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APPLICATION OF IMPRECISE MODELS IN ANALYSIS OF RISK MANAGEMENT OF SOFTWARE SYSTEMS

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Abstract

The analysis of functional completeness for existing detection systems was conducted. It made it possible to define information systems with a similar feature set, to assess the degree of similarity and the matching degree of the means from the "standard" model of risk management system, that considers the recommended ICAO practices and standards on aviation safety, to justify the advisability of decision-making support system creation, using imprecise model and imprecise logic for risk analysis at aviation activities. Imprecise models have a number of features regarding the possibility of taking into account the experts' intuition and experience, the possibility of more adequate flight safety management processes modelling and obtaining the accurate decisions that correlate with the initial data; support for the rapid development of a safety management system with its further functionality complexity increase; their hardware and software implementation in control systems and decision making is less sophisticated in comparison with classical algorithms.

Keywords: Bayesian networks; cause-and-effect relationships; decision making; risks; risk factors.

1. Introduction

A decision maker usually assesses the situation in a limited and imprecise information environment, and implementation processes are characterized by uncertainty, which significantly affects the quality of the decisions that are made. The reliability increasing of such decisions can be achieved by creating a methodology that considers this uncertainty. The probabilistic approach is based on statistical processing, the evaluation of which is insufficient due to insufficient sample size. It is known that the minimising approach allows decisions to be made based on the best/worst integral assessments that is inefficient, the expert methods are difficult to apply at the operational assessment of uncertainty and risks; in addition, it is difficult to combine quantitative and qualitative factors in one model.

The imprecise math machine usage is an option in those cases, where classical methods do not give an appropriate result, and allow doing formalization and transformation of quantitative and qualitative imprecise concepts. Imprecise models [1] have a number of features regarding the possibility of taking into account the experts' intuition and experience, the possibility of more adequate flight safety management processes modelling and obtaining the accurate decisions that correlate with the initial data; support for the rapid development of a safety management system with its further functionality complexity increase; their hardware and software implementation in control systems and decision making is less sophisticated in comparison with classical algorithms.

2. Analysis of recent research and publications

Various aspects of risk management in socio-economic systems are considered in [8-10], on these studies the nature of risks appearance is investigated, their classification and various methods of qualitative and quantitative assessment, proposed recommendations on the of risk management and decision-making conduction under conditions of uncertainty. There are approaches described for economic and mathematical methods usage at different stages of risk management in studies [11-12].

Analysis of current scientific studies represented that assessments of the risks is most commonly used with statistical techniques today, including Bayesian networks, which are effective graphical tools for representation of cause-and-effect relationships between multiple variables. At the same time, existing and applied in practice methods and tools of risk management does not fully allow to record different types of information uncertainties and to analyse quantitative and qualitative risk specialties and, consequently, to assess and to manage risk, taking the enterprise state and characteristics of internal and external environment into account.

3. Formulating of the article purpose

To develop risk management tools that arise in the process of aviation activity, for analysis and assessment of these risks, using a combination of Bayesian imprecise models to determine the possibility of occurrence of undesirable events of various types and imprecise-logic procedures, to predict the risks damage to enhance the validity of managerial decisions to ensure a guaranteed level of safety.

4. Main body

Systems that are based on imprecise logic link the dynamic processes between input and output by a set of imprecise rules, using linguistic variables, instead of complicated dynamic models. The figure 1 shows the overall structure of the imprecise model of decision-making.

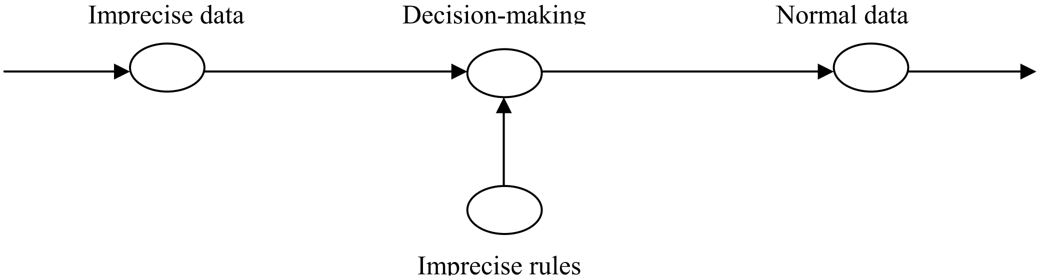

Fig. 1. Imprecise decision-making model graph

The principle of the linguistic approach applying at decision-making in the process of analysis and management of flights safety is carried out by the terms "low risk", "permissible risk" and "high risk", however, it is difficult for the person making the decision to give an objective evaluation and to describe it using a mathematical language. The application of methods, imprecise logic models for risk assessments obtaining allows getting the comprehensive accounting of various factors, and there is a possibility for constructing models of subject areas that are characterized by uncertainty using imprecise numbers, plural and linguistic variables [2].

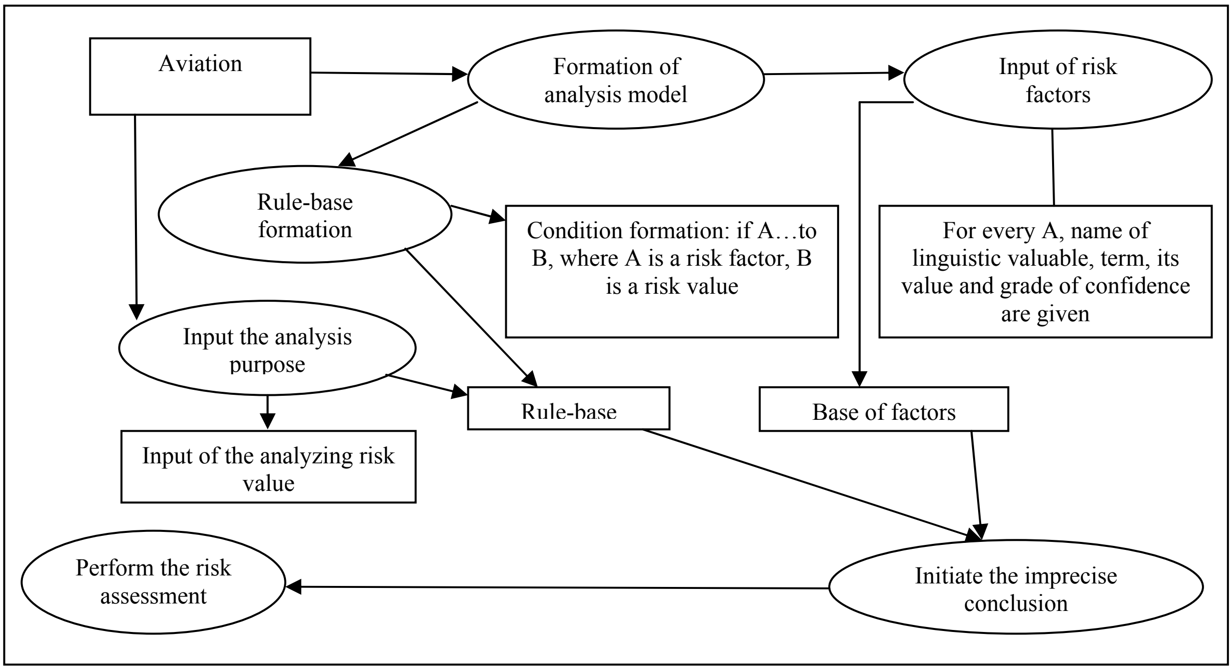

Fig. 2. Functional requirements to «Standard» RMSS model

Automation of identification processes, qualitative and quantitative risks analysis through the support system for decision-making on safety management, significantly improves the efficiency of the decision maker.

Figure 2 shows the functional requirements of the "standard" model of the RMSS risks management, which integrates the accounting of qualitative and quantitative factors in risk assessment [5].

Development of the high quality RMSS depends on the structural decisions taken in the design process [3,4,5,6].

Figure 3 represents the general scheme on the RMSS structure.

The decision maker, in the process of risk analysis, takes the option of using “Forming Analysis Model”, which includes the option of using «Input of risk factors» and “Formation of the rule-base”. Next sends a message that activates the use of the Input the analysis purpose. The chosen purpose of the analysis indicates which input risk factors and the manager to implement imprecise modelling must fill in the rule-base. A work area that consists of rule-bases and fact databases, determines whether it is possible to execute the "Initiate Imprecise Conclusion" option, which calculates the appropriacy of the function for the output linguistic variable that characterizes the risk parameter. At the final stage, the decision maker uses "Perform a risk assessment", which, in its turn, causes the use of the "Initiate Imprecise Conclusion".

The interface management system provides a simple communication between the user, the subsystem of data and the subsystem of models, and provides conduction of problem analysis and modelling for assistance in making management decisions [7].

Application of the specified method in the tasks of choosing a support system for decision-making on risk management will allow: to highlight the main functions of information systems; to determine groups of similar systems; to rank systems according to functional completeness; to determine systems that outperform others; to compare systems with the requirements of the "standard" model of RMSS.

Let us take S = {S;}, (i = 1, п) to implement various analysed IS risks assessments –

«Systems-expectants».

Let us define the set that makes up the vocabulary of functions implemented by the IS,

in the following form

$$F = \{F_j\}, (j = 1, m)$$

The total number of analysed functions (Table 2) for the IS was - 35, i.e.; j= 35.

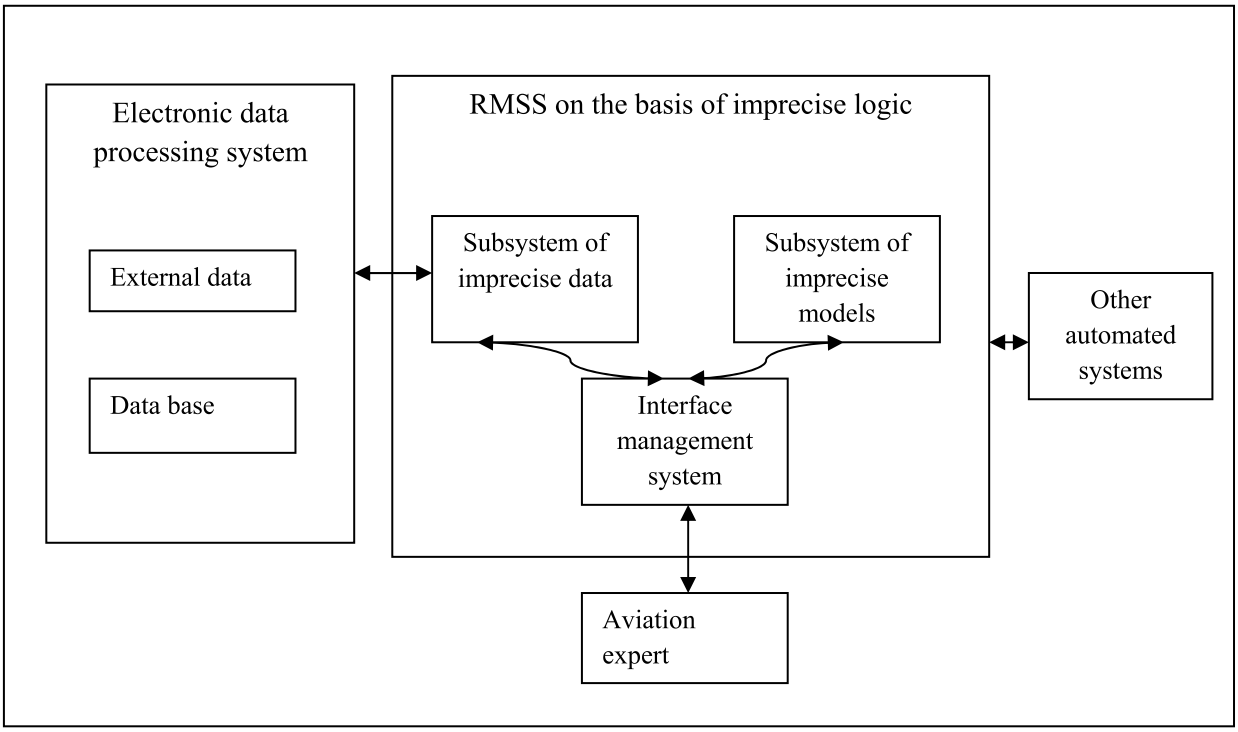

Table 2 – Analysed IS functions

Code	Function name
Group of functions «Risk management at aviation activity»	
F1	Support of users' mode
F2	New project design
F3	Set project properties
F4	Export/Results saving
F5	Import/Results downloading
Group of functions «Risk management»	
F6	Risks adding
F7	Risks editing
F8	Risks deleting
F9	Designing of rule-base for risks model
F10	Identification of risks
F11	Risks volume editing
F12	Choice of risks influence domain
F13	Help with risks form fulfilling
F14	Control parameters of risks identification
F15	Risks description
F16	Choice of risks factors
F17	Choice of analysed groups of risks
F18	Qualitative assessment
F19	Quantitative assessment
F20	Integral qualitative and quantitative assessment
F21	Choice of editing method at database support
F22	Accounting of completed projects
F23	Support of different types distribution
F24	Reference to additional sources of risks occurrence
F25	Addition of comments to the give type of risk
Group of functions «Accounting»	
F26	Printing of report
F27	Saving of report
F28	Publication in HTML form
F29	Displaying of the analysis results for the entire observation time
Group of functions «Additional possibilities»	
F30	Risks functions graphical form
F31	Client-server support
F32	Web-access to data
F33	Support OLE
F34	Access to methodologies and databases assignments
F35	Assignment of database right

Then, let us represent information in the form of a matrix *X* (Table 3), elements of which were determined in the following way: $x_{ij} = 1$, if j-function is implemented *i*-m PC $x_{ij} = 0$, if it is not implemented.

Table 1.5 – Matrix X elements

Code	S1	S2	S3	S4	S5	S6	S7	S8	S	S10
F1	0	1	1	1	1	1	0	1	1	0
F2	1	1	0	1	1	1	1	1	1	1
F3	1	0	1	0	0	1	1	1	1	1
F4	1	1	0	1	1	1	1	1	1	1
F5	1	1	0	1	1	1	1	1	1	1
F6	1	1	1	1	1	1	1	1	1	1
F7	1	1	0	1	1	0	1	1	1	1
F8	1	1	0	1	1	0	1	1	1	1
F9	0	0	0	0	0	0	0	0	0	1
F10	1	1	0	1	0	0	0	1	1	1
F11	1	0	0	1	0	0	0	1	1	1
F12	1	1	0	1	1	1	1	1	1	0
F13	0	0	0	0	1	0	0	0	1	0
F14	0	1	0	1	1	1	1	1	0	0
F15	0	1	0	1	1	1	1	1	1	1
F16	0	1	0	1	1	1	1	1	1	1
F17	0	1	0	0	0	1	1	0	1	1
F18	1	1	1	1	1	1	1	0	0	0
F19	1	1	1	1	1	1	0	1	1	0
F20	0	0	0	0	0	0	0	0	0	1
F21	1	1	0	1	1	1	1	1	1	1
F22	1	1	0	0	1	1	1	1	1	0
F23	1	1	1	0	0	0	0	1	0	0
F24	1	0	1	0	0	0	1	0	0	0
F25	1	0	1	0	1	1	1	1	0	1
F26	1	1	1	1	1	1	0	1	1	1
F27	0	1	1	1	1	1	0	1	0	1
F28	0	1	1	1	0	1	1	1	0	0
F29	0	0	0	1	1	0	0	1	0	1
F30	1	1	1	1	0	1	1	1	1	1
F31	0	1	1	1	1	1	1	1	1	0
F32	0	0	1	1	0	0	0	1	0	0
F33	1	1	1	0	1	0	0	1	1	1
F34	1	0	0	1	0	1	1	1	0	0
F35	0	1	1	1	1	1	0	1	1	0

To determine the absolute estimate of superiority functions AESF of one system over another, the matrix has been made $p^{10} = \left\| p_{ik}^{10} \right\|$, where elements p_{ik}^{10} correspond to the number of functions, conducted by system S_i but not used in the system S_k , where $i,k= 1,n$. Element p_{ik}^{10} is the capacity of difference of sets Z_i and Z_k , i.t. $p_{ik}^{10} = \left| F_i / F_k \right|$

Matrix $p^{10} = \left\| p_{ik}^{10} \right\|$ AESF of one system over another is given in the table 1.6.

Table 1.6 – Matric of the absolute functional superiority

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S1O
S1	0	9	6	10	9	9	6	10	7	7
S2	5	0	4	4	3	3	3	6	3	6
S3	11	13	0	14	13	11	11	15	14	14
S4	6	4	5	0	4	4	4	5	5	6
S5	7	5	6	6	0	5	5	8	5	7
S6	7	5	4	6	5	0	3	8	6	8
S7	9	10	9	11	10	8	0	14	11	11
S8	2	2	2	1	2	2	3	0	2	3
S9	5	5	7	7	5	6	6	8	0	5
S10	7	10	9	10	9	10	8	11	7	0

Relative estimate of the system S_k absorption range regarding system Si was found by means of the matrix $h = \left\| h_{ik} \right\|$, which elements $\left\| h_{ik} \right\|$ were determined in the following way:

$$h_{ik} = \frac{p_{ik}^{11}}{p_{ik}^{10} + p_{ik}^{10}}, (0 \le h_{ik} \le 1$$

Matrix $H = \left\| h_{ik} \right\|$ that gives characteristics to the relative correlation of the programming tools (table 1.7) in the part of duplicated functions there

Table 1.7 – Matrix of the relative correlation of programming tools

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
S1	1	0,762	0,476	0,714	0,667	0,667	0,571	0,905	0,762	0,667
S2	0,640	1	0,480	0,840	0,800	0,800	0,600	0,920	0,800	0,600
S3	0,625	0,750	1	0,688	0,625	0,750	0,438	0,875	0,563	0,438
S4	0,600	0,840	0,440	1	0,760	0,760	0,560	0,960	0,720	0,600
S5	0,609	0,870	0,435	0,826	1	0,783	0,565	0,913	0,783	0,609
S6	0,609	0,870	0,522	0,826	0,783	1	0,652	0,913	0,739	0,565
S7	0,667	0,833	0,389	0,778	0,722	0,833	1	0,833	0,667	0,556
S8	0,655	0,793	0,483	0,828	0,724	0,724	0,517	1	0,724	0,621
S9	0,696	0,870	0,391	0,783	0,783	0,739	0,522	0,913	1	0,696
S10	0,667	0,714	0,333	0,714	0,667	0,619	0,476	0,857	0,762	1

Relative esteem of the similarity degree of systems S_i *and* S_k is described with the matrix $G = \left\| g_{ik} \right\|$ elements of which $\left\| g_{ik} \right\|$ are determined as:

$$g_{ik} = \frac{p_{ik}^{11}}{p_{ik}^{00}}, (0 \le g_{ik} \le 1$$

Matrix $G = \left\| g_{ik} \right\|$ represents relative correlations of the program environment is given in the table

Relative esteem of the similarity degree of systems S_i *and* S_k is described with the matrix $G = \left\| g_{ik} \right\|$ elements of which $\left\| g_{ik} \right\|$ are determined as:

$$g_{ik} = \frac{p_{ik}^{11}}{p_{ik}^{00}}, (0 \le g_{ik} \le 1$$

Matrix $G = \left\| g_{ik} \right\|$ represents relative correlations of the program environment is given in the table 1.8.

Table 1.8

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
S1	1	0,53	0,37	0,48	0,46	0,46	0,44	0,61	0,57	0,500
S2	0,53	1	0,41	0,72	0,71	0,71	0,53	0,74	0,71	0,484
S3	0,37	0,41	1	0,36	0,34	0,44	0,25	0,45	0,30	0,233
S4	0,48	0,72	0,36	1	0,65	0,65	0,48	0,80	0,60	0,484
S5	0,46	0,71	0,34	0,65	1	0,64	0,46	0,67	0,64	0,467
S6	0,46	0,71	0,44	0,65	0,64	1	0,57	0,67	0,58	0,419
S7	0,44	0,53	0,25	0,48	0,46	0,57	1	0,46	0,41	0,345
S8	0,61	0,74	0,45	0,80	0,67	0,67	0,46	1	0,67	0,563
S9	0,57	0,71	0,30	0,60	0,64	0,58	0,41	0,67	1	0,571
S10	0,50	0,48	0,23	0,48	0,46	0,41	0,34	0,56	0,57	1

Then we build logical matrices of superiority

$P_0 = \left\| p_{ik}^0 \right\|$, of similarity

$G_0 = \left\| g_{ik}^0 \right\|$ and of exception

$H_0 = \left\| h_{ik}^0 \right\|$ on the basis of matrices *P, H and G.*

Elements of matrices P_o are calculated according to the following formula:

$$p_{ik}^0 = \begin{cases} 1, & if \quad (p_{ik} \le \varepsilon_p) \cap (i \ne k) \\ 0, if & p_{ik} \langle \varepsilon_p \rangle \cup \quad (i = k) \end{cases}$$

Elements of matrix H_o:

$$h_{ik}^0 = \begin{cases} 1, & if \quad (h_{ik} \le \varepsilon_p) \cap (i \ne k) \\ 0, if & h_{ik} \langle \varepsilon_p \rangle \cup \quad (i = k) \end{cases}$$

Elements of matrix G_o ::

$$g_{ik}^0 = \begin{cases} 1, & if \quad (g_{ik} \le \varepsilon_p) \cap (i \ne k) \\ 0, if & g_{ik} \langle \varepsilon_p \rangle \cup \quad (i = k) \end{cases}$$

Where, ε_p, ε_h, ε_g liminal values of superiority P_0, H_0, G_0

The logical matrix of superiority $P_0 = \left\| p_{ik}^0 \right\|$ for liminal value $\varepsilon_p = 10$ is shown in the table 1.9.

Table 1.9 – Logical matrix of superiority

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
S1	0	1	1	1	1	1	1	1	1	1
S2	1	0	1	1	1	1	1	1	1	1
S3	0	0	0	0	0	0	0	0	0	0
S4	1	1	1	0	1	1	1	1	1	1
S5	1	1	1	1	0	1	1	1	1	1

S6	1	1	1	1	1	0	1	1	1	1
S7	1	1	1	0	1	1	0	0	0	0
S8	1	1	1	1	1	1	1	0	1	1
S9	1	1	1	1	1	1	1	1	0	1
S10	1	1	1	1	1	1	1	0	1	0

Logical matrix of similarity $G_0 = \|g_{ik}^0\|$ for liminal value $\varepsilon_g = 0,5$ is given in the table 1.10.

Table1.10 – Logical matrix of similarity

	S1	S2	S3	S4	S5	S6	S7	S	S	S10
S1	0	1	0	0	0	0	0	1	1	1
S2	1	0	0	1	1	1	1	1	1	0
S3	0	0	0	0	0	0	0	0	0	0
S4	0	1	0	0	1	1	0	1	1	0
S5	0	1	0	1	0	1	0	1	1	0
S6	0	1	0	1	1	0	1	1	1	0
S7	0	1	0	0	0	1	0	0	0	0
S8	1	1	0	1	1	1	0	0	1	1
S9	1	1	0	1	1	1	0	1	0	1
S10	1	0	0	0	0	0	0	1	1	0

Logical matrix of functionality for information systems exception $H_0 = \|h_{ik}^0\|$ for the level $\varepsilon_g = 0,8$ is given in the table 1.11.

Table 1.11 – Logical matrix of functionality for information systems exception

	S1I	S2	S3	S4	S5	S6	S7	S8	S9	SIO
S1	0	0	0	0	0	0	0	1	0	0
S2	0	0	0	1	1	1	0	1	1	0
S3	0	0	0	0	0	0	0	1	0	0
S4	0	1	0	0	0	0	0	1	0	0
S5	0	1	0	1	0	0	0	1	0	0
S6	0	1	0	1	0	0	0	1	0	0
S7	0	1	0	0	0	1	0	1	0	0
S8	0	0	0	1	0	0	0	0	0	0
S9	0	1	0	0	0	0	0	1	0	0
S10	0	0	0	0	0	0	0	1	0	0

On the basis of logic matrix of exception $P_0 = \|p_{ik}^0\|$, of similarity $G_0 = \|g_{ik}^0\|$ and exception $H_0 = \|h_{ik}^0\|$ the graphs of advantage (fig. 4), similarity (fig. 5) and exception (fig. 1.6) of the system.

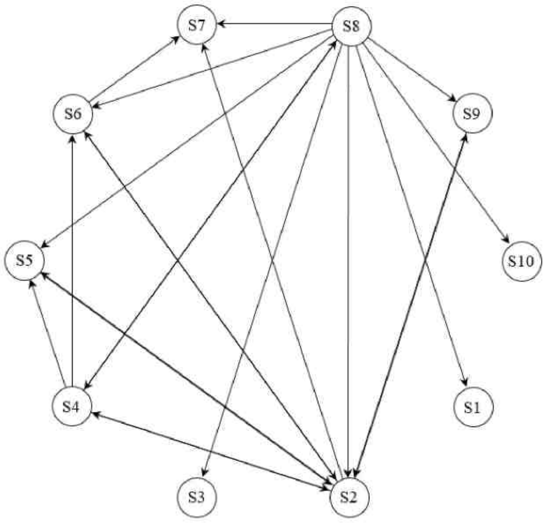

Fig. 4. Graph of system advantage at = 10

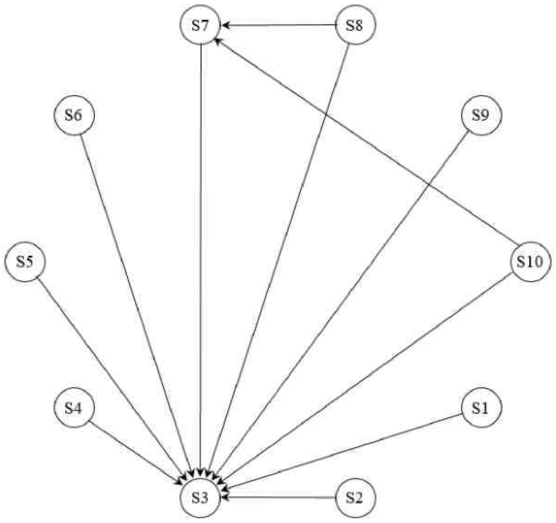

Fig. 5. Graph of system similarity at = 0,6:

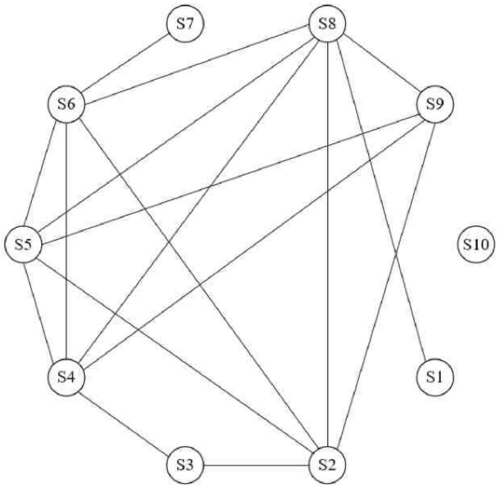

Fig. 1.6. Graph of system exception at = 0,8

5. Conclusions

All the systems take an advantage over S3, but systems S8 and S10 have also an advantage over the system S7. Practically all systems have similar functions with S2, S8 and S9, and the lack of connections with S10 can be explained by the presence of unique risk assessment functions; S2 is absorbed by many systems, but in some cases, there is a mutual absorption present, and S8 absorbs all of them.

According to everything written above, one can say that to increase the effectiveness of risk management we need of risk management formalization and automation at different stages. Such a task can be solved by developing a support system for risk management decision. RMSS should be based on modern methods of information processing at conditions of material uncertainty and allow to conduct risk analysis, production, evaluation and effective decision-making. To provide this, the system should use models that integrate qualitative and quantitative factors that determine aviation risks at any stage of the activity.

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Застосування нечітких моделей при аналізі ризиків в програмному середовищі

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Проведено аналіз функціональної завершеності існуючих систем виявлення факторів ризику. Це дало змогу визначити інформаційні системи з аналогічним набором функцій, оцінити ступінь подібності та ступінь відповідності засобів за допомогою "стандартної" моделі системи управління ризиками, в якій розглядаються рекомендовані практики та стандарти ІКАО щодо безпеки авіації, щоб виправдати доцільність створення системи підтримки прийняття рішень, використовуючи неточні моделі та неточні логіки для аналізу ризиків у авіаційній діяльності. Незрівнювані моделі мають ряд особливостей щодо можливості врахування інтуїції та досвіду експертів, можливості більш адекватного моделювання процесів управління безпекою польотів та отримання точних рішень, які співвідносяться з початковими даними; підтримка швидкого розвитку системи управління безпекою з її подальшою функціональністю, збільшенням складності; їх апаратне і програмне забезпечення в системах управління та прийняття рішень є менш складним у порівнянні з класичними алгоритмами.

Ключові слова: байєсівські мережі; прийняття рішень; причинно-наслідкові зв'язки; ризики; фактори ризику.

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Использование нечетких моделей при анализе рисков программной среде

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Проведен анализ функциональной полноты существующих систем идентификации факторов риска. Это позволило определить информационные системы с аналогичным набором функций, оценить степень сходства и степень соответствия средств из «стандартной» модели системы управления рисками, в которой рассматриваются рекомендуемые практики и стандарты ИКАО в области безопасности полетов, для обоснования целесообразности создания системы поддержки принятия решений с использованием неточной модели и неточной логики анализа рисков в авиационной деятельности. Неточные модели имеют ряд особенностей относительно возможности учета интуиции и опыта экспертов, возможности более адекватного моделирования процессов управления безопасностью полетов и получения точных решений, которые коррелируют с исходными данными; поддержка быстрого развития системы управления безопасностью с увеличением ее функциональной сложности; их аппаратная и программная реализация в системах управления и принятии решений менее сложна по сравнению с классическими алгоритмами.

Ключевые слова: принятие решений; причинно-следственные связи; риски; факторы риска.

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