Chapter

Air Traffic Controllers' Attitude to the Mistakes Hazards during Their Professional Experience

Oleksii Reva, Andrii Nevynitsyn, Serhii Borsuk, Valerii Shulgin and Volodymyr Kamyshyn

Abstract

Air traffic controllers' (ATCs) work process can be presented as uninterrupted set of decisions. These decisions occur and are implemented in both clear and stealth forms being influenced a lot. Determined and stochastic risks are especially important in this process. Human factor (HF) effect on flight safety is proven to be better considered through operators' attitudes toward unsafe acts and conditions. This seamlessly integrates in ICAO safety paradigm. Air traffic controllers' preferences system (PS) is discussed in regard to typical professional mistakes set. Using paired comparison, normative part of summary hazard and differentiating part of summary hazard, the preferences system of air traffic controllers is received. For the first time, mistakes pair summary hazard is determined on the unique qualimetric 100-point scale. Systems pair has high correlation level according to Spearman coefficient (R = 0.9727). Proposed Kendall rank coefficient outweighs the traditional one twice ($W_{traditional} = 0.2722$, $W_{proposed} = 0.55237$). The significance level for all cases is equal to 1%. Multistep procedure of marginal opinions separation is implemented. It increased Kendall rank coefficient value up to $W_{proposed} = 0.7$. Survey procedure influenced positively on the ability of mistakes memorization, recognition, and avoidance during simulation training.

Keywords: flight safety, human factors, decision-making, air traffic controllers, typical mistakes, preferences system

1. Introduction

As for today human factor (HF) has approved dual influence on flight safety (FS). Unfortunately the statistics of dangerous air events and serious accidents shows that negative component of this influence has advantage. This stimulated ICAO to publish multiple circulars, annexes, and manuals with generalized world experience on the topic. They are based on the reports and proceedings of air companies and regional administrations dedicated to negative HF influence prevention [1–4]. It is natural that all kinds of such generalization should be scientifically based.

Frontline air operators (in this chapter we talk only about air traffic controllers (ATCs)) work process can be presented as uninterrupted set of decisions. They are generated and implemented in clear and stealth forms under the influence of various factors. These factors could be classified as external/internal, biased/unbiased, stochastic and deterministic, etc. [5]. Thus it seems possible to present actual ICAO FS paradigm [4] with leading role of HF influence on decision-making (DM). **Figure 1** proposed by authors and cited in various proceedings proves this thesis [6–9].

It is important that blocks (a)–(e) designation in **Figure 1** is used according to the ICAO safety concept introduction. Components (h)–(l) inserted in block (e) correspond to the authors' vision of HF influence on the DM process. They draw "attitudes toward unsafe acts and conditions" which also belongs to the mentioned concept. Blocks (h, i, j) are already researched both for ATC students and professionals. Research results are summarized and published [10]. Less attention is paid to (k) and (l) components.

Taking into account all mentioned above, this chapter is dedicated to the preferences system (PS) research. The system is referred as HF to DM influence component, thus playing its role in "attitudes toward unsafe acts and conditions." Such attitudes are reasonable to be determined via ATC PS across typical errors set in professional activity process.

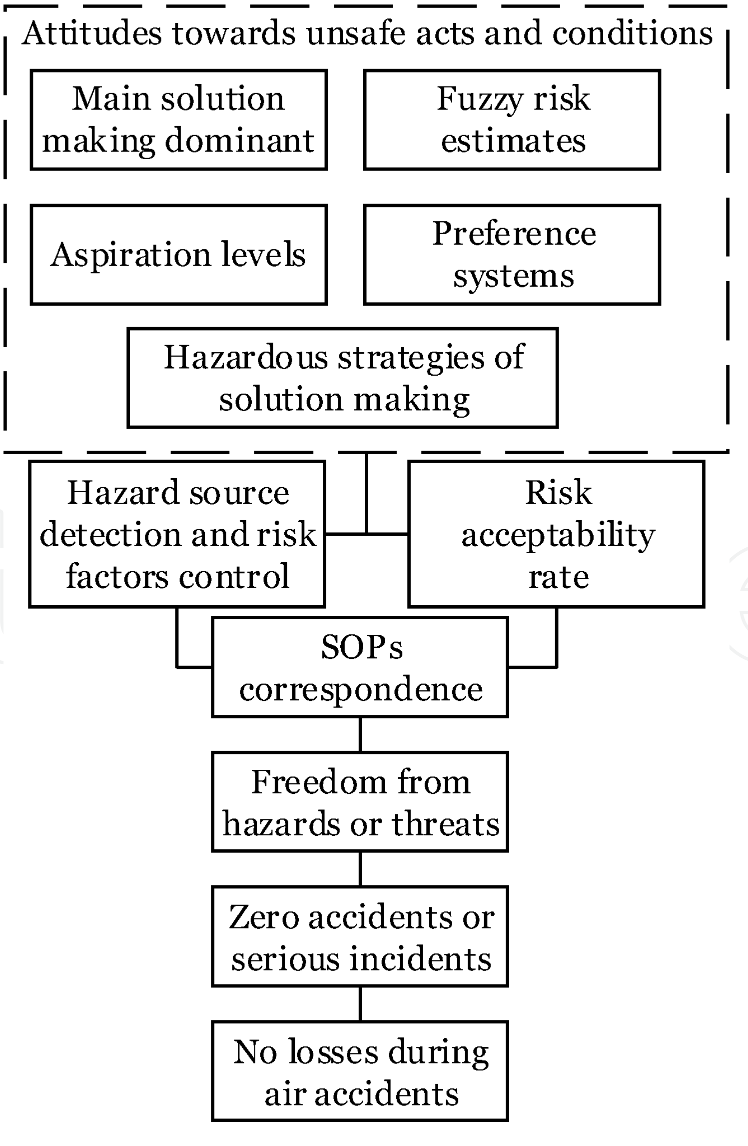

Figure 1.
Influence scheme of HF in regard to decision-making and ICAO flight safety concept components interaction.

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2. Theoretical fundamentals of preferences system determination technology

On the basis of such sources like ICAO recommendations, air accidents statistic, specific ATC experience, and ATC personnel education experience, the following list of typical errors for ATC during their professional activity was composed [9, 11, 12]:

- Er.1—Radiotelephony phraseology violation.
- Er.2—Inconsistent aircraft entry into the adjacent ATC zone.
- Er.3—Longitudinal course time interval violation.
- Er.4—Counter course time interval violation.
- Er.5—Cross-aircraft separation violation at crossing courses.
- Er.6—No address in ATC messaging.
- Er.7—Error in aircraft call sign determination.
- Er.8—Error in aircraft identification.
- Er.9—Misuse of ATC schedule.
- Er.10—Absence of the note of control transfer to the adjacent air traffic control center in the ATC strip.
- Er.11—Absence of the coordination mark for aircraft entrance into adjacent ATC in the ATC strip.
- Er.12—Violation of coordinated geographic control transfer boundary by ATC.
- Er.13—Violation of coordinated time control transfer boundary by ATC.
- Er.14—Non-efficient/saving ATC.
- Er.15—Negligence while applying of the letter-digital information (potential multiple interpretations) to the strip.
- Er.16—Violation of shift transition procedures.
- Er.17—Issued commands to change the altitude or direction of flight are not reflected on the strip.
- Er.18—Attempt to control the aircraft under condition of TCAS system operation in the "resolution advice" mode.
- Er.19—Errors at aircraft concerning information input into the automated system.
- Er.20—Emergency procedures violation.
- Er.21—Airspace use violations.

Different errors obviously possess different hazard levels. This requires ATC attitude to be found and arranged in preferences system for those errors. Referring to proceedings [9, 11–13] and current research context, this PS is considered as ATC hazard levels experience. This includes the most hazardous error, the least hazardous error, and all other error types arranged in hazard descending order.

Finalized PS is important for ATC correct person-targeted professional training arrangement. Also it can be used in preventive maintenance of HF negative influence on FS. Really all information of FS allows experienced instructors to determine peculiarities of ATC individual experience, including air accidents and catastrophic experience. On the other hand, such knowledge might contribute revealing of flaws in professional training and conceptual safety model. The latter two grow during professional activity process.

There are several most common ways to determine PS. They could be used for ATC attitude identification toward hazards of typical errors and mistakes with ranking method [9, 13]:

1. Sorting is used in case of previous clustering of huge number of alternate options. For example, the ICAO states that ATC mistakes and errors clustering should be performed with regard to such types and sources [3]: mistakes caused by incorrect equipment utilization, procedural mistakes, and communication mistakes. At that point the proposed list of typical mistakes was also partially based on the ICAO recommendations.

   This set of mistakes significantly exceeds operative capabilities of human memory expressed with "magic Miller's number" (7±2 units at the same time) [14] and reaches the so-called Parkinson's inefficiency coefficient [15]. However participants encouraged to pass the survey are highly experienced ATC. Each of them has significant real occupational experience including nonstandard situation solving. These situations include potential conflicts, urgent conflicts, catastrophic, high work pressure, and psychological overload. They also had teaching experience. Thus in their case, clustering procedure with secondary ranking step was unnecessary.

2. Direct ranking is a simple process, although its application has certain limits. They are operating memory capacity and cognitive functions limitations mentioned above.

3. Pair comparison and relative input calculation.

4. Determination of weighted hazard coefficients (importance, significance, etc.).

5. Determination of biased hazardous mistakes probabilities.

6. Application of fuzzy variables in order to find mistakes rate.

For the current research, the pair comparison method was chosen with further relative contribution calculation for both components. It was applied for every mistakes pair. Such approach could be presented [9, 13, 16] as following:

$$c_{ij} = \begin{cases} 1 + z & -\text{preference} \quad Er._i \succ Er._j \\ 1 & -\text{no preference} \quad Er._i \approx Er._j \,, \\ 1 - z & -\text{preference} \quad Er._j \succ Er._i \end{cases} \tag{1}$$

where c_{ij} is the quantitative index of preferences of mistake $Er._i$ over mistake $Er._j$ in regard to hazard level and z is the index that describes summary hazard level of mistakes $Er._i$ and $Er._j$.

Proposed method of PS calculation is quite simple since researched mistakes are compared in pairs. This pushes expert's attitude to other mistakes out of the single comparison scope. All presented is a part of wide class of experts' opinions explication methods where expert opinion is taken as basic undividable statement.

Preferences c_{ij} value sequence determination as quantitative characteristics of mistakes comparison is the following:

1. Experts express their statements via pair comparisons of mistakes hazards. They use their own professional experience and statistics of accidents and incidents. Initially it's just a prevalence or equality of hazard level that is determined for each pair without quantitative estimation.

2. Using information analysis or ATC experts support, the range in hazard values is determined for mistakes being compared. These estimations are saved as ranked set boundary components ratio.

$$\frac{C\left(Er._i^{max}\right)}{C\left(Er._j^{min}\right)} = K_p, \tag{2}$$

where $Er._i^{max}$, $Er._j^{max}$ are mistakes with maximal $C\left(Er._i^{max}\right)$ and minimal $C\left(Er._j^{min}\right)$ hazard values and K_p is the compared mistakes hazard ratio coefficient.

3. Desired values of integral mistakes hazard coefficients z are found with coefficient $K_{p.}$

$$z = \left(\frac{K_p - 1}{K_p + 1} + \sqrt{\frac{0.05}{n}}\right), \tag{3}$$

where n = 21 is the number of mistakes being arranged.

4. On the basis of paired mistakes hazard level comparison systems and with the help of c_{ij} coefficients, squared matrix $C = \|c_{ij}\|$ is created:

$$C = \begin{Vmatrix} c_{11} & c_{12} & \cdots & c_{1j} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2j} & \cdots & c_{2n} \\ \vdots & \cdots & \vdots & \vdots & \cdots & \vdots \\ c_{i1} & c_{i2} & \cdots & c_{ij} & \cdots & c_{in} \\ \vdots & \cdots & \vdots & \vdots & \cdots & \vdots \\ c_{n1} & c_{n2} & \cdots & c_{nj} & \cdots & c_{nn} \end{Vmatrix}. \tag{4}$$

5. With iterative priority arrangement method (PAM) [16], the values of mistakes hazards priorities $C_i(k)$ are found.

6. Actual coefficient of mistakes hazard level ratio K_A is calculated. It is compared to the empiric coefficient of the same kind K_p. If they match, then the task of z index determination is successfully solved. Otherwise coefficient correction is performed.

The proposed method has several major advantages:

1. Simplification of the statements of expression procedure (no quantitative estimation of compared mistakes is required).

2. The method of c_{ij} selection coefficients matches quantitative empiric estimations with their real quantitative hazard ratios.

3. Non-transitive input data is allowed along with non-transitive output preferences.

There is one most important and valuable step in this method application. It is the estimation of boundary mistakes hazard ratio empiric coefficient K_p. If it is possible to estimate mistakes ratio, then they should be arranged to define boundary elements of their whole set. PAM with z coefficients can be used for that purpose. In whole task this is the only part with quantitative estimation. Thus it should be paid more attention. If pair comparison systems are non-transitive or possess equality (indifference), the z values procedure calculation should be changed in a proper way [16]. This happens when certain mistakes make no difference in ATC expert opinions, thus receiving "average" ranks.

For this reason formula (1) is commonly transformed into two formulas. They have summary quantitative estimations of compared alternatives (mistakes) equal to 1 or 2:

$$c_{ij} = \begin{cases} 1 & - \text{ if mistake } Er_{\cdot i} \text{ is more hazardous than} Er_{\cdot j}: \quad Er_{\cdot i} \succ Er_{\cdot j} \\ 0 & - \text{ if vice versa}: \quad Er_{\cdot i} \prec Er_{\cdot j}; \\ 0.5 & - \text{ if mistakes } Er_{\cdot i} \text{ i } Er_{\cdot j} \text{ possess equal hazard}: \quad Er_{\cdot i} \approx Er_{\cdot j} \end{cases} \quad (5)$$

$$c_{ij} = \begin{cases} 2 & - \text{ if mistake} Er_{\cdot i} \text{ is more hazardous } Er_{\cdot j}: \; Er_{\cdot i} \succ Er_{\cdot j} \\ 0 & - \text{ if vice versa}: \quad Er_{\cdot i} \prec Er_{\cdot j} \\ 1 & - \text{ if mistakes } Er_{\cdot i} \text{ i } Er_{\cdot j} \text{ possess same hazard}: \quad Er_{\cdot i} \approx Er_{\cdot j} \end{cases} . \quad (6)$$

Formulas (5) and (6) show that part of summary mistakes hazard is normalized. It supposed to simplify their pair comparison and PS determination. Indeed human thinking deals better with qualitative comparative tasks rather than quantitative. However normalizing makes results rough and brings methodology error in final conclusion about real hazards (actual mistakes place in the ranked sequence).

3. Normative approach application to find ATC preferences system on the set of typical mistakes

So formula (5) is used to find individual PS (IPS) of National Aviation University and DP "Ukraeroruh" employees m = 37. All of them have significant work experience and methodical (training) practice. IPS found with the help of group decision method was ere aggregated in generalized group PS (GrPS) via averaging and summation:

$$\begin{aligned} &Er_{\cdot 18} \underset{tr.}{\succ} Er_{\cdot 20} \underset{tr.}{\succ} Er_{\cdot 5} \underset{tr.}{\succ} Er_{\cdot 4} \underset{tr.}{\succ} Er_{\cdot 21} \underset{tr.}{\succ} Er_{\cdot 3} \underset{tr.}{\succ} Er_{\cdot 8} \underset{tr.}{\succ} Er_{\cdot 2} \underset{tr.}{\succ} Er_{\cdot 17} \underset{tr.}{\succ} Er_{\cdot 13} \underset{tr.}{\succ} Er_{\cdot 6} \underset{tr.}{\succ} \\ &\quad Er_{\cdot 12} \underset{tr.}{\succ} Er_{\cdot 16} \underset{tr.}{\succ} Er_{\cdot 1} \underset{tr.}{\succ} Er_{\cdot 19} \underset{tr.}{\succ} Er_{\cdot 7} \underset{tr.}{\succ} Er_{\cdot 9} \underset{tr.}{\succ} Er_{\cdot 14} \underset{tr.}{\succ} Er_{\cdot 11} \underset{tr.}{\succ} Er_{\cdot 15} \underset{tr.}{\succ} Er_{\cdot 10}, \end{aligned} \quad (7)$$

where $\underset{\text{tr.}}{\succ}$ – defines the preference of one mistake comparing to the other one in GrPS. All IPSs used for this purpose are received with traditional method using formula (5).

Hence GrPS of type (7) is received via "traditional" method of the distribution of normative mistakes hazard sum which is equal to 1. It clearly shows their ordered set starting with the most hazardous (Er.18—Attempt to control the aircraft under condition of TCAS system operation in the "resolution advice" mode) down to the least hazardous one (Er.10—Absence of the note of control transfer to the adjacent air traffic control center in the ATC strip). Although before the conclusion about GrPS of type (7) acceptability could be made, the consistency verification of ATC experts engaged in the process should be performed.

The indicator for such consistency is Kendall multiple rank correlation coefficient (RCC) $W_{tr.} = 0.2728$. The low value of this indicator can be explained by several reasons: firstly, the big variety of mistakes and big variety of ATC experts engaged to the research inevitably influenced the diversity of opinions and thus influenced RCC, and secondly, no efforts to find and remove marginal opinions were made (by marginal here, we understand certain extremely specific experience rather than roughly wrong).

Taking into account that low absolute value of RCC could be statistically acceptable, let us use Pearson χ^2 criterion to test the corresponding hypothesis. It is found that $\chi^2_{calc.} = 201,412 >> \chi^2_{\alpha=1\%,\ k=36} = 58,619$ which allows to state that RCC indicator value is statistically acceptable. Thus opinions of ATC experts engaged to the research are consistent for (7). It means that GrPS of the type (7) can be used in flight safety management processes or during ATC training procedures.

However it should be stated that the absolute value of RCC criterion $W_{tr.} = 0.2728$ does not satisfy criterion [17]:

$$W \geq 0.7, \tag{8}$$

thus type (7) GrPS is not absolutely acceptable as well.

4. Differential approach application to the preferences system determination within the set of typical mistakes

Let us consider all mentioned above taking into account proceeding [9]. It allows to dedicate current section to the development of enhanced method of mistakes hazard levels sum distribution. Its efficiency and application are also discussed.

Once again let us underline that formulas (5) and (6) hold mistakes hazard levels sum equal to 1 or 2. It is normatively distributed by the expert among mistakes being compared. In other words each mistake's contribution in aggregate hazard value is limited. It does not operate with [0, 1] or [1, 2] ranges but uses simple decision about "$\succ$" or "$\prec$" preference (or their equality indifference "$\approx$"). This simplifies IPS construction but makes final estimations result rough. Such roughness is transferred further to the generalized results of mistakes hazards set arrangement.

To get rid of this flaw, the partial and overall mistakes hazard is proposed to be calculated. Special absolute qualimetric scale with 100 points [13] is proposed for this purpose. Expression (1) evolution in this case is the following:

$$c_{ij} = \begin{cases} 51 \le c_{ij} \le 100, & \text{if mistake } Er._i \text{ is more hazardous than } Er._j: \quad Er._i \succ Er._j \\ 0 \le c_{ij} \le 49, & \text{if vice versa}: \quad Er._i \prec Er._j \\ 50 & \text{if mistakes } Er._i \text{ i } Er._j \text{ are equally hazardous}: \quad Er._i \approx Er._j \end{cases} \tag{9}$$

Same m = 37 professional ATCs were engaged in the second round of the survey. They fulfilled 210 paired comparisons one more time with the help of expression (9) and constructed new IPSs. IPS to GrPS generalization is once again performed with ranks averaging and summation strategy for group decisions. The formal overview of new empiric GrPS is the following:

$$Er._{18} \underset{dif.}{\succ} Er._{20} \underset{dif.}{\succ} Er._5 \underset{dif.}{\succ} Er._{21} \underset{dif.}{\succ} Er._4 \underset{dif.}{\succ} Er._3 \underset{dif.}{\succ} Er._8 \underset{dif.}{\succ} Er._{17} \underset{dif.}{\succ} Er._{13} \underset{dif.}{\succ} Er._2 \underset{dif.}{\succ} Er._{16} \underset{dif.}{\succ}$$
$$Er._{19} \underset{dif.}{\succ} Er._6 \underset{dif.}{\succ} Er._{12} \underset{dif.}{\succ} Er._7 \underset{dif.}{\succ} Er._1 \underset{dif.}{\succ} Er._{14} \underset{dif.}{\succ} Er._{11} \underset{dif.}{\succ} Er._9 \underset{dif.}{\succ} Er._{10} \underset{dif.}{\succ} Er._{15}, \tag{10}$$

where $\underset{dif.}{\succ} -$ determines the preference of one mistake to the other.

The absence of tied mistakes ranks is noticeable while comparing GrPS (7) and (10). It means that the ranking of researched mistakes is strict. The rate of two GrPS coincidences is checked with Spearman rank correlation coefficient. Its value is equal to $R_S^{tr.-dif.} = 0.9727$. This witnesses about overwhelming match of ATC experts' opinions about mistakes hazards in compared GrPS (7) and (10).

Finding opinions consistency in (10) with the help of RCC gives $W_{dif.} = 0.5237$, that is, 1.92 times more than the initial one. It shows the efficiency of newly proposed method in general (partial mistakes inclusion).

The coefficient value is statistically acceptable which is proven by hypothesis testing with Pearson χ^2 criterion. For newly calculated value, it is equal to $\chi^2_{dif.} = 387,508 > > \chi^2_{\alpha=1\%,\ k=36} = 58,619$. This means that GsPS of type (10) can be considered as generally consistent.

Yet again there are a big number of ATC respondents and a big number of mistakes proposed for arrangement. It influences in adverse way on the RCC absolute value. Requirement (8) is not satisfied again.

With the given significance level, both of GrPS are statistically acceptable. However even in brief comparison of GrPS indexes ($W_{tr.} = 0.2728$ and $W_{dif.} = 0.5237$), it is clear that current research points on the second result to be used. It includes a negative HF influence prevention on the FS as flight safety management measures and ATC professional training.

Proposed differentiating method disadvantage lies in the quantitative requirement. It forces experts to express their opinions about mistakes hazards levels in numerical values. But it is well known that people tend to operate with qualitative information. Altogether this requires only high-quality ATC experts to be engaged in the survey.

5. Multistep method of determination and losing marginal ATC opinions concerning mistakes hazards

As it was mentioned before, the marginal opinions of ATC engaged in the survey are not examples of their bad training or experience. In current research context, it's rather a certain particular experience. Such rarity greatly influences their personal

IPS, making a difference with others' opinions. Because of that, it is very important to pay attention to their opinions separation and analysis. This is what briefly explained in proceeding [18].

Let us measure single ATC influence on group estimate as

$$C = \frac{\overline{a}_{m+1}}{\overline{a}_m}, \tag{11}$$

where $\overline{a}_m$ is the average estimation of experts group with m members and $\overline{a}_{m+1}$ is the average group estimation with m + 1 members.

Let us specify acceptable influence level for single opinion *b* of (m + 1)th ATC expert. Basing on the proceedings [18, 19], it can be limited with 5–10% change:

$$\begin{cases} 1.05 \le C \le 1.10, & \text{if } b > \overline{a}_m \\ 0.90 \le C \le 0.95, & \text{if } b < \overline{a}_m \end{cases}. \tag{12}$$

This is valid for ATC opinions analysis. It can be applied both for particular mistakes and already given integral indexes of mistakes hazards set. Once again the nature of these estimates is numerical and quantitative, while people better operate with qualitative and comparative ranking meanings. Thus it is important to develop corresponding procedures and methods of ATC experts' competence determination based on the mistakes hazards they work with.

Let us apply research results and methods of image detection theory [20–22] to find experts' competence. Risk recognition term is introduced. It is a mathematical expectation of information losses due to recognition mistakes for qualified and unqualified ATCs.

$$r(\delta) = \int_X \sum_{i=1}^{I} L[i, k = \delta(x)P(i)p(x/i)dx], \tag{13}$$

where X is the space for x signals (these are hazards scoring characteristics, assigned by the ATC experts to the mistakes), $i = \overline{1, I}$ estimation classes numbers, $k = \overline{1, K}$ recognition alternatives numbers $\delta(x)$, $L(i, k)$ information losses during class assignment of estimate from class i to the class *k*, $P(i)$ classes probabilities known in advance, and $p(x/i)$ classes probability densities known in advance.

So it is all about distance calculation between points in the image space. Herewith the particular point belongs to certain class if it is determined with the distance to the reference point. Members that belong to the same class should form a compact cluster in the system parameters space.

In observed case the following distance is used as a generalizing value:

$$L_j = \sum_{i=1}^{n=21} \left| r_{ij} - r_{ig} \right|, \tag{14}$$

where L_j is the generalized distance of IPS of jth ATC expert toward GrPS and r_{ig} is the rank of ith mistake in GrPS.

It is important to underline that GrPS consistency here is taken as an assumption. For further convenience, normalized L_j index value is introduced:

$$L_j^* = \frac{L_j}{L_j^{max}}. \tag{15}$$

The next step is to calculate average group mistake value:

$$\overline{L}_g = \frac{1}{m}\sum_{j=1}^{m} L_j^* \tag{16}$$

and corresponding to formula (12), the criterion for marginal IPS of ATC experts is determined.

$$L_{j\ \text{marg.}}^* \geq 1.1 \cdot \overline{L}_g, \tag{17}$$

Applying formulas (14)–(17) to IPSs that are found with proposed differentiated method (which uses mistakes hazards sum distribution), it is possible to find the following opinions marginality criterion:

$$L_{j\ \text{marg.}}^* \geq 0.57, \tag{18}$$

It is calculated that marginal thoughts are expressed by 10 ATC experts, which is shown in **Figure 2**. Removing their IPS allows to receive subgroup A with $m_A = m - m_{marg} = 27$ ATC members with such GrPS:

$$\begin{gathered} Er._{18} \underset{m_A}{\succ} Er._{20} \underset{m_A}{\succ} Er._5 \underset{m_A}{\succ} Er._{21} \underset{m_A}{\succ} Er._4 \underset{m_A}{\succ} Er._3 \underset{m_A}{\succ} Er._8 \underset{m_A}{\succ} Er._{17} \underset{m_A}{\succ} Er._{13} \underset{m_A}{\succ} Er._2 \underset{m_A}{\succ} \\ Er._{16} \underset{m_A}{\succ} Er._{19} \underset{m_A}{\succ} Er._6 \underset{m_A}{\succ} Er._{12} \underset{m_A}{\succ} Er._7 \underset{m_A}{\succ} Er._1 \underset{m_A}{\succ} Er._{14} \underset{m_A}{\succ} Er._{11} \underset{m_A}{\succ} Er._9 \underset{m_A}{\succ} Er._{10} \underset{m_A}{\succ} Er._{15}, \end{gathered} \tag{19}$$

where $\underset{m_A}{\succ}$ – shows the prevalence of one mistake hazard level over another mistake in GrPS combined with m_A ATC expert opinions.

It is found that correspondent correlation coefficient value is equal to $W_A = 0.7$ for m_A subgroup. It satisfies the requirements of criterion (13) and is statistically acceptable because $\chi_A^2 = 377,743 >> \chi^2_{26,\ \alpha=1\%} = 45,642$. Thus GrPS found for $m_A = 27$ subgroup actually can be used for flight safety management measures and ATC professional training.

Further filtering and analysis could be performed with the same proposed method for $m_B = m - m_A = 10$ ATC subgroup as is shown in **Table 1**. **Figure 3** clearly shows the main steps of presented multistep algorithm.

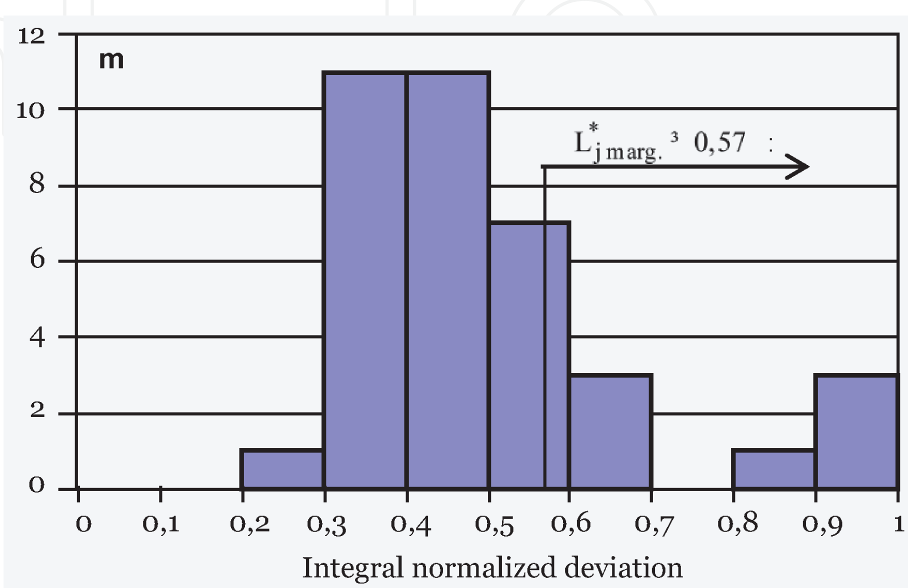

Figure 2.
Finding ATC marginal opinions about mistakes hazards in their professional experience.

Experts groups	W	χ^2_A	$\chi^2_{k=m-1,\ \alpha=1\%}$
1	2	3	4
m = 37	0.5237	387,508	$\chi^2_{36,\ \alpha=1\%} = 58,619$
m_A = 27	0.700	377,743	$\chi^2_{26,\ \alpha=1\%} = 45,642$
m_B = 10	0.2727	55,305	$\chi^2_{9;\ \alpha=1\%} = 21,666$
m_C = 6	0.4934	59,211	$\chi^2_{5;\ \alpha=1\%} = 15,086$
m_D = 5	0.5629	56,292	$\chi^2_{4;\ \alpha=1\%} = 13,277$

Table 1.
Multistep method of determination and losing marginal opinions of ATC experts about mistakes hazard levels.

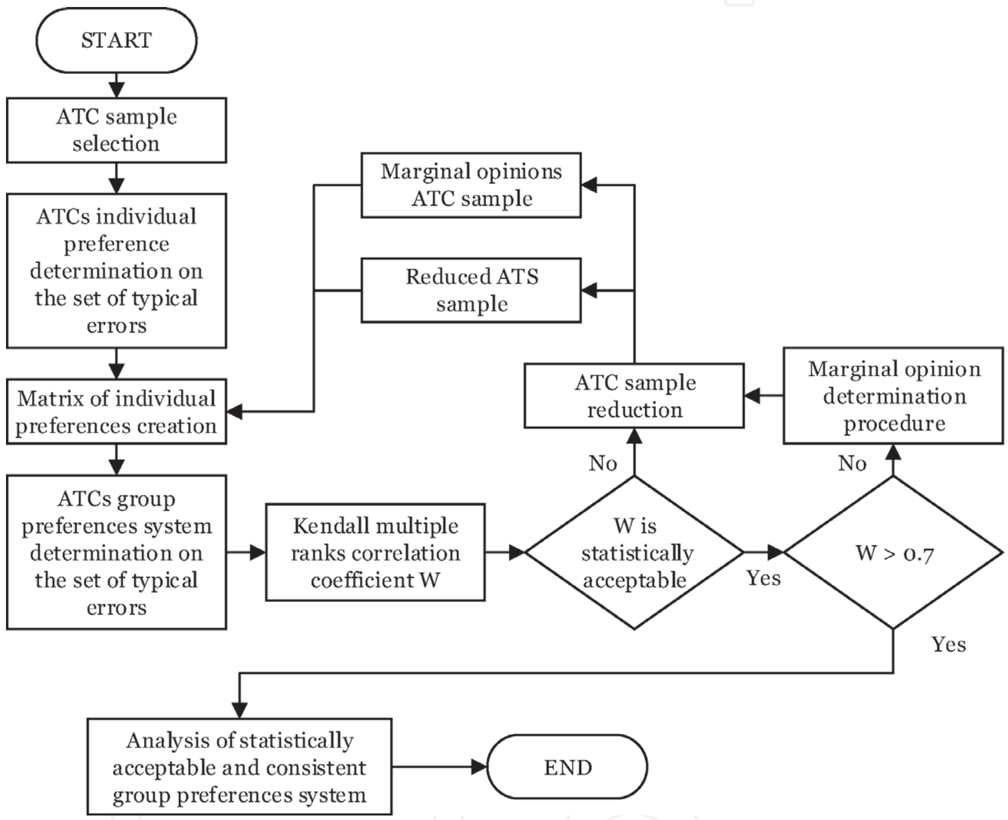

Figure 3.
Multistep algorithm of ATCs' group preferences determination on the set of typical mistakes.

It is clear that after m_A subgroup separation, it was impossible to find any other subgroups with internal opinions consistency. That is the reason for these 10 ATCs to be under increased attention during prevention of negative HF influence upon FS.

Finally it is worth mentioning the positive influence of the procedure on the ATC experts' personal traits. Since during the survey, they had to imagine and compare 210 pairs of mistakes with an attempt to determine their hazard levels.

6. Conclusions

Scientific results received and presented in this chapter explain proactive attitudes of ATCs to the mistakes hazards. Summarizing them allows to state the following:

1. The most comprehensive list of n = 21 typical mistakes for ATC allows to fully analyze their mistakes.

2. There are 37 IPSs received with the help of normative and proposed mistakes hazard analysis methods. They are generalized in GrPS afterward. Proposed method efficiency is defined by Kendall rank correlation coefficient which is 1.92 times greater than the normative method.

3. Multistep method of determination and losing marginal opinions of ATC experts which allows to separate subgroups with increased internal opinions consistency.

4. Taking initial group of m = 37 participants, there was m_A = 27 subgroup separated. Their internal opinions consistency was higher. Other 10 people should be paid increased attention during prevention of negative HF influence upon FS.

5. Positive influence of the procedure on the ATC experts' personal traits is determined.

Further researches of PS determination for ATCs' typical mistakes set should be performed in the following areas:

- Classic decision-making criteria application to determine ATCs' group preferences systems and their risk level analysis.

- Kemeny median determination as optimum indicator for group opinions in regard to mistakes risk levels.

- Frames and neural networks application for ATC incorrect actions analysis and modeling.

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