way to investigate the potential interference, and to look for technological or administrative solutions to mitigate from these risks.

R7, the signal derogation due to lightning, is a different one in terms of its mitigation plans when compared with the other six risks. A recent study of Federal Aviation Administration revealed that aircrafts and aircraft equipments are struck by lightning for every 1000 hours Therefore the manufacturers has to verify the systems with EMI/EMC test. There are many standards to prevent the avionic systems from the lightning effects. These are (HV Technologies, 2006);

- DO 160: Environmental Conditions and Test Procedure for Airborne Equipment (Radio Technical Commission for Aeronautics)
- EUROCAE / ED-84 (1997): Aircraft Lightning Environment and related Test Waveforms. (European Organisation for Civil Aviation Equipment (EUROCAE))
- Advisory Circular 20-136 (1990): Protection of Aircraft Electrical/Electronic Systems against the indirect effects of lightning US Department of Transportation, Federal Aviation Authority (FAA)
- ISO 7137 (2001): Aircraft - Environmental conditions and test procedures for airborne equipment. International Standards Organisation (ISO)

The avionics on A/C should be compatible with these standards. Because of the nature of aerospace industry, generally the manufacturers are already verifying and validating their systems according to these standards. However, awareness and care for these kinds of standards in Turkish Aviation will be very helpful when new systems are needed to implement to A/Cs. New implementations or modifications in instruments should be compatible with these standards.

In Table 4-32, the overview of risk management activities studied until this section is presented.

Table 4-32 ILS Risk Analysis & Planning Results

Risk No	Risk Event	Risk Priority	Risk Plan	Responsible Bodies
R3	EM Interference due to multi-path such as reflection of the signal by large objects	0.241	Regular Checks at and around airports	TSAA
			EM environment simulation of airports Interference Analysis (IA)	TSAA-Research Centres-Universities
			Modulating airports wrt the IA results	TSAA
R1	EM Interference due to FM Radio Stations	0.162	Strict regulations and checks on FM radio stations	TTA
			Modulating the ILS receivers at aircrafts to FM immune state	TCAA, Users (Airliners, Turkish Armed Forces)
			Regular checks if they are all FM immune or not	TCAA
			Broadcasting Interference Software	TSAA-Research Centres-Universities
			Regulating the FM stations wrt the IA results	TTA
R4	EM Interference due to change of permeability of ground	0.159	EM environment simulation of airports Interference Analysis	TSAA-Research Centres-Universities
			Regulating the ILS use wrt. the results of the IA	TSAA

Table 4-32 Continuing

Risk No	Risk Event	Risk Priority	Risk Plan	Responsible Bodies
R6	EM Interference due to systems operating on adjacent frequencies on aircraft	0.137	EMI/EMC Tests should be applied in every modification	Users
			EM environment simulation of aircrafts Interference Analysis	Users-Research Centres-Universities
			Frequency Management Activities	TSAA-TTA
R7	Signal derogation due to lightning	0.128	Checking the new or modified instruments to be compatible with the lightning standards of the A/C	Users
R2	EM Interference due to machines operating at factories around airports	0.107	Creating Awareness at factories about EMI threats to airports	TSAA
			Regular checks at and around airports	TSAA
			EM environment simulation of airports Interference Analysis	TSAA-Research Centres-Universities
			Putting an end to the use of the machines	TSAA
R5	EM Interference due to powerful systems as RF Jammer at aircraft	0.064	EM environment simulation of aircraft Interference Analysis	Users-Research Centres-Universities
			EMI/EMC Tests should be applied in every modification	Users

The preventive actions for the most critical risks are presented in this section. However, the other steps of risk management approach are as important as the defined preventive actions in risk mitigation. The following actions create a platform to increase accuracy in handling risk mitigation scenarios.

- Detection
- Notification
- Communicating Risk Knowledge
- Capturing Risk Knowledge

When a risk event is detected by aircrew, it should be notified to the operators and the responsible aviation authorities immediately. These notifications should be communicated in a standard format, as with standardized checklists, risk forms etc. These actions are also an important part of risk control, tracking and documenting phases of risk management process, and therefore will be presented in the following section in a detailed manner.

4.4 SUGGESTIONS FOR ILS RISK CONTROL, TRACKING, AND DOCUMENTING

Risk control, tracking and documenting are the crucial steps of risk management. Unless these steps are implemented properly within risk management process, then all the identification or analysis period will not be helpful in mitigating the risks. The risk identification, analysis and the planning phases of the ILS risks are completed up to this section. From this point, suggestions for risk control, tracking and documenting will be presented.

Being the control points of Turkish Aviation, TSAA and TCAA can administrate the risk management activities with the collaboration of users, the research centres and universities. Risk Management Database (RMDB) can be very helpful in mitigation of all kinds of aviation risks. The ILS case study can be one of the risk management activities handled in this database. The main aim of RMDB is to provide an easily accessible way to store and retrieve risk information and thereby help every step of the risk management process. Tracking and analyzing risks will be very easy with the use of such a database. Moreover keeping archive of all the information related to the past risks, program managers and engineers can plan for and prevent the risks. Risk mitigation process will also be more effective, because methods used in the past risk management activities and their results will be available for all to view in the archives. This will support the lessons learned approach which helps the organizations to work in a more professional manner. Knowledge obtained in defining and conducting risk mitigation actions generates 'candidates for lessons learned' (Regan & Cornell 1997 p.161).

The main inputs of the risk management database are;

- Risk Information Sheets
- Risk Analysis Reports
- Risk Mitigation Status Reports
- Risk Management Plans

These are the inputs, which should take place in every risk management activity. Risk Information Sheets are used to present all information about a risk event including risk description, risk likelihood, risk consequences, mitigation plans, contingency plans, risk status and if closed, the closing date of the risk. At Figure 4-39 an example for a risk information sheet is presented. In addition to general risk management documents, ILS specific documents as ILS Interference Information Sheet should also take place in this database. This sheet is a standardized form to be filled by the aircrew in order to gather detailed information when there is EM interference. In Figure 4-40, a suggestion for ILS Interference Information Sheet is presented. This sheet can be filled in by the aircrew who encountered the ILS interference. The filled forms should be added to Risk Management Database immediately. The analysis document that is done for any interference should also be added in to this database. Risk Management Database should be accessible by the

TSAA professionals working at airports. These documents will be input of potential probabilistic risk analysis studies in future. Therefore, for the research purposes the research centres and universities should have restricted access to this database for research purposes.

<table>
<tr><td>ID</td><td colspan="2">Risk Information Sheet</td><td>Date Identified:</td></tr>
<tr><td>Priority</td><td colspan="3" rowspan="3">Risk Statement</td></tr>
<tr><td>Probability</td></tr>
<tr><td>Impact</td></tr>
<tr><td>Timeframe</td><td>Originator</td><td>Classification</td><td>Assigned to:</td></tr>
<tr><td colspan="4">Context</td></tr>
<tr><td colspan="4">Approach: Research / Accept / Watch / Mitigate</td></tr>
<tr><td colspan="4">Contingency Plan and Trigger</td></tr>
<tr><td colspan="3">Status</td><td>Status Date</td></tr>
<tr><td colspan="4">Lessons Learned</td></tr>
<tr><td>Approval</td><td>Closing Date</td><td colspan="2">Closing Rationale</td></tr>
</table>

Figure 4-39 Risk Information Sheet (NASA, n.d])

<table>
<tr><td>ID</td><td>ILS Interference Information Sheet</td><td colspan="2">Date Identified:</td></tr>
<tr><td>AIRLINE NAME</td><td colspan="3"></td></tr>
<tr><td>FLIGHT NUMBER</td><td colspan="3"></td></tr>
<tr><td colspan="4">Did the ILS display show OFF Flag when you encounter the ILS problem?</td></tr>
<tr><td colspan="4">Did the CDI needle disappear when you encounter the ILS problem?</td></tr>
<tr><td colspan="4">Did you realize any unusual deviation in the CDI display?</td></tr>
<tr><td colspan="4">How long did the ILS problem take?</td></tr>
<tr><td colspan="4">Did you hear any noise on the system?</td></tr>
<tr><td colspan="4">Did you hear any FM broadcasting?</td></tr>
<tr><td colspan="4">Where did you encounter the ILS problem exactly?

Before outer marker?
Somewhere between the outer marker and the middle marker?
Somewhere between the middle marker and the inner marker?</td></tr>
<tr><td colspan="4">While Descending which frequencies were selected on your radio equipment?</td></tr>
<tr><td colspan="4">Any Other Comments</td></tr>
<tr><td colspan="4">For Formal Use Only</td></tr>
<tr><td>Approval</td><td>Closing Date</td><td colspan="2">Status of the Problem</td></tr>
</table>

Figure 4-40 ILS Interference Information Sheet (proposed by the author)

Moreover an ILS Risk Management Plan should be prepared. It should contain the identified risks, their analysis; identified risks mitigation scenarios with responsible bodies and due date as well as an assessment of the residual risk when the mitigation actions are completed (Larr'ere, 2004). This document will be an essential guide for professionals studying on risk management activities.

CHAPTER 5

5 CONCLUSION

The main aim of this thesis is to investigate the risk management methods and develop a risk management strategy on wave propagation in aerospace medium. For this purpose, at first, a research methodology for the research was generated. Literature review and the other data collection methods such as interviews and questionnaires were performed. According to literature review, it was revealed that the risk management activities involves risk identification, risk analysis, risk planning, risk tracking, risk control and documentation processes. The risk management success depends on effective application of these processes. It was understood that risk management is a continuous activity which should be carried on throughout the project life cycle. Being a technology deriver, Aerospace Industry, has closely related activities with risk management practices. Since the faults in aeronautical activities may be extremely dangerous, even fatal, risk management research and applications are inseparable part of all existing and future technologies of aerospace medium. The two important phenomena of aerospace industry, safety and reliability can be improved by efficient and effective risk assessment studies. To increase safety and reliability, the risk management process must include all the relevant aerospace applications. However it was revealed that there are not enough research studies on risk management issues within Turkish Aerospace Industry. It was a great motivation for this study to be an initial step for this type of studies; however, on the other hand it was also including the difficulty of being first. But these difficulties could be solved by looking for the alternative research methods and trying to reveal the existing knowledge that can be used for risk management studies in aerospace medium.

The Instrument Landing System (ILS) has been considered only in order to facilitate a demonstration how risk management can be done in this context. The ILS is one of the main international, ICAO approved, precision landing system that is used under poor visibility conditions such as foggy and stormy weather. In this thesis, the ILS is studied in terms of the risks which may prevent its operation due to Electromagnetic Interference (EMI). Within this case study, the experts from Turkish aviation industry as, TSAA (Turkish State Airports Authority), TCAA (Turkish Civil Aviation Authority), Turkish Armed Forces (TAF), Turkish Airforce (TA), Turkish Airlines and TUBITAK shared their knowledge. They were ILS experts or pilots having avionics background. Risk identification phase of ILS was conducted by using the experience of these experts and the literature review on ILS wave propagation. 7 risks on ILS EM interference were identified. Following the risk identification, relevant data was searched for; however, the most difficult point in this study was the lack of proper historical or statistical data in order to make a probabilistic analysis. However, it is known the experience and knowledge gained from the experts are at least valuable as the historical and statistical data itself. Moreover risk assessment does not have to be based on probabilistic analysis. On the other hand, at this step the main consideration was how to transform this valuable knowledge into a tangible form. The literature review on risk management was a great guide to solve this problem. Two very important and widely used methods were selected to make a qualitative assessment with the help of a quantitative approach. These methods were risk ranking and the Analytic Hierarchy Process (AHP). Risk ranking was an easy but meaningful method to start risk analysis. Risk ranking involves ranking of risks with respect to their likelihood and consequences. 9 experts from the various organizations of Turkish Aviation Industry were asked to decide the likelihood and consequence level of each risk by taking into account their experiences. Their answers were averaged and reflected on the risk matrix. The severity of each risk was obtained from the risk matrix as, very low, low, medium, high and very high. 1 low, 1 high and 5 medium risks were ranked with the knowledge of experts. At this point, another method was used called AHP in order to rank the risks in a more detailed manner and to increase the quality of the analysis. AHP is a decision making method in multi-criteria multi-factor analysis environment. AHP helped to organize the research problem in hierarchical structure which allowed the participants to think about the risks one at a time. The main objective of the AHP in this research was to rank the risks. There were 7 risks as alternatives that will be compared with each other. The criteria which the alternatives were compared to were likelihood and consequences respectively. The comparison was made with respect to the intensity of relative importance table. The participants were asked to compare each risk with respect to first, likelihood then consequences. The participants selected the scale that reflects their decision, and filled in the risk comparison matrix. 18 matrixes corresponding to 9 participants were obtained. The matrices were controlled in terms of any inconsistency, and the matrixes which were inconsistent were revisited by the responsible participants. Expert Choice Trial version was used to obtain the priority of each risk. By the help of Expert choice, the priorities of each risk were obtained. The results were quite compatible with the first ranking analysis. It was encouraging since it was a sign that the participants concentrated well in this analysis and they are expressing their knowledge in an accurate way in different methods in other words, they verified and validated their decisions in risk ranking analysis phase. Following the risk assessment phase, risk planning was performed starting from the critical risks. The main concern was to define plans to decrease the likelihood and severity of the consequences of risks. This study was carried out by taking into account the responsible bodies who may handle the risk mitigation plans. Following the risk planning practices, some suggestions for risk control, risk tracking and risk documentation were made. It was suggested that risk management database will be helpful for all risk management activities. Risk management database should include risk information forms, risk analysis reports, risk plans etc. For the ILS risk documentation, an example of risk information sheet and ILS EM Interference form were presented. It was stated that this kind of systematic approach will increase the effectiveness and accuracy in risk management activities.

Summarizing, the key achievements of this study are as follows;

- Awareness for risk management activities were created within various parties of Turkish Aviation Industry.
- First step was taken for risk management activities in aerospace medium.
- Suggestions and analysis were made to create a platform in order to study on probabilistic analysis in further research.
- Risk management methods were adapted to a specific case study.
- Awareness for knowledge management and data organization activities was created.

As a conclusion, it can be stated that the main aims and objectives defined at the beginning of this study was achieved with the review of risk management methods, and with the application of proper risk management practices into a case study concerning the wave propagation in aerospace medium.

REFERENCES

The Aerospace Institute, 2003. '*Risk Management Quick Reference Guide'* http://www.aero.org/education/tai/documents/RiskMgtQuickRef.pdf#search=%22NASA%20RISK%20MATRIX%22> [Accessed at 15.03.06]

Arslan M., unpublished audio interview, 15.04.06, Turkish State Airports And Atc Authority, 2 hours

Arslan M., unpublished audio interview, 07.07.06, Turkish State Airports And Atc Authority, 2 hours

Burns et al, 2001, "NASA Risk Assessment and Management Roadmap" <http://www.sys.virginia.edu/students/capstone/past/cap2001/2001-04.doc> [Accessed at 06.04.06]

Carter, B., Hancock, T., Morin, J., Robins, N., 1996. *Introducing RISKMAN Methodology*, London: Stationery Office Ltd.

Celikbilek H. unpublished audio interview, 05.08.06 TUBITAK, 2 hours.

Australia Civil Aviation Authority Department of Aviation, 2001, '*ILS Operational Notes'* <www.airservices.gov.au/aboutus/corpdocuments/ILS_Operational_Notes.pdf> [Accessed at 05.05.06]

Conrow, E.H., 2003. *Effective Risk Management: Some Keys to Success*, Second Edition, Virginia: American Institute of Aeronautics and Astronautics Inc

Cornel & Regal, 1997. Normative Engineering Risk Management Systems Reliability Engineering and System Safety 57(1997) p. 159-169

Creswell, J. 2003. *Research Design*, Second Edition, Thousand Oaks: Sage Publications Inc.

Dallas, M.. F. 2006. *Value & Risk Management- A Guide to Best Practice*, Oxford : Blackwell Publishing Ltd.

De Giorgio, 2002. "*Understanding Your Risk The risk Assessment Process*" <http://www.nepss.org/presentations/1> [Accessed at 06.04.06]

Department of Defence (DoD) and Department of Transportation (DoT), 2003. '*2001 Federal Navigation Systems'*, <http://www.navcen.uscg.gov/pubs/frp2001/FRS2001.pdf> Accessed at [17.05.06]

Department of Defence (DoD) and Department of Transportation(DoT), 2006. '*2005 Federal Radio Navigation Plan*', <http://www.navcen.uscg.gov/pubs/frp2005/2005%20FRP%20WEB.pdf> [Accessed at 20.06.06]

EUROCONTROL, 2001. '*Risk Management Plan'*, < www.eurocontrol.int/safety/ _ Risk_Management_Plan_Iss_1_0.pdf> [Accessed at 15.03.06]

Expert Choice, 2005. <http://www.expertchoice.com> [Accessed at 15.08.06]

Fellows, R., Liu, A. 2003 *Research Methods for Construction*, Second Edition, Oxford: Blackwell Publishing Company.

Fairly, R., 1994. Risk Management for Software Projects, *IEE Software*, 11(3) p.57-67

Finnie G.R. & Witting, G.E 1999. An Intelligent Web Tool for Collection of Comparative Survey Data with an Application to IS Curriculum Design *Proc. 10th Australasian Conference on Information Systems*

Flight International, 2006. 'Modelling may end ILS interference' 17 January http://www.flightglobal.com/Articles/2006/01/17/Navigation/251/204119/+Modelling+may+end+ILS+interference.html [Accessed at 04.09.06]

Forman, E. H. and Gass, S. I. 2001. ‘The Analytic Hierarchy Process: An Exposition’ , *Operations Research* 49(4): 469-486 .

Gittins, R. 1999, “*An investigation into methods and concepts in qualitative research*” <http://www.sesi.informatics.bangor.ac.uk/english/home/research/technicalreports/sesi-020/formats/SESI-020.pdf> [Accessed at 04.04.06]

Gonzales P. 2000. Risk Management Procedures Application of Technical Risk Assessment in FESTIP, *Acta Astronautica,* 47(2-9), p. 677-686

Greenfield, 1998. “*NASA Risk Management: Risk As A Resource*” <http://www.hq.nasa.gov/office/codeq/risk/risk.pdf> [Accessed at 15.04.06]

Greenfield A., 2001. ‘*Risk Management What We Have Learned Symposium on Risk*’ <www.hq.nasa.gov/office/codeq/risk/incose.pdf> [Accessed at 20.05.06]

Gupta S.S. Dey P.K 2001. Risk based model aids selection of pipeline inspection & maintenance strategies *Oil Gas* p.54-60

Heller S. 2006. Managing Industrial Risk- Having a tested and proven system to prevent and assess risk *Journal of Hazardous Materials* 130(2006) p.58-63

Henley, E. J., Kumamoto, H., 1981. *Reliability Engineering and Risk Assessment*. Englewood Cliffs, USA: Prentice-Hall

Howde G.K., 2000. Frequency Management and SETI:Threats to SETIObservations in the 1-3 GHz Band *Acta Astronautica* 46(10) p. 677-682

HV Technologies, 2006. ‘*Avionics Test System’* <http://www.hvtechnologies.com/images/products/emc%20products/eaircraft.pdf#search=%22lightning%20avionics%20tests%22> [Accessed at 06.04.06]

Institution of Civil Engineers (ICE), 2005. ‘*Risk Analysis and Management for Projects (RAMP)’,* London:Thomas Telford Publishing Ltd.

Instrument Landing System, [n.d] <http://www.gmu.edu/departments/seor/student_project/syst101_00b/team05/2> [Accessed at 05.05.06]

ISYAM Communications and Spectrum Management Research Centre, 2004, '*FM Broadcasting Module'* <http://www.isyam.bilkent.edu.tr/> [Accessed at 05.08.06]

Janic M., 2000. An assessment of risk and safety in civil aviation, *Journal of Air Transport Management* 6 (2000) p.43-50

Jean-Luc Larrere, 2004. Risk management and lessons learned solutions for satellite product assurance *Acta Astronautica* 55 (2004) p. 811 – 816

Kaya O., unpublished audio interview, 19.03.06 Turkish Civil Aviation Authority, 1 hour

Kinali C., unpublished audio interview, 16.04.06 Turkish State Airports And Atc Authority, Esenboga, 1 hour

Kumar, R. 1999. Research Methodology, London: SAGE Publications.

Lang, G., Heiss, G. D., 1985. *A Practical Guide to Research Methods*, New York: University Press of America.

Macharis et. al., 2004. PROMETHEE and AHP: The design of operational synergies in multi-criteria analysis. Strengthening PROMETHEE with ideas of AHP *European Journal of Operational Research* 153(2004) p.307-317

Moore N., 2000. *How to do research*, 3rd edition London: Library Association Publishing.

NASA, [n.d]. '*Example of Risk Information Sheet'*, <appel.nasa.gov/ask/pdf/58844main_Risk_Info_Sheet.pdf> [accessed at 06.08.06]

NASA Office of Safety and Mission Assurance, 2002. *NASA Risk Management Procedures and Guidelines*

Osei-Bryson K.M. & Ngwenyama O.K., 2006. Managing Risks in Information Systems Outsourcing: An Approach to Analyzing Outsourcing risks and Structuring Incentive Contracts *European Journal of Operational Research* 174(2006) p.245-264

Ozkaya A., unpublished audio interview, 10.07.06 Helicopter 5th Maintenance Centre, Department of Avionics, 2 hours

Raftery, J. 1994. *Risk Analysis in Project Management*, London: St. Edmundsbury Press Ltd.

Rakov & Uman, 2003. The interaction of lightning with airborne vehicles *Progress in Aerospace Sciences* 39 (2003) 61–81

Roger M., [n.d.] '*History Of Aircraft Landing Aids US Centennial Of Flight Commission*' <http://www.centennialofflight.gov/essay/Government_Role/landing_nav/POL14.htm> [Accessed at 05.05.06]

Saaty L. T. 1982. *Decision Making for Leaders* Wadsworth: Lifetime Learning Publications

Saaty L. T., 1986. Axiomatic Foundation of the Analytic Hierarch Process *Management Science* 32(7) p.841-855

Saaty L.T. 1990. An Exposition Of The AHP In Reply To The Paper "Remarks On The Analytic Hierarchy Process" *Management Science* 36(3), p.259-268

Saaty L.T. 1994. How to make a decision: The analytic hierarchy process. *Interfaces*, 24(6) p.19-43

Saaty L. T., 2006. Rank from Comparisons and from Ratings in the Analytic Hierarchy/ Network Processes *European Journal of Operational Research* 168(2006) 557-570

Sadiq R. Tahir H. Vetich B. Bose N., 2004. Risk based decision making for drilling waste discharges using a fuzzy synthetic evaluation technique *Ocean Engineering* 31(2004) p.1929-1953

Safety Regulation Group, 1998. '*ILS Immunity to FM Broadcast*', < www.caa.co.uk/docs/33/FOD199802.PDF> [Accessed at 05.05.06]

Schroer R., 2003. Navigation and Landing, *IEEE AES Systems Magazine*, p.27-36 <www.ewh.ieee.org/soc/aes/taes/aes404/aes00-03.pdf> [Accessed at 15.04.06]

The Sirena Consortium, [n.d.]. *'Exploitation Requirements'* <www.aero-scratch.net/Dissemination/Sirena/D_3.pdf > [Accessed at 06.08.06]

Stamatelatos M., Vesely W., Dugan J., Fragola J., 2002. NASA Fault Tree Handbook with Aerospace Applications

Student Peer Evaluations Using the Analytic Hierarchy Process Method, 1995. <http://fie.engrng.pitt.edu/fie95/4c3/4c31/4c31.htm> [Accessed at 06.08.06]

Suh B. Han I, 2002. The IS Risk Analysis Based on a Business Model *Information & Management* 41(2003) p.149-158

Tang H.K., 2005. Adoption of navigation Technologies: Five Historical and contemporary cases *Technological Forecasting& Social Change* p.1-15

TSAA Air Navigation Department, 2002. *ILS Investigation Notes*, Ankara

TSAA Department of Navigation, 2003. *Radio Navigation Aids – Training Notes*, Ankara

Tsaur R.C., 2002. Extrapolating Internet Users in Taiwan by Risk Assessment *An International Journal of Computers & Mathematics with Applications* 46(2003) p.1725-1734

Turkish Armed Forces (TAF), [n.d], Instrument Landing System, Helicopter 5th Maintenance Centre, Department of Avionics, Ankara.

Tweeds, Chartered Quantity Surveyors, Cost Engineers and Construction Economists 1996. *Guide to Risk Analysis and Management*, Oxford: Laxton`s.

FURTHER READING

Newman Stewan J. 2001. Failure Space A Systems Engineering Look At 50 Space System Failures *Acta Astronautica* 48(5-12) p. 517-527

Central Queensland University, 2006. 'Harvard (author-date) Referencing Guide' www.cqu.edu.au/referencing/ref_style/harvard_guide.pdf [Accessed at 06.08.06]

APPENDIX A

PROBABILSTIC RISK ASSESSMENT METHODS

Probabilistic risk assessment methods evaluate the failure scenarios in a probabilistic way identifying the risks and ranking the individual contributors. Probabilistic risk assessment methods 'examine complex systems to assess the probabilities and consequences of different failure modes, with particular attention to the risk of catastrophic failure' (Henley & Kumamoto 1981 p.15). PRA can be performed to 'assure that an existing system is 'safe enough', to set priorities among a set of possible risk management options, or to validate a proposed engineering system design' (Cornel & Regal, 1997 p. 160). These probabilistic methods can be counted as Probabilistic Risk Assessment (PRA), Fault Tree Analysis (FTA), Failure Modes and Effects Analysis (FMEA) or Reliability Block Diagram etc. Some of these risk assessment methods are deductive and some of them are inductive. Inductive approaches involve reasoning from individual cases to general conclusion. If in the consideration of a certain system, a particular fault or initiating condition is postulated and an attempt to ascertain the effect of that fault or condition on system operation is made an inductive system analysis is being conducted. Inductive approaches are termed bottom up approaches that start at the bottom at the failure initiators then proceeds upwards to achieve effects of the resulting system (NASA 2003). The following approaches are obtained from NASA Risk Management Guide and Procedures. (NASA Office of Safety and Mission Assurance, 2002)

- **The Part Count Approach:** All the components are listed along with their estimates probabilities of failure and then the individual component probabilities are then added and this sum provides an upper bound on the probability of system failure. It is obvious that this approach is a pessimistic estimate since it assumes that any single component failure will produce complete system failure.

- **Failure Mode and Effect Analysis (FMEA):** This analysis is a bit less conservative analysis with respect to the Part Count Approach. The failure modes of the components are separated as critical or non-critical and the probability of the failure of the system is calculated with respect to the critical failure modes. The basic assumption is single failure causes system failure. The probabilities of critical failures are added and the sum gives the system failure.

- **Failure Mode Effect and Criticality Analysis (FMECA):** This analysis is similar to FMEA except its detailed approach in criticality analysis and its method to provide assurances and control for limiting the likelihood of such failures. The four fundamental facets of this method are fault identification, potential effects of the fault, existing or projected compensation, and summary of findings. These facets are analysed under four columns, which ask for risk identification, analysis and mitigation. This analysis deals with single component or event as the other analysis and do not consider combination of component faults.

- **Preliminary Hazard Analysis (PHA):** This method is primarily deals with the potential hazards, which are occurred by the system to plant personnel or other humans. The simplest columnar format for this analysis includes such columns; Component subsystem hazard modes, possible effects, compensation and control, findings and remarks.

- **Fault Hazard Analysis (FHA):** This technique is especially can be used for analysing faults that cross organizational interfaces. FHA includes such columns; component identification, failure probability; failure modes, percent failures by mode, effect of failure, identification of upstream component that could command or initiate the fault in question, factors that could cause secondary failures (failures outside the design envelope), and remarks.

- **Double Failure Matrix (DFM):** This approach provides an extension of inductive approaches from single failure causes to multiple failure causes. In this approach the multiple causes are categorized according to the severity of the system effect. The basic fault severity categories are given as negligible, marginal, critical and catastrophic in MIL-STD-882. This categorization can be refined in several ways according to the detail level of the analysis.

- **Reliability Block Diagram (RBD):** This model is a diagram of blocks that represent distinct elements such as components or subsystems in a system. In this approach separate blocks representing each system element are structurally combined to represent the potential flow paths through the system. This is a very helpful approach to understand the flow path of the system entirely and to find the potential faults. Software exists to convert RBDs into FTAs.

In deductive methods, it is postulated that the system itself has failed in a certain way and an attempt is made to find out what modes of system or subsystem behaviour contribute to its failure. It constitutes reasoning from the general to specific. (NASA Office of Safety and Mission Assurance, 2002 p.11)

- **Fault Tree Analysis:** 'Fault Tree Analysis (FTA) is a graphical model that displays the various combinations of equipment failures and human errors that can result in the main system failure of interest' (De Giorgio, 2002). FTA starts with the undesired event and traces backward to the necessary and sufficient causes. FTA starts with determining the top event. After considering the top event, main causes and their relationships, a FTA model for the defined top event can be built by the event symbols and gate symbols (and, or etc.) The main problem in the evaluation of the probability of the top event is the availability of probability of the basic event data. To make this analysis the probability of the basic event should be known.

APPENDIX B

INTERVIEWS & QUESTIONNARIES

For the risk identification phase, four interviews were done with the participation of;

- Mr. Orkun Kaya at the department of Turkish Civil Aviation Authority at 19 March 2006.
- Mr. Mevlüt Arslan Director of Flight Aids Div, Turkish State Airports And Atc Authority, 15 April 2006
- Mr. Abdurrahman Çetin Kınalı, ILS Systems Chief, Turkish State Airports And Atc Authority, Esenboga , 16 April 2006
- Yzb. Atınç Özkaya Electric Electronics Eng., Helicopter 5th Maintenance Centre, Director of Avionics Div., 10 June 2006

The interviews were started at March 2006 with Mr Orkun Kaya, Electric Electronics Engineer, from the department of Turkish Civil Aviation Authority. This interview was an unstructured one based on the availability of historical or statistical data at Turkish Civil Aviation Authority. Unfortunately any statistical or historical data could not be accessed from Turkish Civil Aviation Authority. However, this interview was a good start to understand the availability of risk management approach at Turkish Aviation Industry.

The other three interviews were semi-structured interviews performed for risk identification. Three main questions were asked at this stage.

- What are the reasons of RF signal derogation or interruption during the ILS operation?

- Is there any statistical or historical data kept or analysis done about these problems?
- What are the main consequences of these derogation or interruption?

Following the semi structures interviews, in the risk analysis phase, questionnaires were developed and performed.

The questionnaires were done with the participation of;

- Mr. Mevlüt Arslan, Turkish State Airports And Atc Authority, Director of Flight Aids Div.
- Mr. Abdurrahman Çetin Kınalı, ILS Systems Chief, Turkish State Airports And Atc Authority, Esenboga
- Yzb. Atınç Özkaya, Electric Electronics Eng. M. Helicopter 5th Maintenance Centre, Director of Avionics Div.
- Mr. Huseyin Çelikbilek, Project Manager (Avionics-Helicopter Pilot), TUBITAK
- Mr. Gökhan Karakuş, A/C Pilot, Turkish Airlines
- Mr. Levent Güçlü, A/C Pilot, Turkish Airlines
- Bnb. Ertan Güngör, Helicopter Pilot, Turkish Armed Forces
- Yzb. Rahmi Özmen, Helicopter Pilot, Turkish Armed Forces
- Yzb Murat Mocan, A/C Pilot, Turkish Airforce

The participants were given the following questionnaire.

The definitions of risk likelihood, risk consequence and risk matrix are given as below.

- **Likelihood** is the probability that an identified risk event will occur.

- **Consequence** of a risk is an assessment of the worst credible potential result of that risk.

- **Risk matrix** is a matrix to evaluate the risk severity by taking into account the likelihood and consequence probabilities.

TABLE B 1 Likelihood Level

What is the Likelihood of This Risk?		
LEVEL	**PROBABILITY**	**DESCRIPTION**
5	VERY HIGH	Continously Experienced (Frequent)
4	HIGH	Will Occur Frequently (Probable)
3	MODERATE	Will Occur Several Times (Occasional)
2	LOW	Unlikely, But Can Reasonably Expected To Occur (Remote)
1	VERY LOW	Unlikely To Occur, But Possible (Improbable)

TABLE B 2 Consequence Level

What is the Level of Impact of This Risk?					
LEVEL	1	2	3	4	5
DESCRIPTION FROM TECHNICAL POINT OF VIEW	Minimal or No Impact	Mod. Reduction Same Approach Retained	Mod. Reduction but Workarounde Available	Maj Reduction but Workarounde Available	Unaceptable/ No Alternatives Exist

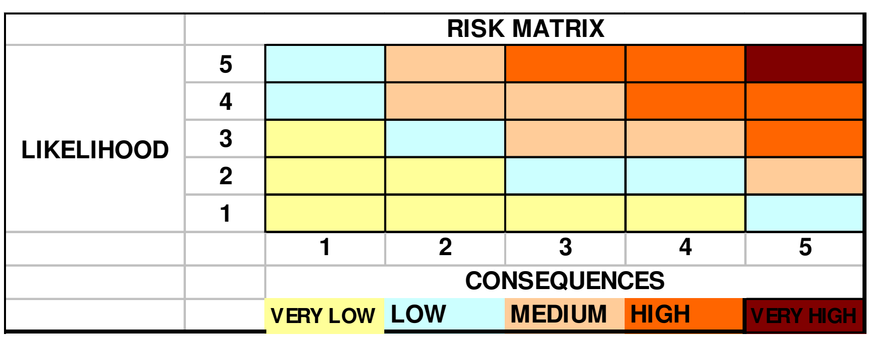

Figure B 1 Risk Matrix

Analysis 1: Can you please fill in the risk matrices given below using the score system presented at Table B 1 and Table B 2?

RISK EVENT 1	EM interference due to FM radio stations					
LIKELIHOOD	5					
	4					
	3					
	2					
	1					
		1	2	3	4	5
		CONSEQUENCES				
		VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

RISK EVENT 2	EM interference due to machines					
LIKELIHOOD	5					
	4					
	3					
	2					
	1					
		1	2	3	4	5
		CONSEQUENCES				
		VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

RISK EVENT 3	EM interference due to multipath					
LIKELIHOOD	5					
	4					
	3					
	2					
	1					
		1	2	3	4	5
		CONSEQUENCES				
		VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

RISK EVENT 4	EM interference due to change of permeability					
LIKELIHOOD	5					
	4					
	3					
	2					
	1					
		1	2	3	4	5
		CONSEQUENCES				
		VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

RISKEVENT 5	EM interference due to RF jammer					
LIKELIHOOD	5					
	4					
	3					
	2					
	1					
		1	2	3	4	5
		CONSEQUENCES				
		VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

RISKEVENT 5	EM interference due to powerful systems as RF jammer					
LIKELIHOOD	5					
	4					
	3					
	2					
	1					
		1	2	3	4	5
		CONSEQUENCES				
		VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

RISK EVENT 6	Interference due to systems operating at adjacent RFs					
LIKELIHOOD	5					
	4					
	3					
	2					
	1					
		1	2	3	4	5
		CONSEQUENCES				
		VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

RISK EVENT 7	Derogation of the ILS signal due to lightning					
LIKELIHOOD	5					
	4					
	3					
	2					
	1					
		1	2	3	4	5
		CONSEQUENCES				
		VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

Analysis 2: Two 7 to 7 matrices are given below. The main aim of this study is to compare each risk with respect to others considering first the likelihood then the consequence as the main criteria. The 1-9 score system is given below. Can you

please compare each risk according to the scores in this table for each risk combinations?

LIKELIHOOD	R1	R2	R3	R4	R5	R6	R7
R1	1						
R2		1					
R2			1				
R4				1			
R5					1		
R6						1	
R7							1

IMPACT	R1	R2	R3	R4	R5	R6	R7
R1	1						
R2		1					
R2			1				
R4				1			
R5					1		
R6						1	
R7							1

SCORES AND THEIR MEANINGS TO FILL IN THE MATRIX
1-R1 has equal importance with R2 with respect to C1.
3-R1 has slightly more importance than R2 with respect to C1.
5- R1 has essentially more importance than R2 with respect to C1.
7- R1 has a lot more importance than R2 with respect to C1.
9- R1 has extreme importance and totally dominates R2 with respect to C1.
1/3- R2 has slightly more importance than R1 with respect to C1.
1/5- R2 has essentially more importance than R1 with respect to C1.
1/7- R2 has a lot more importance than R1 with respect to C1.
1/9- R2 totally dominates R1 with respect to C1.
You can also use the intermediate numbers as 2,4,6,8 or 1/2,1/4,1/6,1/8

In this study, all the participants were always reminded that they are comparing each risk with respect to other one according to only one criterion in each matrix.

APPENDIX C

INSTRUMENT LANDING SYSTEM

C.1 HISTORY OF ILS

Smooth and safe landing is the last step of successful flight, which can change the turn of fortune's wheel to a fatal direction. In the past years, pilots were flying with simple but dangerous approaches as using farms or fields for landing or facing any direction that gave them the best angle relative to the wind. However, today, and air traffic is developed and landings became limited to certain directions to increase safety. Moreover airports were built up for secure landing. Landing aids were developed to help pilots to find the correct landing course and to make safe landing. In the late 1920s Lighting has been used as one of the most important landing aids. To be easily found in the nights, landing fields were marked with rotating lights. In the early 1930s, airports were installed with approach lighting, which helped the pilots to descend at the correct angle. This approach path was called the glide path or glide slope. International Civil Aviation Organization (ICAO) made landing approach easier by standardizing the colours of the lights and their rates of flash. (Roger, [n.d.]) Radio navigation aids has been started to be used around 1930s. Radio technology matured and started to be used all over the world. Radio stations increased and this development served as a basis for the use of radio aids in landing. (Tang, 2005) The four-course radio range where the pilot was guided by the strength of Morse code signals was first introduced in 1929. Moreover low-frequency radio beam was tried experimentally. “These radio beams flared outward from the landing point like a “v,” so at the point farthest from the runway, the beams were widely separated and it was easy for the pilot to fly between them. But near the landing point, the space between the beams was extremely narrow, and it was often easy for the pilot to miss the exact centre point that he had to hit for landing. Another new method had a pilot tune into a certain frequency at a checkpoint far from the airport, and then uses a stopwatch to descend at a precise rate to the touchdown area of the runway. This method was also difficult. Another landing aid; the introduction of the slope-line approach system was a very important approach in safe landing. Developed in the 1940s, the aid consisted of lights in rows that showed the pilot a simple funnel of two rows that led him to the end of the runway. Other patterns showed him when he was off to the right or left, or too high or low. The system was inexpensive to build and operate although it had some limitations and was not suitable for certain airports. (Roger, [n.d.])

The Instrument Landing System (ILS) incorporated the 'best features of both approach lighting and radio beacons with higher frequency transmissions' (Roger, [n.d.]) It was using the same radio technology used that days but instead of music or speech it broadcast radio signals 'modulated by two tones and used directional antenna arrays' (Tang, 2005). It was a consequence in aviation industry searching ways to deal with foggy and stormy weather. ILS was painting an electronic picture of the glide slope onto a pilot's cockpit instruments. It is known that first tests of the system began in 1929, and the Civil Aeronautics Administration (CAA) authorized installation of the system in 1941 at six locations. The first ILS landing was carried out by U.S. passenger airliner in 1938. Pennsylvania-Central Airlines Boeing 247-D flew from Washington, D.C., to Pittsburgh and landed in a snowstorm by the help of the ILS system (Roger, [n.d.]). By World War 2, ILS went in to operation in US military forces. There is not a significant change in the system architecture of modern ILS since that time. (Tang, 2005)

C.2 ILS OPERATION PRINCIPLES

ILS ground station includes two transmitters called Localizer and Glide Path and three markers. This system is used with a standardised lighting system and DME (distance measurement equipment).

Localizer operates between 108.11- 111.95 MHz (VHF) frequency band. It shows weather the plane is right or left to the imaginary lateral centre line. The transmitting antennas are located approximately 1000 ft distance from the end of the landing runway. They radiate field patterns of 150 Hz modulated energy which is known as blue sector and 90 Hz modulated energy which is known as yellow sector. They provide a course of guidance in azimuth. When a pilot lands by using the outer marker, the blue sector is always at the right hand side of him. The intersection of these two patterns creates a section called localizer course and localizer centre line. Any airplane in this localizer course can make safe landing. The course line is a locus of points of equal 90-150 hertz modulation. It is aligned along the runway centreline extended in both directions and may be separated at the localizer antenna onto a back course and front course. The angle of the localizer is 3° which means the landing runway is located at 1, 5° left and 1, 5° right with respect to localizer centre line. Localizer antennas can also transmit voice to air vehicles. (Australia Civil Aviation Authority, 2001; TSAA Department of Navigation, 2003)

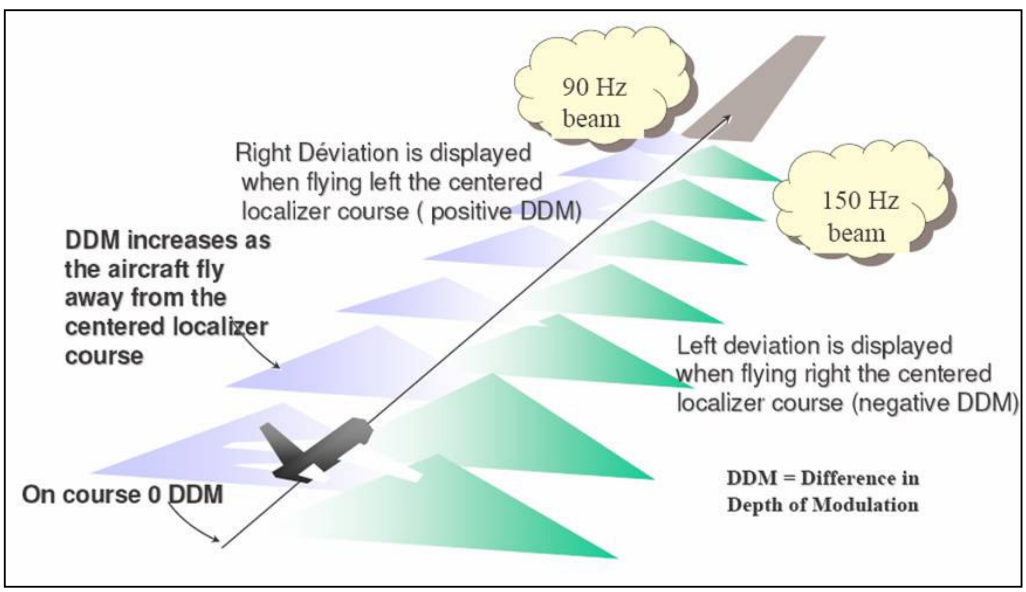

Figure C 1 ILS Localizer Principles (TAF, [n.d.])

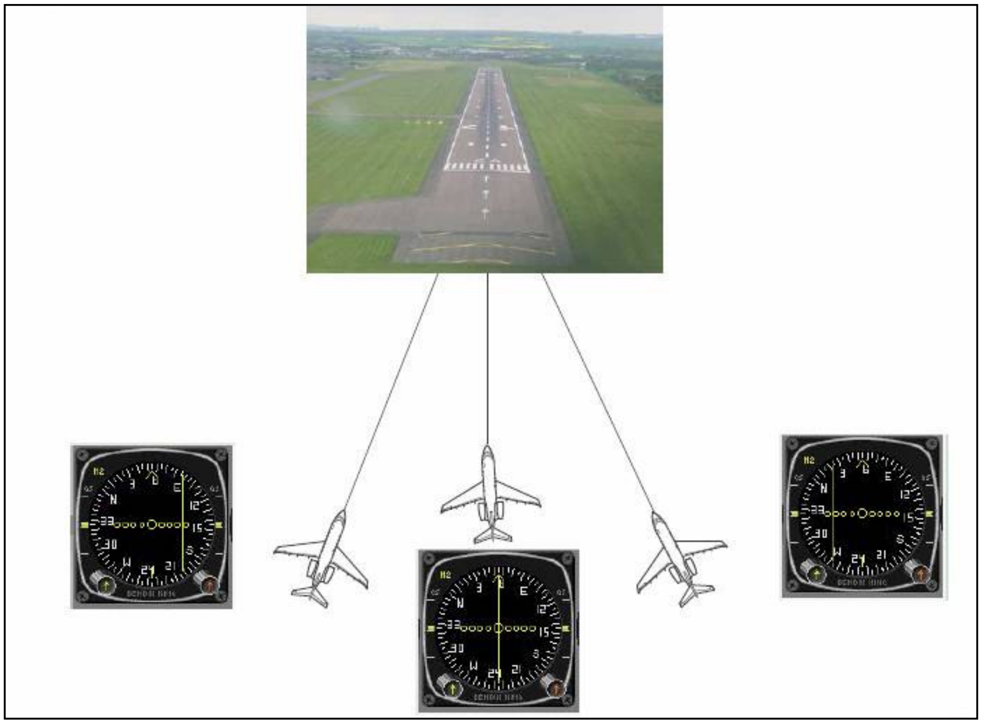

Figure C 2 ILS Localizer: Display Information (TAF, [n.d.])

Glide path shows weather the plane is above or below the imaginary glide slope. Glide path operates between 329.15- 335 (UHF) MHz frequency band. Glide path antennas create 2 patterns like the localizer antennas. As the localizer antennas, one is modulated at 90 Hz, and the other one is modulated at 150 Hz. The line of glide path is a locus of points of equal 90-150 hertz modulation. (Australia Civil Aviation Authority, 2001; TSAA Department of Navigation, 2003)

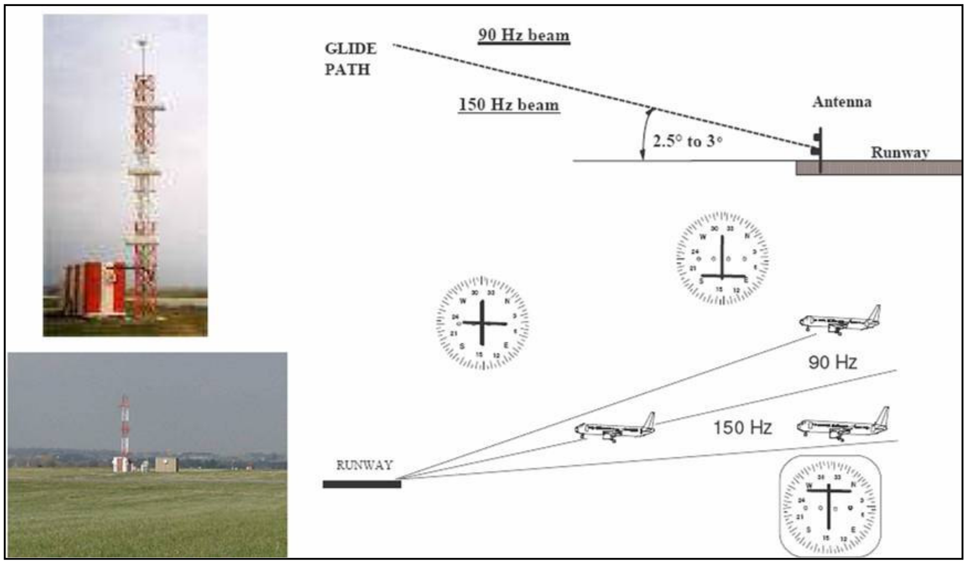

Figure C 3 ILS Glide Slope (TAF, [n.d.])

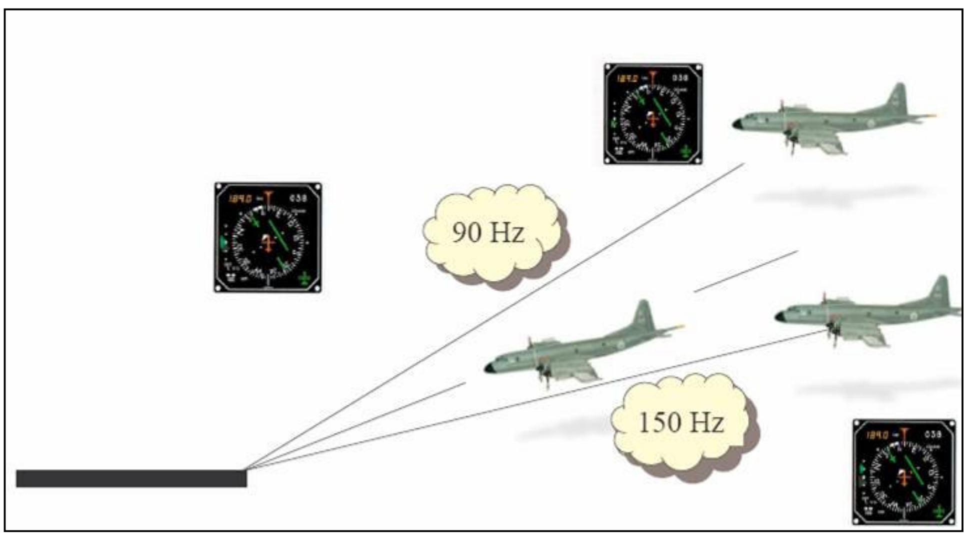

Figure C 4 ILS Glide Slope (TAF, [n.d.])

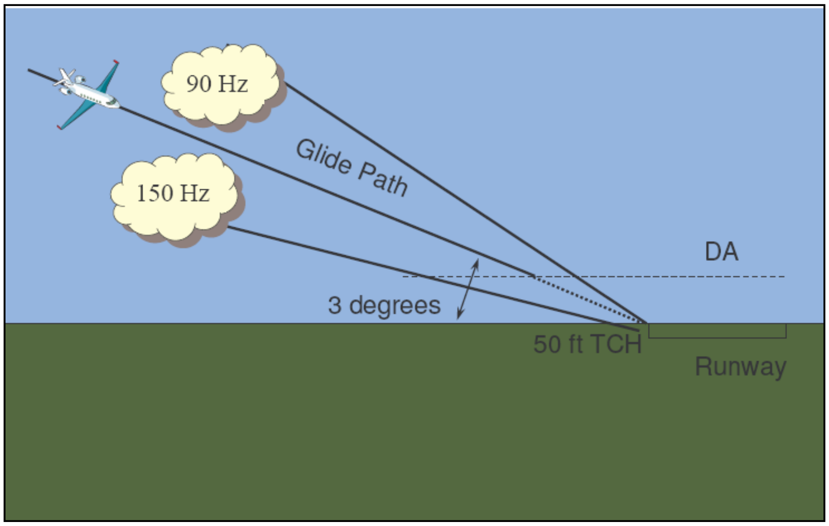

Figure C 5 ILS Glide Slope (TAF, [n.d.])

Each glide path transmitter is synchronized with the localizer frequency, which means that, when the localizer frequency is selected on the control unit, glide path receiver automatically tunes to correct frequency. Moreover when DME is used instead of markers, it is similarly tuned to correct frequency. This pairing of the localizer and gliding path frequencies is determined by ICAO and published as an international standard. . (Australia Civil Aviation Authority, 2001)

Localizer (MHz)	Glideslope (MHz)	Localizer (MHz)	Glideslope (MHz)	Localizer (MHz)	Glideslope (MHz)	Localizer (MHz)	Glideslope (MHz)
108.10	334.70	109.10	331.40	110.10	334.40	111.10	331.70
108.15	334.55	109.15	331.25	110.15	334.25	111.15	331.55
108.30	334.10	109.30	332.00	110.30	335.00	111.30	332.30
108.35	333.95	109.35	331.85	110.35	334.85	111.35	332.15
108.50	329.90	109.50	332.60	110.50	329.60	111.50	332.90
108.55	329.75	109.55	332.45	110.55	329.45	111.55	332.75
108.70	330.50	109.70	333.20	110.70	330.20	111.70	333.50
108.75	330.35	109.75	333.05	110.75	330.05	111.75	333.35
108.90	329.30	109.90	333.80	110.90	330.80	111.90	331.10
108.95	329.15	109.95	333.65	110.95	330.65	111.95	330.95

Figure C 6 ILS Assigned Paired Channels (TAF, [n.d.])

Three markers inform the pilot about the distance of the plane to the beginning to of the landing runway. They are, the outer marker located at 4-7 NM from the beginning of the runway, the middle marker located at 3500 feet distance from the beginning of the runway and the inner marker located at the 50 ft from the beginning of the runway. They operate on 75MHz frequency. The signals of outer marker are modulated at 400Hz. It provides height, distance and equipment functioning checks to aircraft on final approach. When a plane passes from the broadcasting area of the outer marker, blue coloured lamb is turned on. The signals of the middle marker are modulated at 1300Hz. It indicates the imminence in low visibility conditions. When the plane passes from the broadcasting area of the middle marker, amber coloured lamb is turned on. The inner markers provide altitude information. It is modulated at 3000 Hz, and white coloured lamb is turned of when a plane passes from the broadcasting area of the inner marker. (TSAA Department of Navigation, 2003; Australia Civil Aviation Authority, 2001)

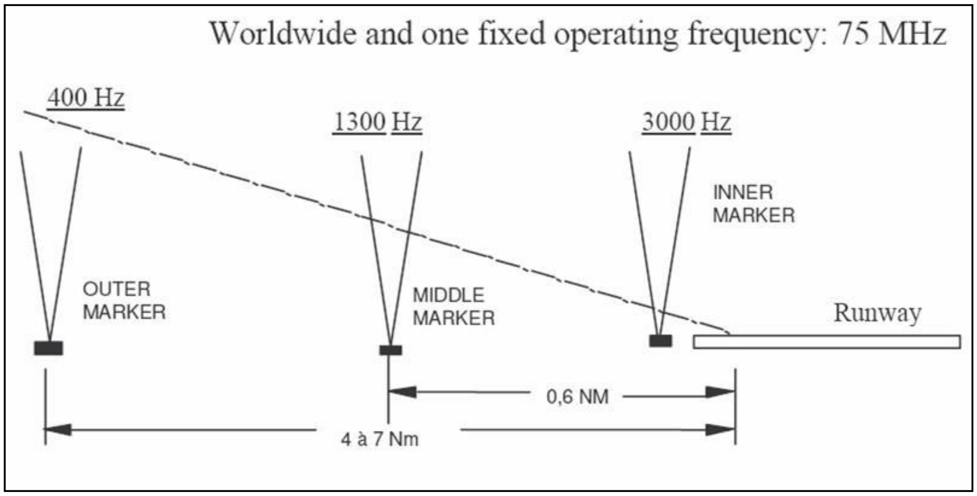

Figure C 7 ILS Marker Beacon (TAF, [n.d.])

	IM	MM	OM
CODE	dots	Dashes and dots	dashes
RATE	6 dots/s	2 dashes/s 6 dots/s	2 dashes/s
FREQUENCY MODULATION	3 000 Hz	1 300 Hz	400 Hz
LAMP	white	Amber	Blue

Figure C 8 ILS Marker Beacon (TAF, [n.d.])

ILS receiver in the airplane uses the received ILS signal to help the pilot to make a perfect landing in poor visibility conditions due to foggy and stormy weather. It provides landing guidance through a display unit as shown in Fig C 9. The display shows how far the craft deviates from the vertical glide path and imaginary lateral centre line to the runway touch down point. Approach lighting and other visibility equipment are part of the ILS and also help the pilot in safe landing. (Tang, 2005)

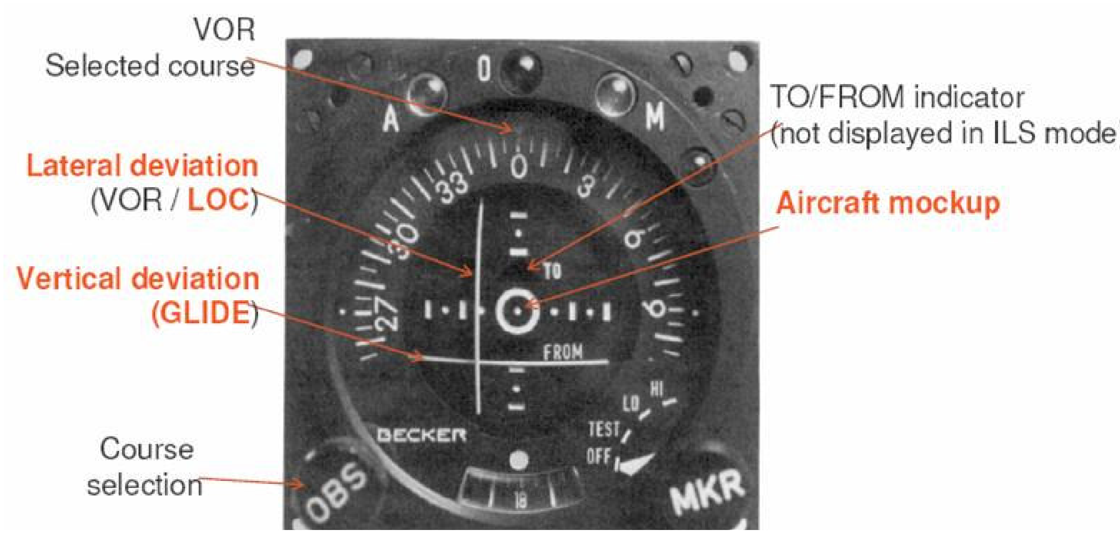

Figure C 9 ILS CDI Display (TAF, [n.d.])

Figure C 10 ILS Glide Slope (TAF, [n.d.])

Figure C 11 ON Boards ILS gauge from a Boing 747-400 aircraft (TAF, [n.d.])

The antennas located on aircraft are shown in Figure C-12 below. Localizer aerials are generally located in the vertical stabilizer. If a third localizer receiver is installed its aerial is located in the nose section, generally within the radome provided for weather radar. The glide path aerial is normally located on the nose of the aircraft or within the radome. But, on very large aircraft or on the crafts that land with an unusually high nose attitude, aerial may be located on the underside of the aircraft or on the landing gear. The reason why it is located such that is; aerial on the nose may result in the wheels being too low over the threshold. By locating them underside or on the landing gear, correct height guidance is obtained. Marker beacon aerials are also located underneath the aircraft. (Australia Civil Aviation Authority, 2001)

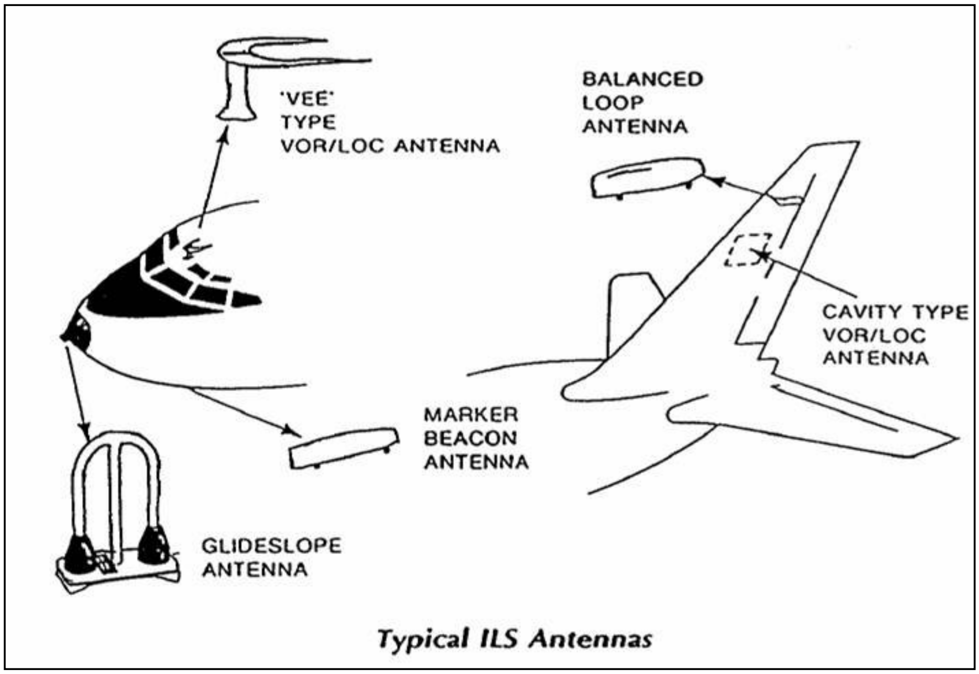

Figure C 12 ILS Antennas (TAF, [n.d.])

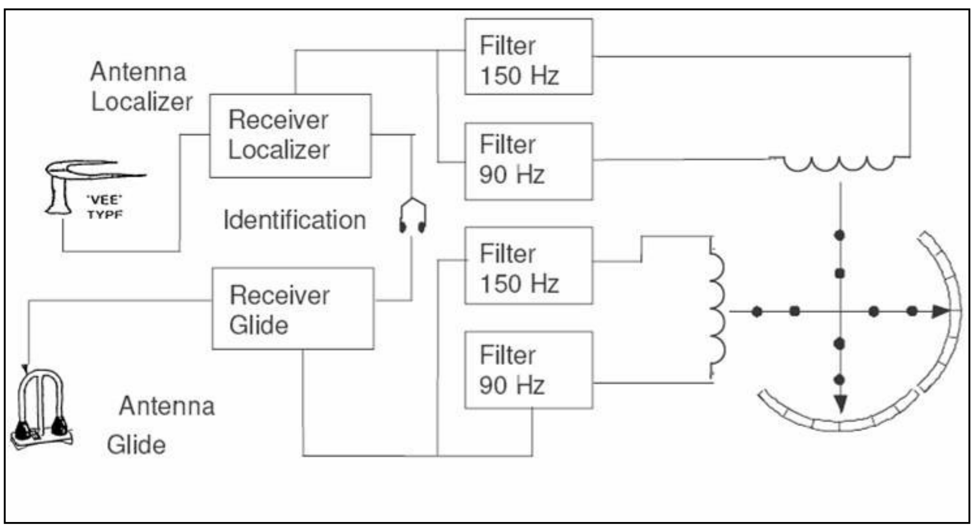

Figure C 13 ILS Receiver Block Diagram (TAF, [n.d.])

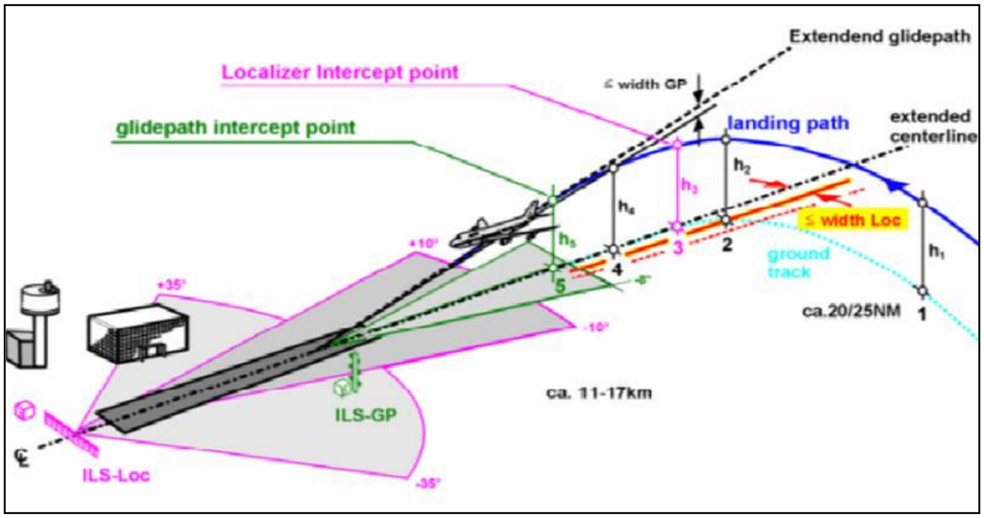

Figure C 14 ILS Glide path- Localizer (TAF, [n.d.])

Today's ILS has three different kinds which are classified with respect to their level of performance. CAT1 (Category 1) is the lowest acceptable standard. CAT 2 has much more requirements and CAT 3 has severe requirement for landing. Below the performance requirement of different ILS classes are given; (TSAA Air Navigation Department, 2002). To change the ILS categories from CAT1 to CAT2/CAT3 standards is highly recommended to Turkish Authorities by EUROCONTROL. It is stated that; today the Turkish airports equipped with ILS serves at CAT 2 requirements. (Arslan M., 2006). The FAA operates 1,275 ILS systems in the NAS of which 225 are localizer only and 115 of which are Category II or Category III systems. In addition, the DoD operates 160 ILS facilities in the U.S. (DoD & DoT, 2006)

Table C-5-1 ILS Categories

CATEGORIES	**Decision Height (DH)**	**Runway Visual Range (RVR)**
CAT 1	DH ≥ 60 m (200 ft)	RVR ≥ 550 m
CAT 2	60 m ≥ DH ≥ 30 m	RVR ≥ 350 m
CAT3a	DH < 60 m	RVR ≥ 200 m
CAT3b	DH < 15 m	200 m > RVR ≥ 50 m