HUMAN RELIABITIY AND FLIGHT SAFETY

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This paper through a systematic view considers the subject of Airplane -Flight crew system, as an intricate system of Man and Machine. And we study its Reliability on Flight Safety with an emphasis on Human factor. Aiming at the above goals:
As we define the constituents of the system from a Socio-Technical perspective, introduce main factors involved in brining about Human errors in such a system. Finally we discuss the methods and procedures for the reduction of these errors which leads eventually to the promotion of Human reliability and consequently the Flight Safety.

Keywords: Human Factors, Flight Safety, Human Reliability, Socio - Technical System

1. Introduction

The subject matter of Reliability and Flight Safety enjoys crucial importance and apex position in flight industry as well as in public opinion. Obviously Flight Safety does not solely hinge on air plane and its navigation system (technical or hardware parts), but at the same time relays heavily on Human Factors which have multiple interaction with hardware and technical parts[1].
In this paper from a systematic outlook we have studied and scrutinized the subject. Accordingly at the outset we define our system which consists of the followings:
Air plane and its machinery and also crew and Human Factors related to Flight which has interaction with each other and finally environmental factors that have

overall effect on them. In this way we can call it a Socio-Technical System (STS) or in the other word a Man-Machine system which has the following two main elements or subsystem that as they interact with each others are under the influence of environmental factors as well.

- ***Technical Section:*** Including air plane and communication equipments for navigating air plan from control tower
- ***Social Section:*** Including crew and logistic personnel and their interaction
- ***Environmental Factors:*** Including natural phenomena such as weather condition, radiation and other environmental factors like the regulation for various operational and passage corridors.

From the Ergonomics prospective such a system is called Work system [2].
Named as such, socio-technical system, or a Work system which we call it here a flight work system, to take advantage of the findings of the scholars in these fields.

2. The Reliability of Man-Machine System

Scholars of Management and Ergonomics in systems consisting of Man and Machine are after the realization of following simultaneous goals:

- *Promotion of System Efficacy and Efficiency*
- *Promotion of System Reliability*

Keeping in mind that reliability in Nuclear and Flight Industry, for their special sensitivity compares to other industries, receives a higher degree of importance and must enjoy special attention [3].
Reliability of socio-technical system from one hand is depended on reliability of Machine and the equipment installed in the Work system that is to say Technical Reliability and from other hand is related to the Reliability of the people working at that system or Human Reliability.
Remembering that the main goal is the promotion of the system total Reliability; consequently the Socio-technical Reliability should be considered as an integrated theme.
In figure No. 1 the reliability in a Flight Work System , from a Socio-Technical prospect and also its effects on Flight safety, has been depicted schematically.
Considering the importance of the system total Reliability in Flight safety and to complete our discussion of this section, we will conclude the section by giving definitions of Technical and Human Reliability.

- ***Technical Reliability:*** It is part of the quality through which the behavior of system in a specified period (equipment/ part life period), with the

condition for their use , is being identified . In this way the effect of environmental factors on its function should be considered [4].

? ***Human Reliability:*** Is the Human competence for the fulfillment of a special duty in a fixed framework for an accepted period [5].

These competences include physical and psychological abilities together with necessary experiences and skills and moral and characteristics peculiarities. Remembering the Human error is possible that through proper arrangement one can reduce the probability of its occurrences [6].

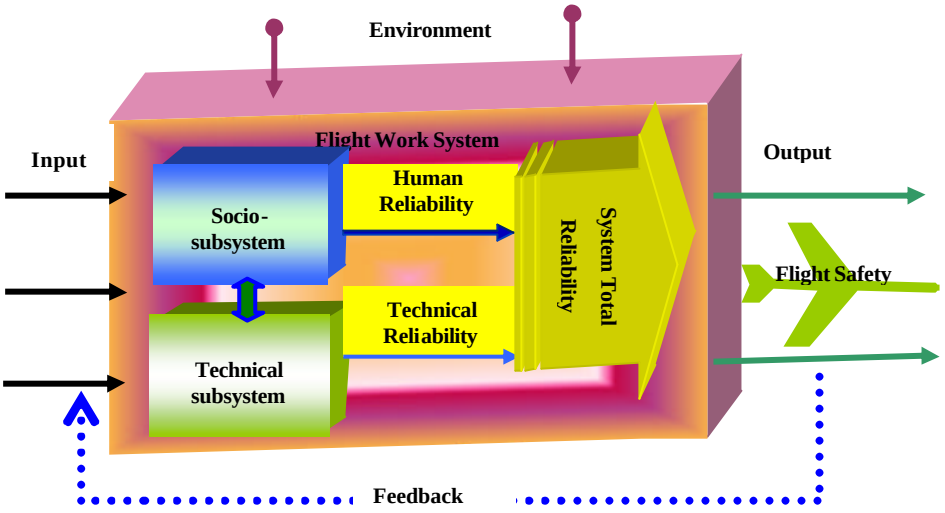

Figure 1: The effect of Human and technical reliability on flight safety

3. Causes for accident in Flight Work System

In this section by studying some statistics of the flight accidents we try to identify the cause of errors related to Flight Work System (Technical or Human Factor).

The potentiality of error is behind every Socio-Technical system [7]. The flight system is no exception. Despite the fact that the air transportation system is 14 times more reliable than road transportation's [8], yet the stress and anxiety in air passengers are 10 times more than the road passengers [9].

Consequently the air accidents have a more profound influence on public opinion, even on the crew and eventually on flight industry and its economy than the road accident. So preventing air accident or in fact upgrading flight safety and ever improving the coefficient of Reliability is a necessary action.

Statistics in this connection shows that air accidents due to Technical section in the passed half century have reduced considerably, nevertheless the Human-caused accidents have increased compare to Technical factors (figure No. 2).

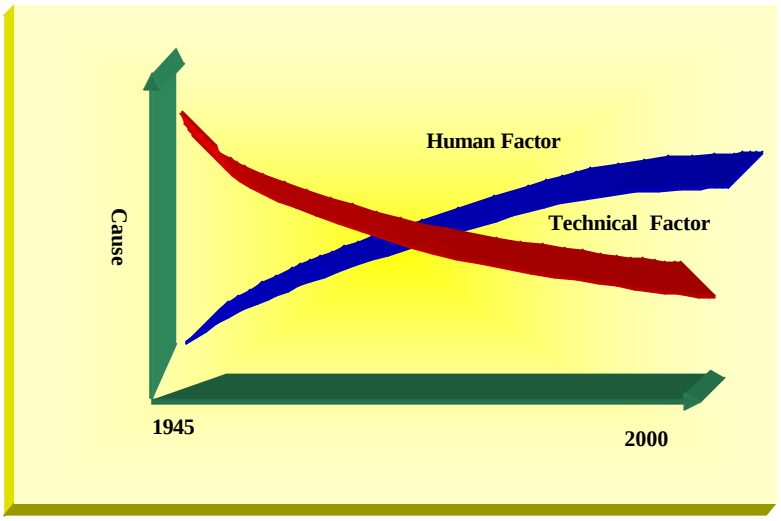

Figure.2: the trend of air accident on the biases of Technical-Human factor [9].

Statistics of various sources confirms that a considerable portion of accidents are due to Human errors (tables 1,2).

Table 1: Commercial Flight accidents Statistics and their Cause[10]

Cause	Percent of Accidents
Human	82% (Including: 75%Crew, 2%Maintenance, 5%Flight Security)
Air Plane Equipments	9%
Weather	7%
Unknown	2%

Table 2: Statistics of Boeing Commercial flight accidents and their Cause[10]

Cause	Percentage
Flight crew	73/8
Airplane	11/9
Maintenance	1/5
Weather	5/1
Airport / ATC	4/2
Others	3/7

Comparing these two statistics shows the similarity of causes and percentage of accidents which about four fifth of the flight accidents are due to Human factors and of these 75% are connected to Crew. On the other hand it can be concluded that despite the focuses and advancement made on technical capabilities, sufficient studies have not been done on Human capabilities.

So it is important for the alleviation of this shortcoming, the study of causes of Human errors for the enhancement of Human Reliability factor and accordingly the flight system total safety be considered seriously as a multi-disciplinary issue. At the same time the subject should receive high priority from the researchers of the flight systems. The ergonomics can and should be utilized along side. In the following as we enumerate the main factors effecting flight safety, with regard to Human, we give strategy for minimizing Human errors.

4. SHEL Model

By our introduction to socio-technical systems and its comparability with Flight Work system and role of Human in such a system and also knowing effective factors on Human Reliability and his work errors, now we are in a position to look into the issue again from the prospect of a new socio-technical system, entitle SHEL model, which Professor Edward has presented this model.

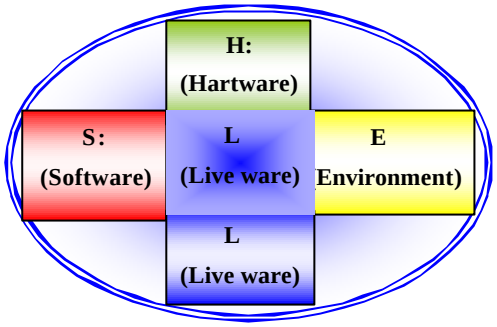

Figure 4: Illustration of SHEL model

The name is the acronym of the words that represent the main elements of the model.

In this model the Human factor is the focal point and as the key and pivotal factor interacting with other factors. Incompatibility of each part with Human and vice versa causes Human error .In view of Human special capabilities and capacities we should after the matching of the other factors with him as much as possible. Finally the logical and engineering arrangement and organization of the elements causes the necessary correlation and cohesion of system for executing job and as so accepting the work with reliability.

Table No. 3 presents the most crucial subjects which must be considered regarding Human factor.

Table 3: ways for matching the Flight work system with Human

Interaction of factors	Explanation
L-H **Matching of Machine with Man**	Precision in machine and equipment making and the location of communication and control equipment and observing ergonomic issue, understandability of automation and heeding to the physical size and biomechanics. Physiology and biology of Human in design and production of air plan
L- S **Matching of software with Man**	Regulations ,Policies ,checklists, displayers, policy unification in organization and meta-organization, its understandability and usability for Human
L-E **Matching of environment with Man**	In design and production of air plan properly reduce negative effects of radiation , air, heat, vibration etc
L-L **Matching of Man with Man**	Enhancement of necessary skills and characteristics peculiarities of personnel and group and personal capabilities for communicating with each other and passengers and air traffic control group through selection ,training , motivation ,organizing, leadership and etc.

5. Human Errors

The ability to fulfill the duties in diverse conditions is a function of various factors. These factors are called Performance shaping Factors. Some of the factors according to the definition given in DIN,4006,1998[11] are as follows:
Available work time, time required for doing the job, stress causing factors , personal and group experience , controlling means ,reflection of operation, work process documentation ,equipment arrangement, social factors, physical factors, interdependency of job with each other and etc.
The figure No. 3 exemplifies the main factors influencing the performance of flight work system with the emphasize on the crew performance. In this figure four groups of the main factors and the major elements of each has been depicted.

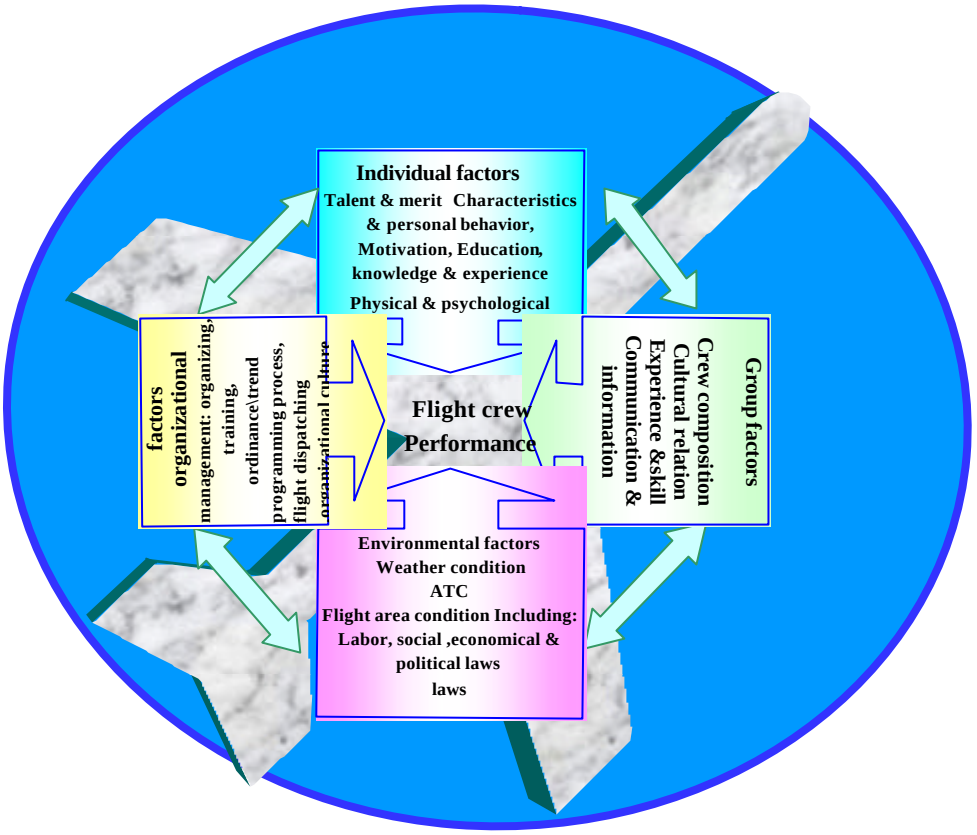

Figure3: Factors effecting crew performance

6. Classification of Human Errors

To reduce the errors, before anything else, it is necessary to know the "How" and "Why" of error happening and then try to eliminate them. Therefore, the existing classification in error researches and causes is a good initiative for the realization of the above goal. Scholars have done various classifications in Human error researches and causes [1,12,13,14,15, 16,22].

In general, these classifications are as follows:

- ***Structural and Fundamental:*** In this approach without considering the kind of duty, we are after the answer to the following questions: ***What, When, How, Where.***
- By finding answer to these fundamental questions, the conditions for come about of errors would be enlightened. This approach is more useful for evaluation of Human capabilities in general.

- ***Concentration on causes:*** In this approach, we try to specify the cause of error .In this way we can find proper solution for eliminating the problem.
- ***Compositional method:*** Here we combine the former two approaches. In this method, first, we recognize roots and causes of errors and then we try to eliminate them.
- ***Statistical grouping:*** By observing the statistics, in this kind of classification, the manner, form and frequency of errors are being classified. Some of the groups of this kind are as follows [3]:
- ***Stochastic:*** Some errors happen stochastically that their causes could not be known clearly and as a result, it would be hard to give solution for them.
- ***Deterministic:*** Some errors happen deterministically that one can know their causes better. Then try to resolve them.
- Another complementary statistical grouping to the above grouping is as follows[17]:
- ***Random errors, Sporadic errors, Systematic errors.***
- For the systematic errors, it is easer to specify the causes and we can find proper solutions for them, yet it is hard for the random and sporadic situations. Fortunately as it is presented in Tables 2,3 we can realize clearly that most of the errors are of the systematic kind.

In this connection and to show how we take advantage of these approaches we refer to statistics that guides us to the causes of errors in three decennial periods (1963-1992) ,(Figure No. 5).

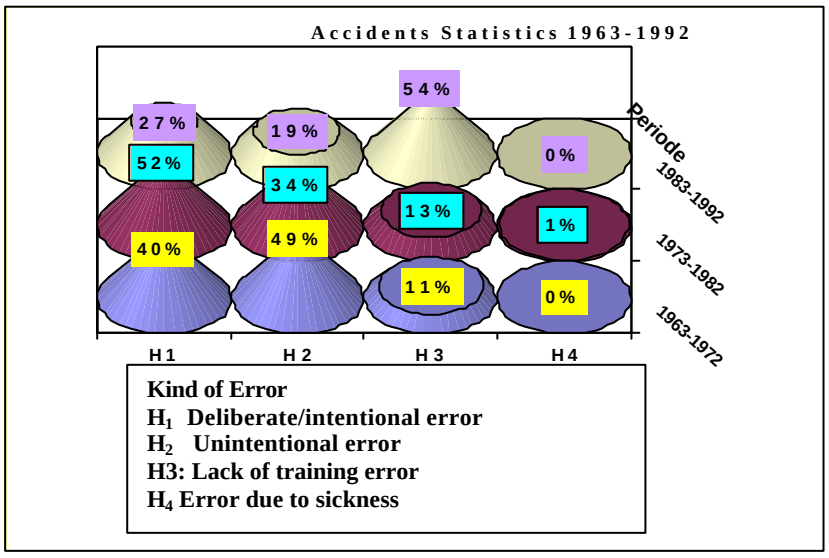

Figure5: Flight accidents statistics [9]

The above Statistics, in the 30 years period of study, shows that ***H3*** errors have increased four times and this means focus on training is vital and this reason is still existing. So training of personnel in university instead of pilot training school has been proposed [20]. Also training in the course of service should be done continuously .Accordingly attending updating courses in the form of Cockpit Resource Management classes is a necessary and useful measure [18].

7. Solution

For improving efficiency and as a result Human Reliability observing a three-phase process which has been presented by Faber,1994 [8] is a good idea .Of course it seems that we should regard the process dynamically and must continuously revise it to match the new situations.

These phases are as follows:

- ***Selection:*** Selecting proper personnel through testing
- ***Organization:*** Proper formulating and organizing of different sections (hardware, software, environment and personnel) specially the connecting points of personnel with equipments and each others through uniformity of technology with Human peculiarity and availability of policies and communication equipment regulations.
- ***Modification:*** Improving and modifying the personnel technical, psychological and physical capabilities via exercising, training and continues education so that the necessary matching of the individual with hardware, software, environment and other people comes about.

We have depicted the process in figure No. 6.

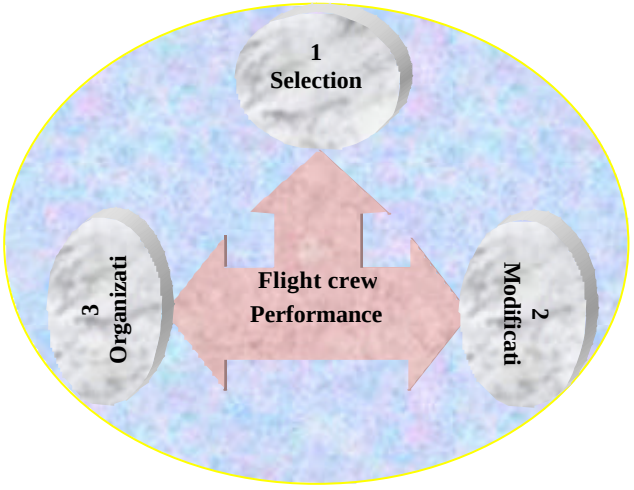

Figure 6: Dynamic process of improving performance of Crew

7.1. Algorithm for Recognition, classification, Determining causes and solution of problem

Now we can summaries the necessary steps for enhancement of flight safety as follows:

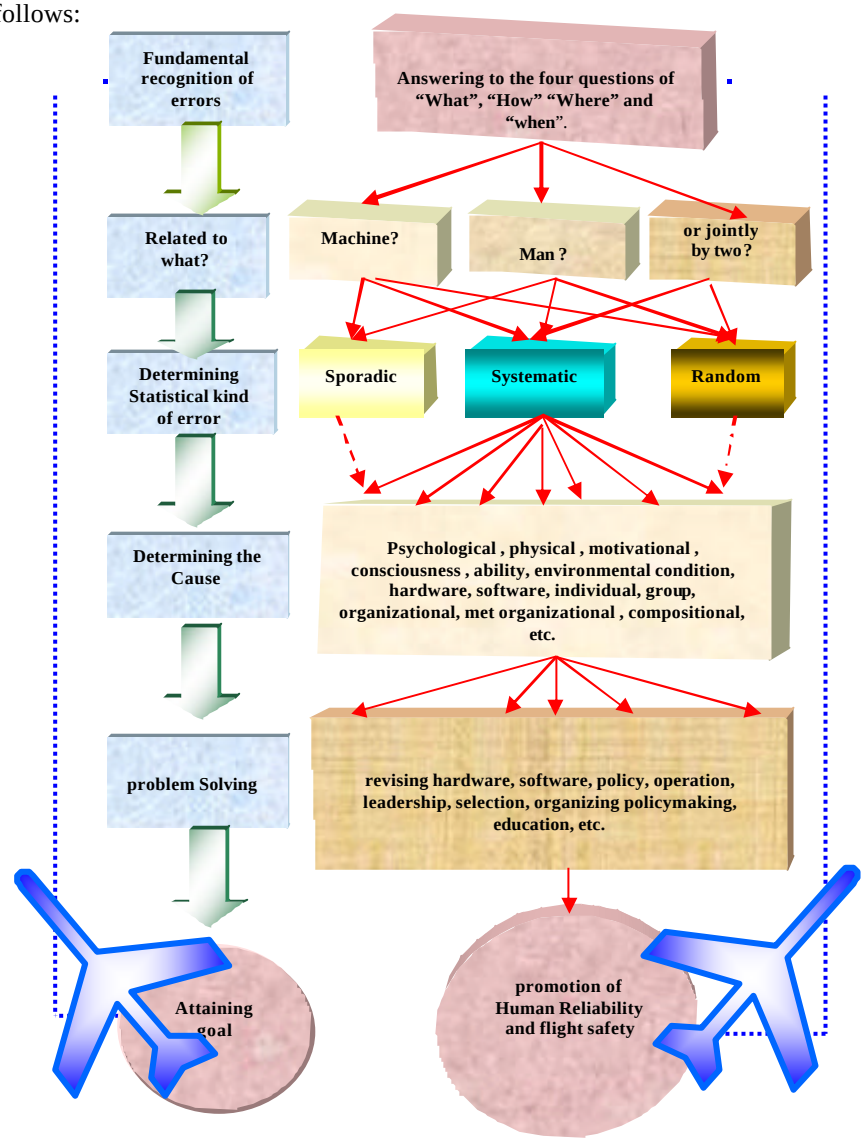

Figure7: Algorithm for Recognition, classification, Determining causes and solution of problem

- ***Fundamental recognition of errors:*** Answering to the four questions of "What" "How" "Where" and "when".
- ***To what element of system is it related?*** Machine, Man or jointly by two
- ***Determining the Statistical kind of error:*** Sporadic, random, and systematic
- ***Determining the Cause:*** Psychological, physical , motivational , consciousness , ability, environmental condition, hardware, software, individual, group, organizational, met organizational , compositional and ect..
- ***Solving the problem:*** With regard to the cause of problem, necessary measures should be taken for its solution: revising hardware, software, policy, operation, leadership, selection, organizing policymaking, education,….
- ***Attaining goal:*** Through execution of the above phases the conditions for promotion of Human Reliability and flight safety will be provided.

Figure No. 7 illustrate these phases in the shape of a problem-solving algorithm.

7.2 Theoretical framework and the application of the presented algorithm

In this section the theoretical base of a problem-solving algorithm is presented. then considering the main theme of the paper which is human ,the main factors which are in relation to productivity and human reliability are introduced. Finally by giving an example the means to utilize the algorithm in order to promote the flight safety considering the human factors are presented.
The theoretical framework of the algorithm presented is based on a three step problem-solving equation. This includes the recognition of the present situation, assigning the reason for and presenting a solution for the system with feedback to continuously improve management [21].

Basically, the management studies on the different subjects in organizations are seeking to find answers to the following three major questions [23]:

a) What are they? ✍ ***Identity***
b) Why are they in this form? ✍ ***Reason***
c) How could the existing situation be improved**?** ✍ ***Improvement***

The main underlying philosophy of this idea is maintaining a continuous improvement trend as well as a procedural approach toward human reliability and flight safety.

In the above mentioned process, the phases 1-2 are an introductory measure to find appropriate growth and development solutions and strategies in the organization/ STS. Procedural approach leads us to an integrated point of view about the three aforesaid phases.

In order to study the different organizational issues including human reliability(flight safety) and according to the above mentioned process, a three phased algorithm with the following features can be developed [24]:

1. Determining and defining the problem (study the current condition)

2. Identifying the factors that resulted in the current condition
3. Offering solutions and strategies to improve the current condition

In this paper, within the framework of the mentioned algorithm, the key issues relating to the human resource and Fight Safety Management (FSM) [19] were integrated in a way that the following goals can be materialized:

a) Determination of the existing human reliability status
b) Identification of the factors that have created the current status of human reliability/errors
c) Offering a proper solution for transition from the current phase to a rather improved phase and to fill the gap between the existing and optimal conditions.

Another point, which has been brought to attention in this article, is the factor influencing human competence, practice and operation. Considering that flight safety has been brought to our attention from the flight group for human reliability and error, justifies the room for it in this section. In addition to the points which have been mentioned up to now about human reliability, the prime influencing factors on human practice will also be discussed. The objective presented through algorithm and the attention given to these points is to increase human reliability. Essentially there are three main influencing factors on human practice which cause human competence. They are Will, Can and May [20, 25, 26].

"Will" gives energy, creates motive and will, and leads to deciding for or against fulfilling a job. *Will* is a function of the value and remuneration system of an individual. On the basis of these two the individual decides whether to accomplish a job or not.

"Can" shows how the created energy should be utilized properly. It is related to physical and spiritual ability, skill, experience, and general qualification of an individual.

"May" creates the necessary background and paves the way for benefiting from the provided energy. It is related to organizational and work surrounding factors such as working tools, technology, resources, organizational structure, methods, regulation and laws and so on.

These main components are known as the necessary *internal* (Will, Can) and *external* (May) factors. The former is related directly to the Human Resource and the latter to organization. The elements of this external factor should be supported by the organization and managers, keeping in mind that supporting the development of the internal factors (creating the necessary motive and abilities) are also among the important responsibilities of the organization[20].

Lack of attention to individual needs causes de-motivation. According to statistical data, negative influences on motivation such as dissatisfaction with salary or managers etc can cause human error within the flight crow [7].

Within “Can”, it is evident that flight staff has high stress levels as a result of the intense competition among the airline companies and lack of human resources for the high number of flights. The airlines must provide sufficient staff training according to existing laws. Such training however can have a negative effect on staff as the stress of interacting with others and working with machinery etc effect their required ability[27].

Within, “May”, paying attention during training and the possibility of creating equal flight groups are necessary. As mentioned before many companies train their staff to the compulsory minimum amount of training. However, it is necessary to invest more in training to increase flight safety.

Another important aspect in human resource is human behavioural competence, which plays a key role in the promotion of human resource practise, reliability and the decrease of errors[28].

In modern management world, knowledge based organisations and knowledgeable workers are a necessity[29]. In such an approach, flight staff must have sufficient knowledge as well as ability.

The behavioural competence necessary for staff is [30]:

1. ***Personality competence:*** includes self management, self control, self confidence and responsiveness.
2. ***Social competence:*** includes appropriate interactions, tolerance of opposition and a good perception of differences.
3. ***Methods competence:*** includes the ability to analyse complex problems, a systematic thought process, a good perception of system demands, ability to communicate efficiently, decision making and problem solving.
4. ***Expertise competence:*** includes a speciality in working with machinery and an acquaintance with the job subject.

Core competence	Art of learning	Art of knowledge
Personality competence	Learning to be	Self Knowledge
Social competence	Learning to live with other	Coexistence Knowledge
Methods competence	Learning to do	Methods Knowledge
Expertise competence	Learning to know	Expertise Knowledge

Table 4: The relation of Knowledge, training/leaming and behavioural competences

The above points on competence are required for creating may, can and will and each of which has an important role in flight safety. The lack of training has been mentioned as the main reason for human errors in existing data (fig.5). The use of sufficient training has been introduced by UNESCO which provides self-actualization and prevents human error.

Knowledge, training/learning and behavioural competence had been presented in Table 4.

To conclude this section, an example is given in relation to how the establishment the necessary competence for promotion of human reliability and reduction of human errors in flight through education. The three steps implementing algorithm that have been brought to attention include recognition of existing situations, assigning the reasons for and presenting a solution. Since the key aspect of flights is the training, it is important to note that it is a major influence on flight safety.

Such points have been brought to attention in the human behavioural competence approach. The first point was that of personality competence, since the careers of such individuals who are involved with working with high technology and responsibility of safety of others proves to be stressful, for those responsible [2], so personal capacity should be increased through improving self-confidence and taking up responsibility. Also since most errors occur in abnormal conditions, it is necessary for individuals to control themselves and analyse the problem through concentration and efficient time management.

Social competence is also a key, as working on board, requires team work. Therefore, appropriate training is very important. The crew team includes flight engineers, a pilot, co-pilot and ATC personnel should show an understanding towards each other, have the ability to solve problems through team work and play their individual roles efficiently. Training of the personnel through simulations could be very useful. The selection and organisation of group members should be done according to the relevant conditions of the individual. Also training personnel to communicate appropriately(sender-message-receiver) should be raised.

An international environment brings up intercultural management which makes necessary standardisation. Providing the same training on an international scale would prove to decrease errors that might occur due to the lack of cultural understanding between individuals.

Methods competence is also important as errors usually occur when there is a greater complexity. It provides individuals with a systems thought and makes them able to classify complex matters into a systematically and detail process with a provided logical linkage between the components, when analyzing the problem. In this topic, the crew must be trained to recognise and solve such problems.

Expertise competence requires regular training for used equipment in order to promote and develop human resources. The importance would be increased particularly in human-computer interaction and software ergonomic. Familiarity with by-laws and learning requires skills for flying the plane manually.

Through the establishment of these four competence and its promotion ,one can expect to minimize human errors and maximize human reliability.

8. Conclusion

Through out this paper we have tried to, as utilizing the related theories and statistics of Ergonomics, study the Flight Work system as a Socio-Technical system. The output of our studies leads us to the point that Human factors in the system play a key and crucial role.

To the same conclusion it is necessary with an eye to his peculiarities, the various parts of Flight Work system (hardware, software, issues related to organization and met organization,) be designed, revised and executed. At the other hand through selection, training and organizing, the Human potentialities should be realized. So that the individual through that be able to, as understand properly the device, equipment and operational process, also fulfill his duty together with other flight crew in sensitive situations with minimum error. In parallel with the above measures for the promotion of Flight Safety, it is necessary to take advantage of following strategy.

- ***Active Safety:*** via the improvement of human information and connecting ground between human and Machine to reduce the probability of error occurrence.
- ***Passive Safety:*** Designing technical systems as such that in the case of collapse or problem the human casualty be minimized.
- At the conclusion we can say that:
- For the promotion of Human reliability and productivity, it is necessary to provide the required internal and external conditions.
- ***Internal conditions:*** These are individual factors as: willingness, motivation, expertise, experience, consciousness, physical and psychological capabilities, workmanship etiquette, readiness for team and individual works,
- These factors are also called ***Expert and Characteristic Maturity.*** These two level of maturity is accomplished thru the Human attainment of four behavioral competence (Personality, Social, Method, and Expertise)
- ***External Conditions:*** these factors are related to organization and environment such as: Technical issues (equipments, devices, work, machine,), Organizational issues (policies, structure, trends and educational, evaluation and remuneration system and management and leadership strategy).
- Through proper engineering, arranging, organizing and management in national and international level, we should prepare better ground for the flourishing of internal and external conditions so as we promote system Productivity and Reliability we can improve life condition of personnel as well.

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