Topic 1: Expert Judgment Method

Lecture 1: Basics of decision-making theory
Lecture 2 Classification of systems / Methods of decision-making / Expert Judgment Method (EJM).
Lecture 3 Algorithm of EJM. Example for using EJM. Estimation the difficulty of procedures of ATCO for aircrafts control
Lecture 4 Expert Judgment Method. Weight coefficients

Laboratory works

1. *Decomposition and aggregation of complex system.*
2. *Expert Judgment Method / Matrix of individual preferences*
3. *Expert Judgment Method Standard task "Definition of the systems of preference of ATC's workload*
4. *Expert Judgment Method Individual task, 1 criteria*

Professor Shmelova T.

National Aviation University
Department of Airnavigation system

Lecture 1: Basics of decision-making theory

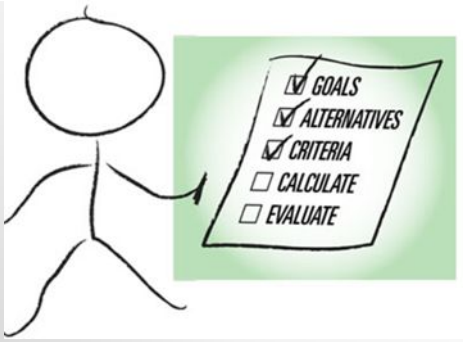
1. *Decision problems. Multi-criteria problems*
2. *Basic definitions of decision-making theory*
3. *Decision Support System (DSS)*

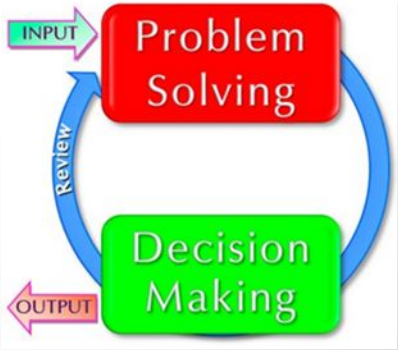
Professor Shmelova T.

Course Basics of decision-making theory/ Informatics of DM

1 semester

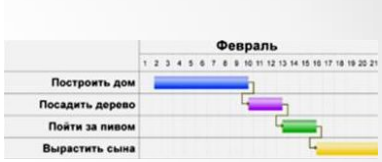
1. Classification of methods of decision-making
2. Expert Judgment Method / Multi-criteria decision problems. Tasks:
   - *2.1 Quantitative estimation of the complexity of the aircraft flight stages - definition of significance (complexity) of the phases of flight of the aircraft*
   - *2.2 Quantitative estimation of the complexity of the navigation parameters in flight of aircraft.*
   - *2.3 Quantitative estimation of significance of the Landing System (GNSS, ILS, VOR,....)*
   - *2.4 Quantitative estimation of the complexity of procedures operators during working process - definition of controller's work load for aircraft (AS) service*
   - *2.5 Quantitative estimation of the Human factor problem*
   - *2.6 Select of the sources of projects financing*
3. Decision making under certainty. The Linear Programming. The Simplex method (Diet Problem, Finance distribution on advertising,...)
4. The Transport task. Method of potentials (Distribution of AS on routes

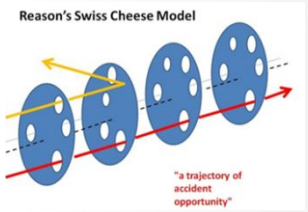


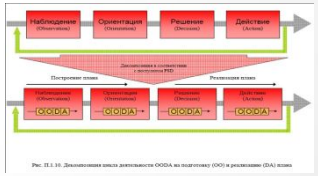


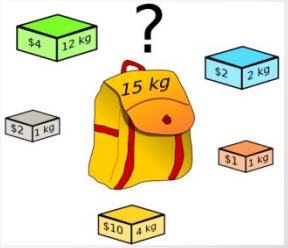
2 semester

1. Network planning. Decision making in emergency situation. The deterministic models for H-O (controller, pilot, engineer …) were obtained in accordance with "ASSIST".
   - *1.1 Designing with MS Excel (MS Project)*
   - *1.2 DM in ES (ATCO)*
   - *1.3 DM for repair (ATSEP)*
2. Decision making under risk. Tasks:
   - *2.1 Design making in risk - construction big or small airport*
   - *2.2 Decision making in risk - Decision Making by H-O in flight emergencies situation using decision tree*
3. Game Theory. A mathematical model of conflict – "teacher – student" *etc*
4. Decision making under uncertainty. Criteria Vald, Laplace, Savage, Hurwicz. Task:
   - *4.1 Choosing optimal landing aerodrome in flight emergencies situation*
   - *4.2 Alternative landing aerodrome*
   - *4.3 Profit and cost*
5. Dynamic programming. Tasks:
   - *5.1 The problem of minimum cost way between places*
   - *5.2 The traveling salesman problem*
   - *5.3 The task of climb of the aircraft*
   - *5.4 The problem of rational loading of backpack*
6. Neural Networks. Neural network admission student to simulator training by the number of hours and level of training.
7. Fuzzy logic. Quantitative estimation of the risk.
8. Decision support system.
9. Expert Systems.
10. Characteristics of the decision maker (the methods of socionics, methods of sociometry).
11. Analysis and synthesis of aviation man-machine system, for example, "pilot – aircraft", using theory of automatic control





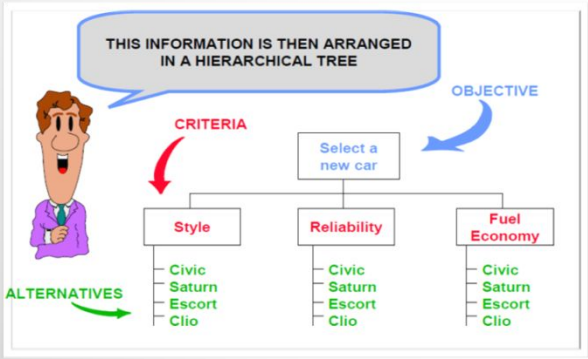


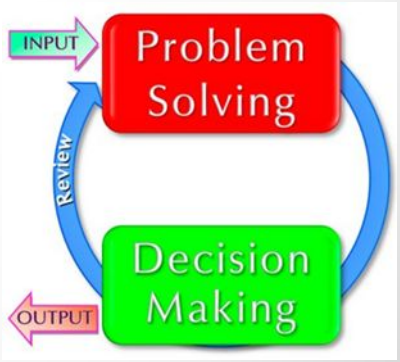


1 семестр

Лекции / практики / лабораторные работы / индивидуальные работы

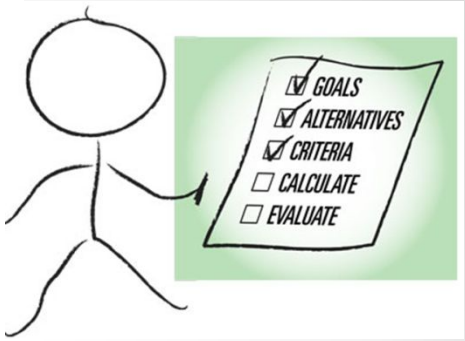
1. Классификация методов принятия решений (по Говарду - 3d классификация)
2. Метод экспертных оценок / Многокритериальные проблемы. Задачи:
   - *2.1. Количественное оценивание сложности этапов полета воздушного судна (ВС)*
   - *2.2. Оценивание значимости навигационных параметров полета ВС на одном из этапов полета.*
   - *2.3. Количественная оценка значимости систем посадки ВС (ГНСС, ILS, VOR)*
   - *2.4. Оценивание сложности процедур, выполняемых оператором во время рабочего процесса, авиадиспетчера при обслуживании воздушных судов*
   - *2.5. Выбор источников финансирования проектов*
3. Принятие решений в условиях определенности. Линейное программирование. Симплекс-метод (задача о диете, распределение финансов на рекламу и тд)
4. Транспортная задача. Метод потенциалов (распределение ВС по маршрутам)

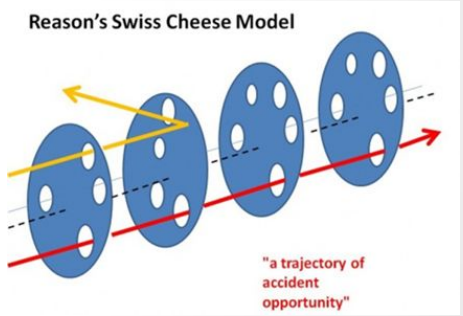


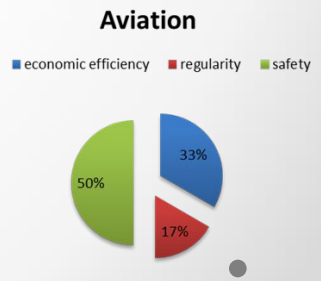


2 семестр

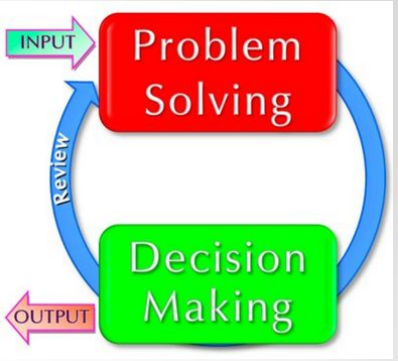
1. Сетевое планирование. Модели принятия решений в аварийных ситуациях. Детерминированные модели принятия решений человеком-оператором (Ч-О) (диспетчер, пилот, инженер ...). Задачи:
   - *1.1.1. Авиадиспетчер - сетевые модели в соответствии с "ASSIST" - технология работы авиадиспетчера в особом случае в полете*
   - *1.1.2. Инженер – сервисное обслуживание техники*
   - *1.1.3. Проектирование с помощью MS Excel (MS Project)*
2. Принятие решений в условиях риска. Задачи:
   - *2.1.1. Проектирование строительства аэропорта*
   - *2.1.2. Стохастические модели принятия решений Ч-О (диспетчер, пилот, инженер ...) с помощью дерева решений.*
3. Теория игр. Математическая модель конфликта – «учитель – ученик», «спрос-предложение», «человек-машина» и т.д.
4. Принятие решений в условиях неопределенности. Критерии Вальда, Сэвиджа, Лапласа, Михайлова. Задачи:
   - *4.1.1. Задача выбора запасного аэродрома*
   - *4.1.2. Задача выбора оптимального аэродрома посадки.*
   - *4.1.3. Прибыль / Затраты*
5. Динамическое программирование. Задачи:
   - 5.1.1. Поиск пути минимальной стоимости между пунктами
   - 5.1.2. Задача коммивояжера
   - 5.1.3. Задача набора высоты ВС
   - 5.1.4. Задача рациональной загрузки рюкзака (самолета)
6. Нейронные сети. Нейронная сеть допуска студента в тренажерной подготовке.
7. Нечеткая логика. Количественное оценивание риска при развитии аварийной ситуации в полете ВС
8. Системы поддержки принятия решений
9. Экспертные системы
10. Характеристика лица, принимающего решения (ЛПР) (методы соционики, социометрия)
11. Анализ и синтез авиационной человеко-машинной системы, например, "пилот - самолет" - с применением теории автоматического управления







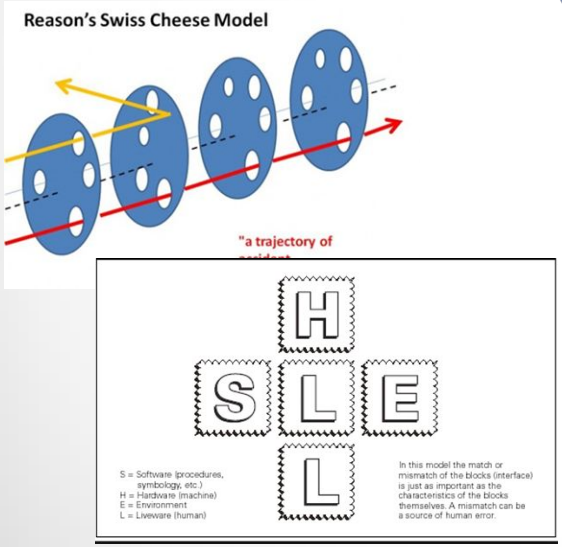
1. Decision problems. Multi-criteria problems



- **Select the best solution**

Multi-criteria problems

- **Quantitative estimation**
- **Analyze of Complexity system**



- **Aviation:** Quantitative estimation of the complexity of the stages the aircraft flight; Quantitative estimation of the complexity of the navigation parameters of flight; Air Craft Landing system (GNSS, ILS, VOR,…); Quantitative estimation of the complexity procedures operators during working process, the procedures for service an aircrafts; Quantitative estimation of the Human factor problem; Aviation Safety (safety, regularity, economic efficiency)
- Management of enterprise
- Select the best Smart Phone
- Choosing a telecommunication system
- Choosing a product marketing strategy
- Choosing Software
- Cross-Browser Website Testing
- **Select of the sources of projects financing**

etc

Systems analysis of decision problems

Systems analysis is a problem solving method **that decomposes** a system into its component pieces for studying of component parts (systems, subsystem, elements, parameters, procedures, factors, etc).

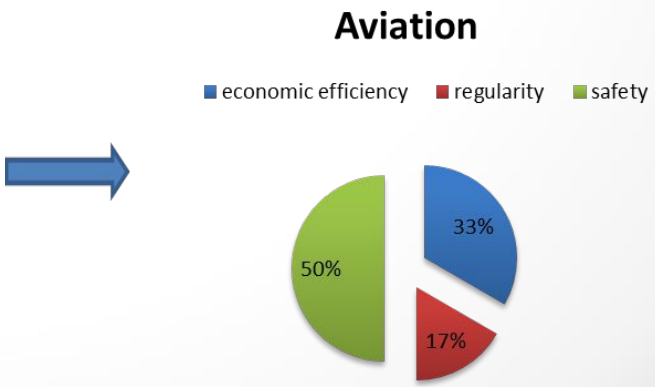
The basic procedures of system analysis is the **decomposition and aggregation**.

- **Decomposition** - separation of complex system into separate parts (subsystems) in order to study separate systems: determining relationships between subsystems and its priorities.

- **Aggregation** – consolidation of the subsystems in the system with one main goal.

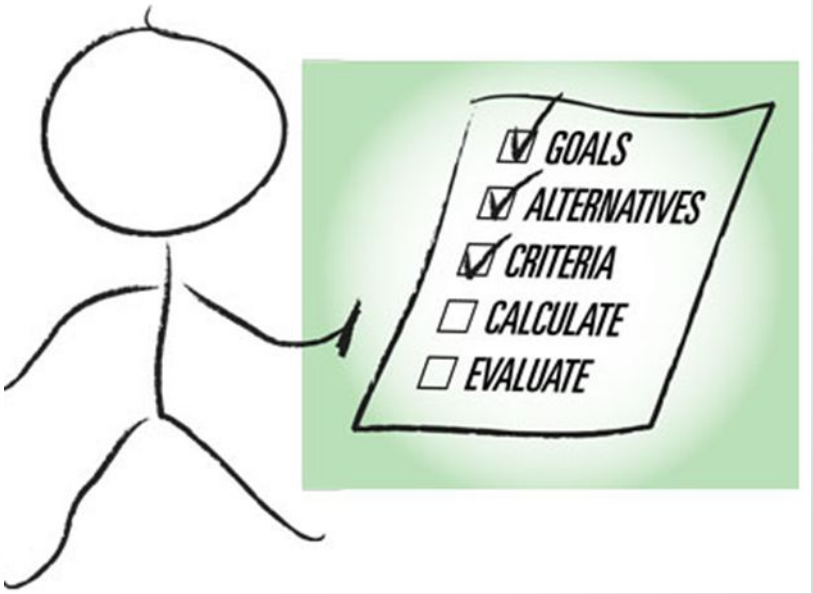
Aviation criteria:

•safety,
•regularity,
•economic efficiency



Algorithm of systems analysis of complex problems

1. **Analysis** of complex problems – alternatives, subsystems, goal..
2. Definition of **criteria**
3. **Decomposition** of a complex problem into subsystems
4. Studying of characteristics of **subsystems**
5. Identification of priorities (importance) subsystems using **expert estimation** by each criterion
6. **Aggregation** of subsystems into one system (additive aggregation, multiplicative aggregation) - decision multi-criteria problems



Methods of Aggregation of subsystems into one system - decision multi-criteria problems

1. Additive aggregation $$W = \sum_{i=1}^{n} w_i f_i$$

2. Multiplicative aggregation $$W = \prod_{i=1}^{n} f_i^{w_i}$$

were

w_i - weight coefficients $$w_i = \frac{C_i}{\sum_{i=1}^{n} C_i} \qquad C_i = 1 - \frac{R_i - 1}{n}$$

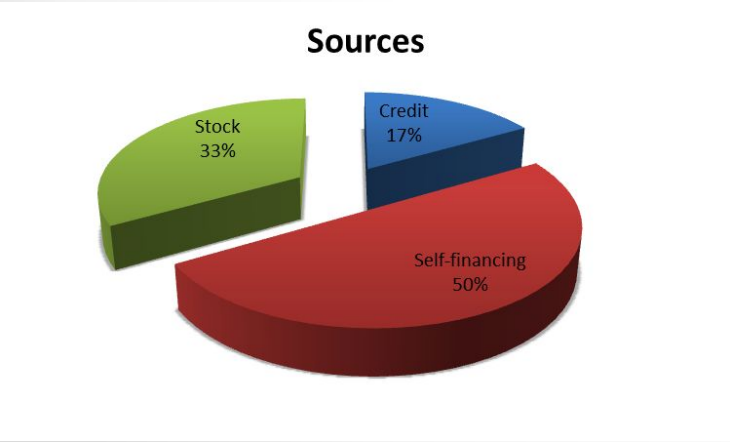
f_i - criteria (function) estimation

Example: Definitions and estimation of the sources of the projects financing

Where to take 100 000 EUR on the projects financing?

Sources	R	C	w	€
Credit	3	0,3333	0,1667	16667
Self-financing	1	1	0,5	50000
Stock	2	0,6667	0,3333	33333
		2	1	100000

Additive aggregation: $W = \sum_{i=1}^{n} w_i f_i = 0{,}166667 * 100000 + 0{,}5 * 100000 + 0{,}333333 * 100000 = 100000€$



Example 1 Definitions and estimation of the sources of the projects financing (decomposition and aggregation)

	Sources	R	C	w	€
1	Credit	3	0,6	0,2	20000
2	Self-financing	1	1	0,3333	33333
3	Stock	2	0,8	0,2667	26667
4	Investmens	4	0,4	0,1333	13333
5	Subsidy	5	0,2	0,0667	6666,7
	sum		3	1	100000

Example 1 Definitions and estimation of the students of 4 course (Additive and Multiplicative aggregation)

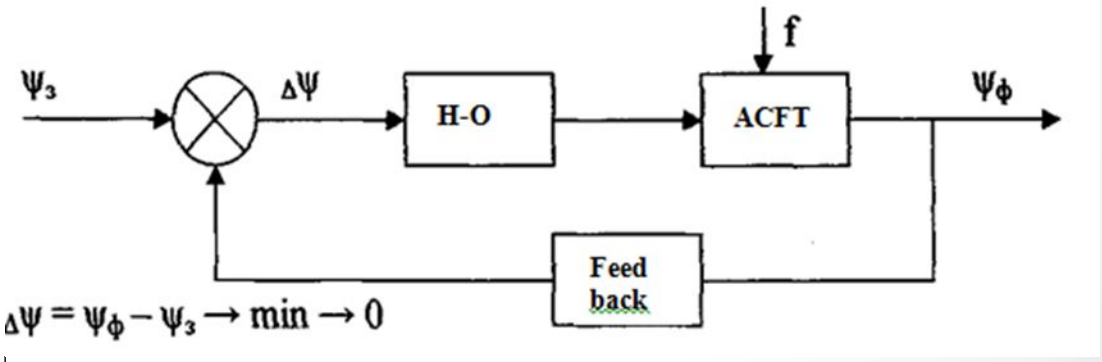
			Estimation of the students			Additive					Multiplicative		
	Subjects	R'	R	C	w	1(good)	W(good)	2 (bad)	W(bad)	1(good)	W(good)	2 (bad)	W(bad)
1	Are Navigation	1,2,3	2	0,833333	0,2380952	5	1,1904762	5	1,190476	5	1,466971	5	1,466971
2	Aerodromes	4,5,6	5	0,333333	0,0952381	4	0,3809524	0	0	4	1,14114	0	0
3	Meteorology	1,2,3	2	0,833333	0,2380952	4	0,952381	4	0,952381	4	1,391066	4	1,391066
4	Communication	1,2,3	2	0,833333	0,2380952	5	1,1904762	5	1,190476	5	1,466971	5	1,466971
5	IT	4,5,6	5	0,333333	0,0952381	3	0,2857143	3	0,285714	3	1,110299	3	1,110299
6	English	4,5,6	5	0,333333	0,0952381	4	0,3809524	4	0,380952	4	1,14114	4	1,14114
	sum			3,5	1	25	4,3809524	21	4	25	4,328214	21	0

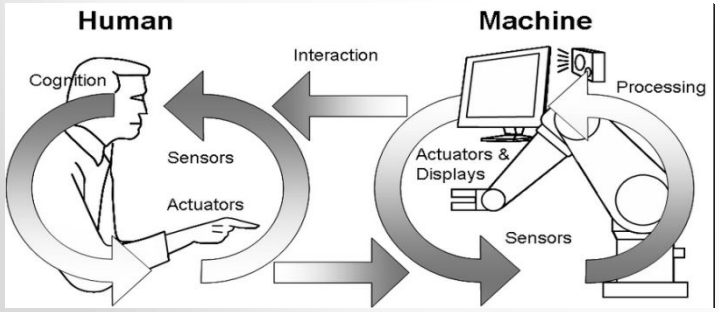
2. Basic definitions of decision-making theory

Decision-making - a goal-oriented choice of the one alternative from several alternatives using methods of optimization

Decision-making theory – theory, which studies mathematical methods for finding optimal solutions in **man-machine system**.

A system - a set of elements and subsystems that are interconnected to set and they have main goal





Maine properties of systems:

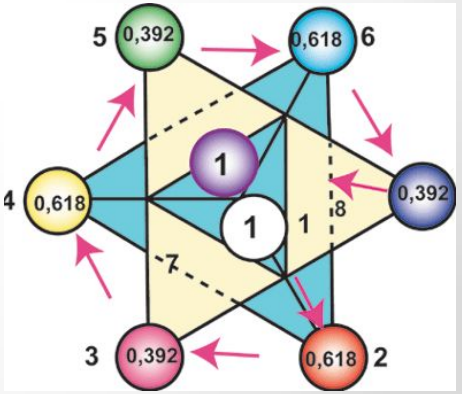
Emergence - the appearance of the property not previously observed as a functional characteristic of the system (the emergence of new properties in the system)

Synergetic - enhancing properties of the system (2+2=5), *working together; cooperative*. In system theory - optimization of system, emergence additional properties by using mathematical methods

Remark

(Синергетика (от греч. synergetike - содружество, коллективное поведение) - наука, изучающая системы, состоящие из многих подсистем самой различной природы; наука о самоорганизации простых систем и превращения хаоса в порядок. - http://www.milogiya2008.ru/sinergia.htm*)*

Method - a way to achieve the goal (*Metodos (latin)) word)*

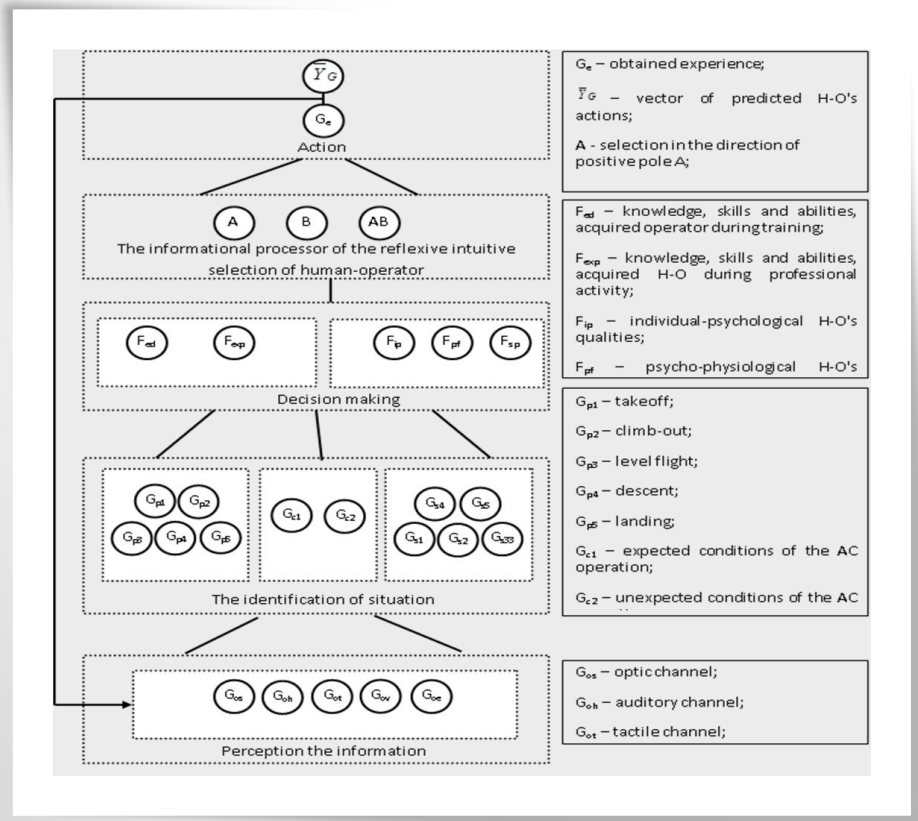


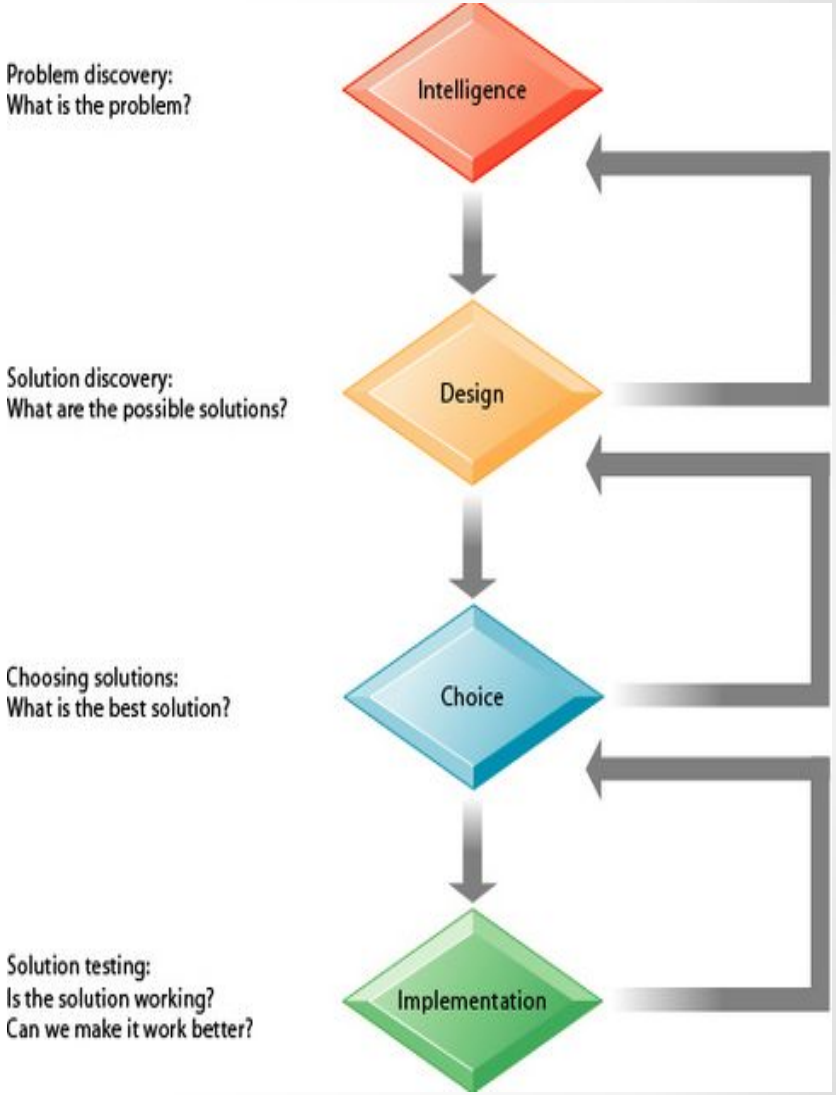
Decision-making theory answers questions:

- ***where*** decisions are made - man-machine systems (pilot – aircraft, air traffic controller - pilot – aircraft, etc)
- ***who*** make decisions - the human - operator, the decision-maker, manager
- ***how*** to make optimal decisions – using decision-making methods

Decision-making stages:

I.perception of information
I.identification of information
I.decision-making
V.action



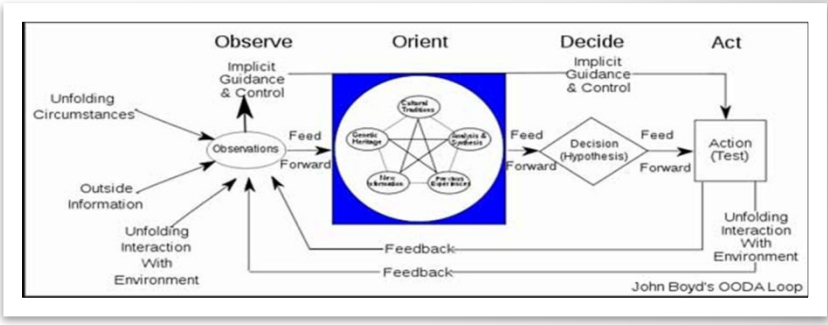


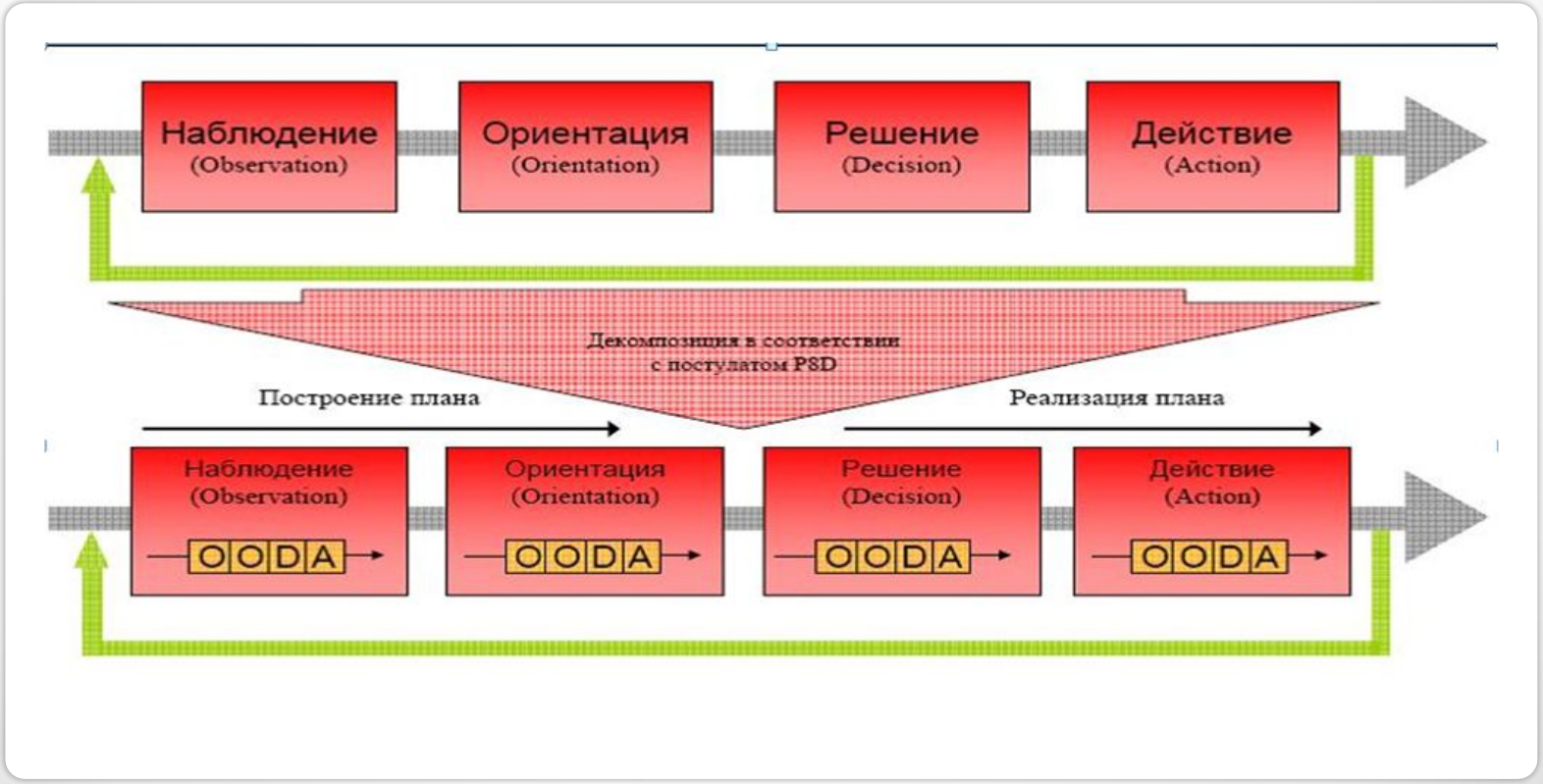
OODA Model

John Boyd cycle (OODA):

- Observe
- Orient
- Decide
- Act

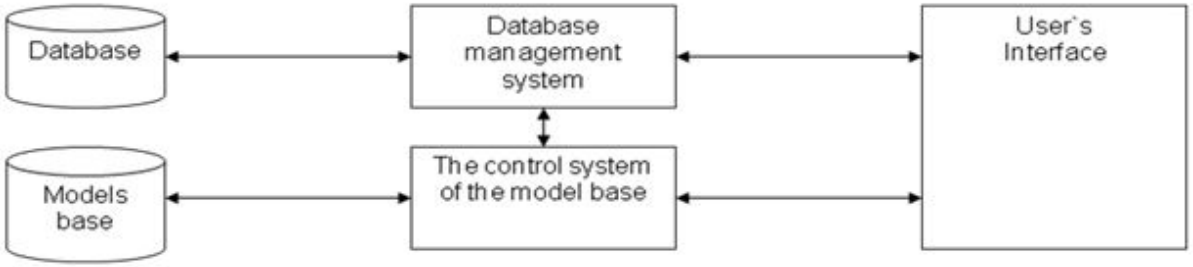
John Richard Boyd (January 23, 1927 – March 9, 1997) was a United States Air Force fighter pilot and Pentagon consultant of the late 20th century, whose theories have been highly influential in the military, sports, business, and litigation





3. Decision Support System (DSS)

Decision Support System (DSS) is a computerized system designed to help a user make decisions



Database (DB) - information structure that reflects the status and relationship of objects analyzed
Database management system
The model base - a set of mathematical, logical, linguistic and other models used for comparative analysis of multi-alternative decision
Users interface

1) The first generation of DSS (1970-1980 years) almost completely repeated the usual functions of management systems to provide computerized assistance in making decisions. The main components of the DSS had the following characteristics:

- **Data Management** - large amounts of information, internal and external databases , processing and evaluation of data;
- **Management of computation (simulation)** - the model developed by experts in the field of computer science for specific problems;
- **User interface language (communication)** - a programming language designed for large computers used exclusively by programmers.

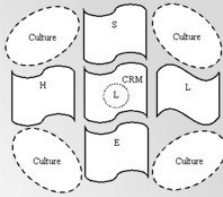
2) DSS second generation (early 1980s - mid 1990's) have had a fundamentally new features:

- **Data management** - a necessary and a sufficient amount of information on cases according to the perception of the person who makes the decision maker (DM), covering hidden assumptions , interests, and quality assessment;
- **Management of calculations and simulations** - flexible models that reproduce the mindset ATS in decision -making;
- **User Interface** - software, "friendly" to the user, a common language, a direct end-user.

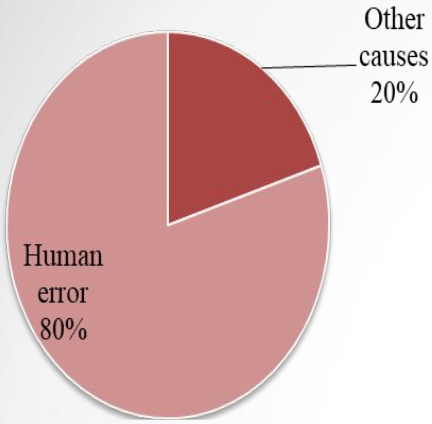
3)DSS third generation (mid -1990s to the present day) has the same features as the second generation, but there were more opportunities with the introduction of new information technology tools and **methods of artificial intelligence**:

- **Warehousing data**;
- **OLAP (*online analytical processing*)** - systems that enable users to quickly and easily manipulate large databases for the study of many indicators of business activity in different angles;
- **Data mining** - Data Mining techniques to search through databases and data warehouses unknown (hidden) patterns and trends;
- **New means of telecommunication** which provide effective communications between users when creating a group decision (Groupware), virtual organizations and offices;
- **Geographical databases** and geographic information systems that provide users with access, display and analysis of data with geographical (territorial) content and meaning, using maps.

Human Factors (HF) problem. Evolution of HFs Models.



Statistical data shows that human errors account for up to 80 % of all causes of aviation accidents



<SHEL→SHELL→SHELL-T→SCHELL → *balance models*
→Collaborative Decision Making (CDM) / AI > etc.

SCHELL model and CRM
C - culture
SCHELL-T model M
T – TEAM

Artificial Intelligence (AI):
FF-ICE - Flight and Flow Information for a Collaborative Environment
SWIM -System-Wide Information Management
PBA - Performance-based approach
CDM - Collaborative decision making
DM - Decision Making
ES – expert systems
DSS – decision support system, etc.

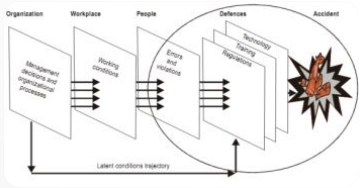
→ **Socio-technical systems**

Culture is a "collective programming of the mind" (Hofstede)

ICAO: Human Factors Guidelines for Safety Audits Manual, Doc. 9806

SHELL model

James Reason model - mistakes



Safety - effectivity /balance model

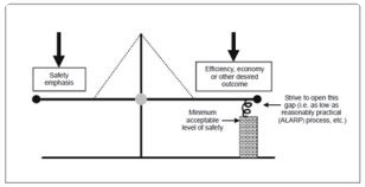
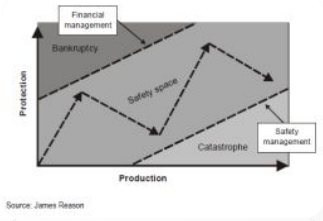
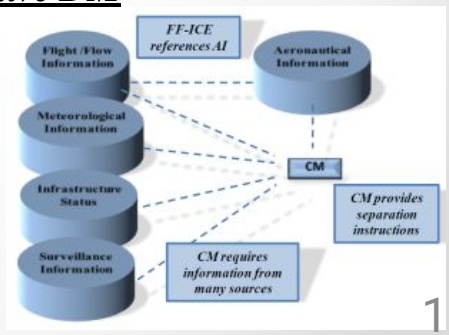


Figure 0-2. Safety balance model



Example of AI / CDM - Collaborative DM



Evolution of HFs Models.

Socio-technical systems **-** "Large-scale, high-technology systems *such as nuclear power generation and aviation have been called* ***socio-technical systems*** *because they require complex interactions between their human and technological components"*

Cross-Cultural Factors in Aviation Safety : Human Factors Digest No. 16 / Circ. ICAO 302-AN/175. – Canada, Montreal : ICAO, 2004

Culture is a "collective programming of the mind" (Hofstede)

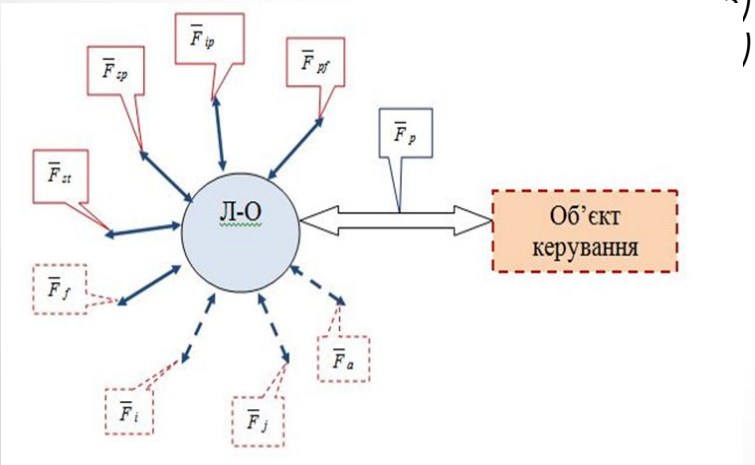
ICAO: Human Factors Guidelines for Safety Audits Manual, Doc. 9806

AI (artificial intelligence) is the simulation of human intelligence processes by modeling, computer systems, and machines

IATA, White paper, 2018

Stages of the evolution of the HF's models:

1) *Professional Skills of H-O / Interaction of H-O's / Definitional of H-O's Errors.*
2) *Cooperation in team / Interaction of H-O's in team / Error detection.*
3) *Influence of Culture / Safety / Error prevention.*
4) *Safety Management / Safety balance models / Minimization of errors.*
5) *Collaborative Decision Making (CDM) / Data for DM*
6) *Artificial Intelligence in aviation, etc.*



Factors:

- ***social-psychological;***
- ***individual-psychological;***
- ***psycho-physiological, etc.***

AI

- ***minimization of errors***
- ***CDM***

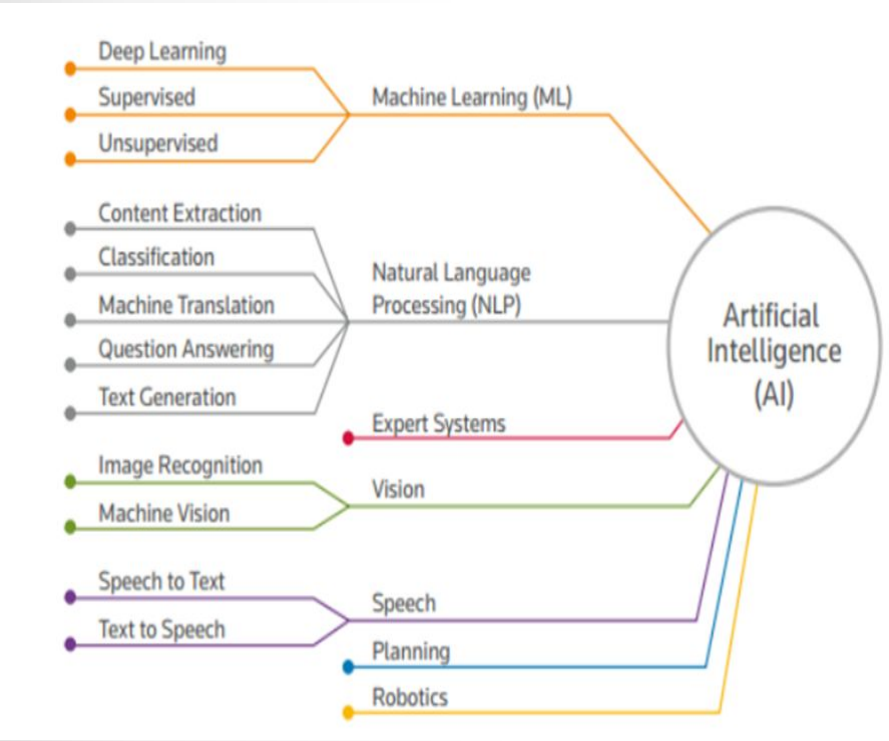
Evolution Human factor's models

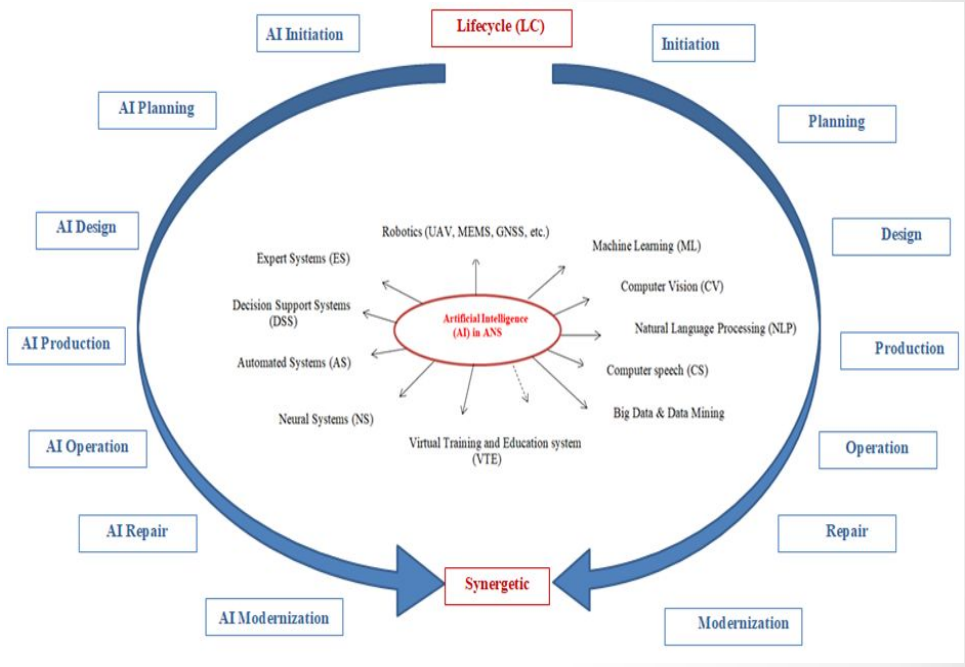
Years	Models	Content of models	Content
1972	SHEL	Software (procedures) - Hardware (machines) - Environment - Liveware	I stage **Professional skills** Interaction Errors
1990	Reason's "Swiss Cheese Model"	Active errors - Latent errors - Windows of opportunity - Causation chain	
1993	SHELL	Software (procedures) - Hardware (machines) - Environment - Liveware - Liveware (humans)	
1999	CRM	Crew - Resource - Management	II stage **Cooperation in team** Error detection
2000	TEM	Threat and Error - Management	
2000	MRM	Maintenance - Resource - Management	
2004	SHELL-T (SHELL-Team)	Software (procedures) - Hardware (machines) - Environment – Liveware - Liveware (humans) - Team	
2004	SCHELL model and CRM	Software (procedures) – Culture - Hardware (machines) - Environment - Liveware - Liveware (humans)	III stage **Culture** Safety Error prevention
2004	LOSA	Line - Operation - Safety - Audit	
2009	HEAD	Human - Environment - Analysis - Design	
	PBA	Performance-Based Approach	
2010	HFACS	Human Factors - Accident - Classification - System	
2013	SMS Safety Balance Model	Safety Management System	IV stage **Safety / Efficiency / Minimization of errors**
2016-now	**AI** CDM	Collaborative Decision Making (CDM) System-Wide Information Sharing and Management (SWIM) Flight & Flow Information for a Collaborative Environment (FF-ICE)	V stage ***Collaborative DM Artificial Intelligence***

The synergetic effect - LS of aviation technique with using AI capability

AI White Paper / IATA

https://www.iata.org/publications/Pages/AI-white-paper.aspx

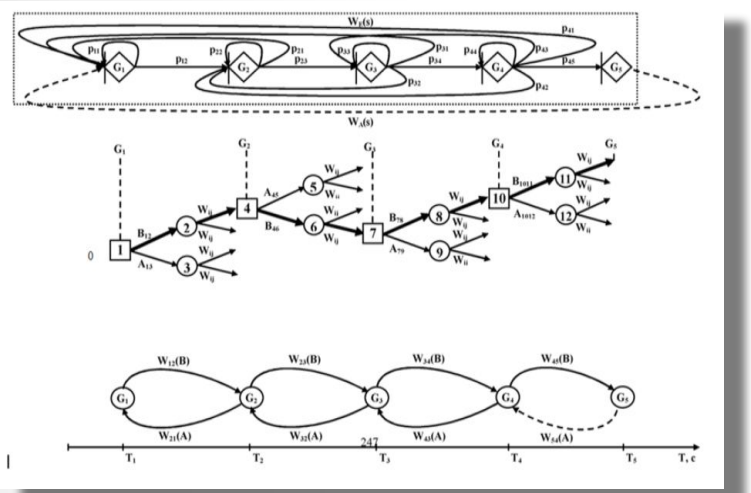


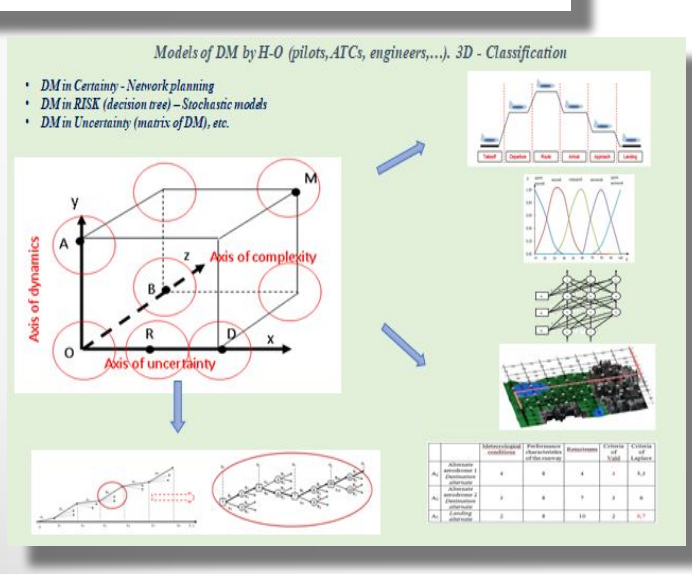


Artificial Intelligence Applications in the Aviation and Aerospace Industries 2019
https://www.igi-global.com/publish/call-for-papers/call-details/3799

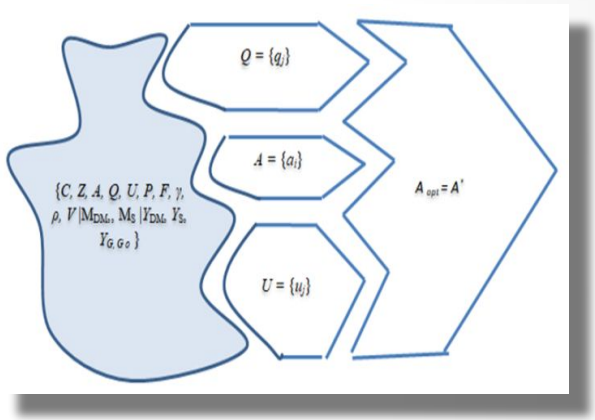
The synergetic effect: analysis of problem (DM) and synthesis of problem (AI)

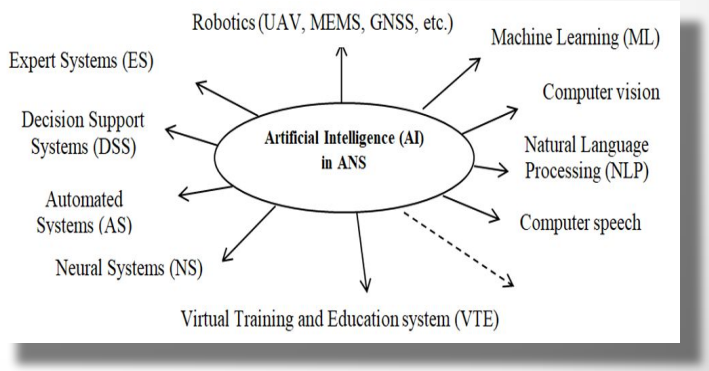
Analysis (DM) – integrated of models





Synthesis (AI) – classification of problem and obtained deterministic models od DM by AI



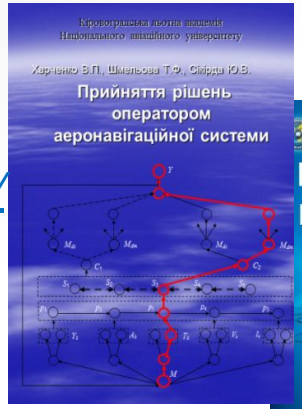


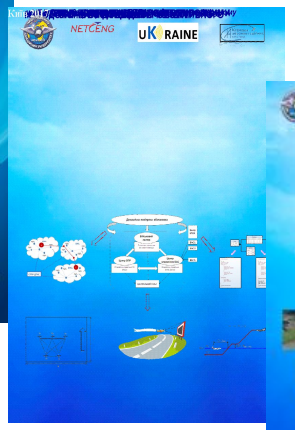
Books about DM of H-O in ANS: DM of ATC; pilot of AC/ UAV; engineer; flight dispatch etc.

Ukraine

http://er.nau.edu.ua/

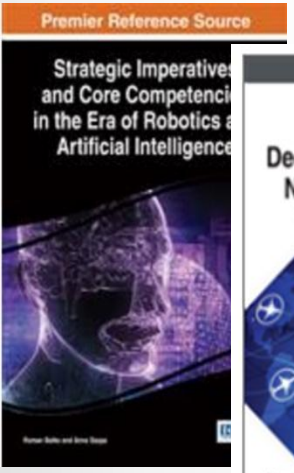
2020

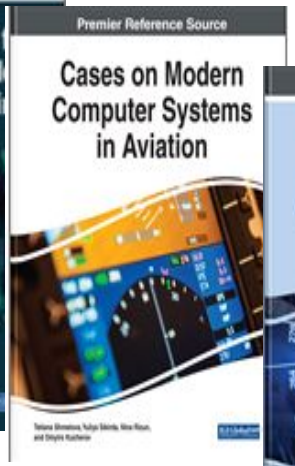


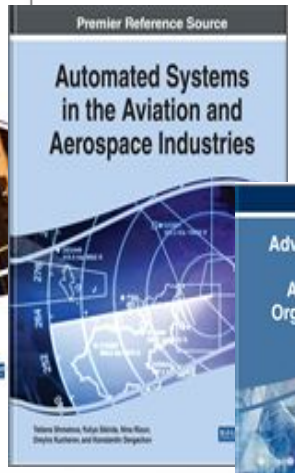


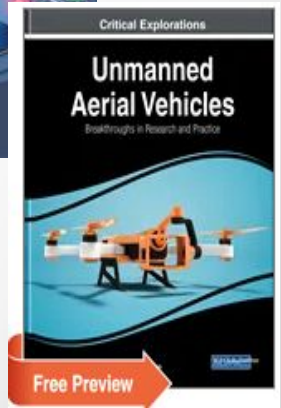
IGI GLOBAL (USA)

https://www.igi-global.com/









2017

2018

2019

National Aviation University
Department of Airnavigation system

Lecture 2:
Classification of systems / Methods of decision-making. Expert Judgment Method (main steps of Method). Matrix of individual preference

1. *Types of system*
2. *Classification of methods of decision-making*
3. *Expert Judgment Method (main steps of Method). Matrix of individual preference*

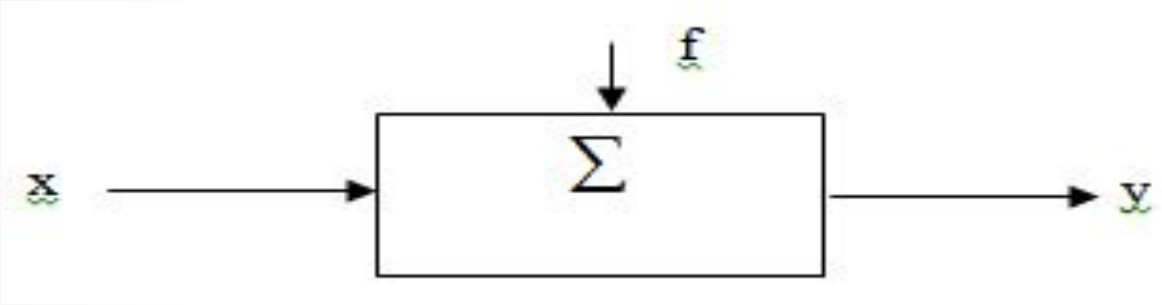
Professor Shmelova T.

1. Types of Analysis and Synthesis of system (SISO & MIMO)

1) One input - One output.

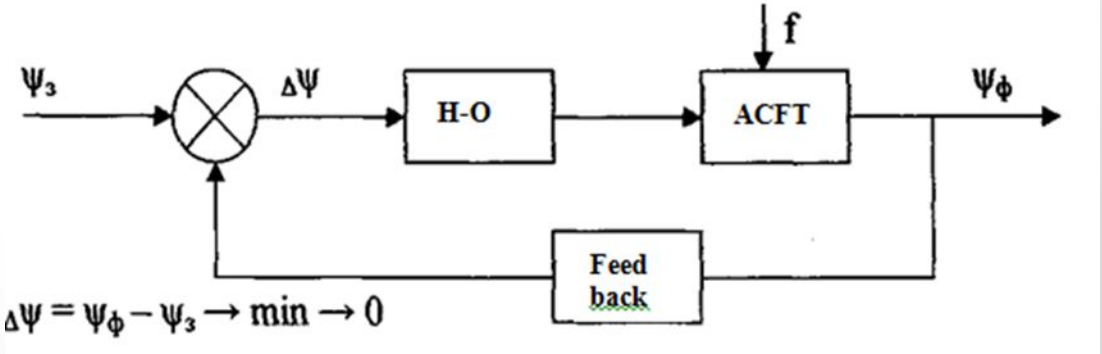
Mathematics for solving problems **-** ***differential equations*** *(f(x)=dy/dx etc)*

Engineering approach - this is the ***theory of automatic control*** *(W(p)= Y(p)/X(p) etc)*



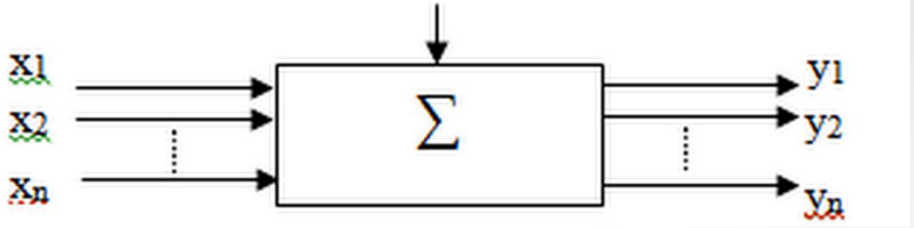
∑ - system
x - input
y - output
f - disturbing influences

Research methods - Analysis and synthesis of aviation ergatic system (man-machine system), for example, pilot – aircraft, operator - aircraft for using **theory of automatic control**



2. Many inputs ($\bar{X}$)– many outputs ($\bar{Y}$)

Mathematics for solving problems - Optimization Methods



Many inputs - $X = \{x_1, x_2, x_3, \ldots\}$

Many outputs - $Y = \{y_1, y_2, y_3, \ldots\}$

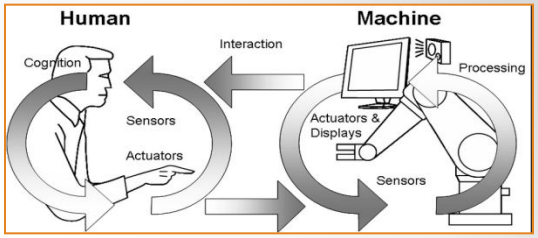
Using optimization methods we choose from many alternatives to one alternative. Optimization problem must have

- **goal (objective function)**
- **constraints**
- **criteria (minimum, maximum) of optimality**

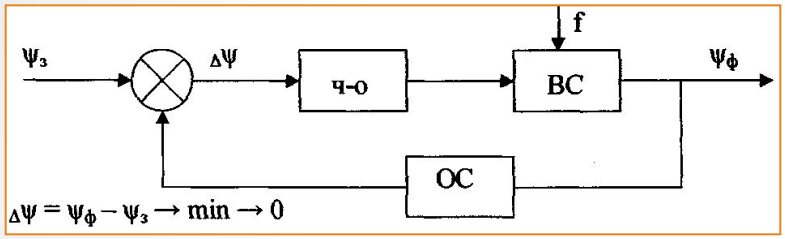
Remark . *According on the type of task variables, constraints and objective function there are following methods:*

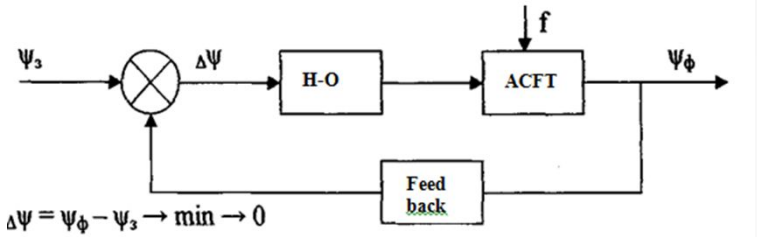
- *Decision making under certainty (LP/DP)*
- *Decision making under risk.*
- *Decision making under uncertainty*
- *Game Theory*
- *Neural Networks*
- *Fuzzy logic etc*

APPLICATIONS - systems

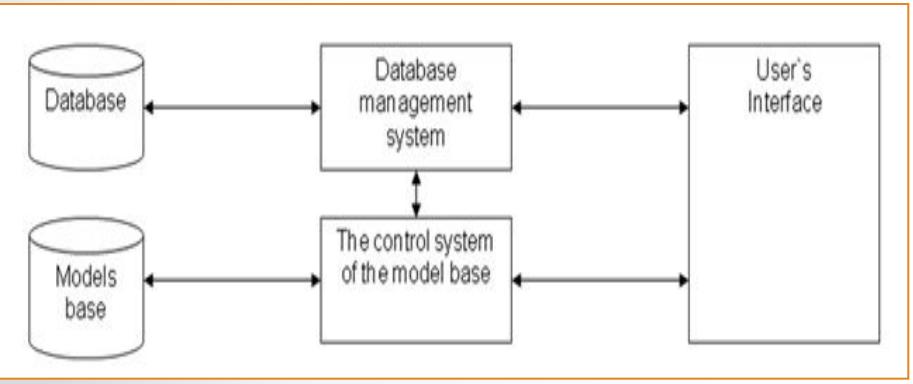


Ergatic (man-machine system) system

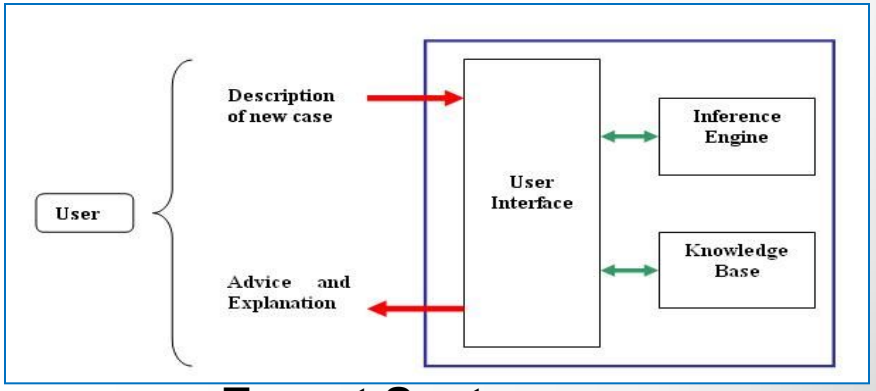




Artificial Intelligence AIS



•Decision support system



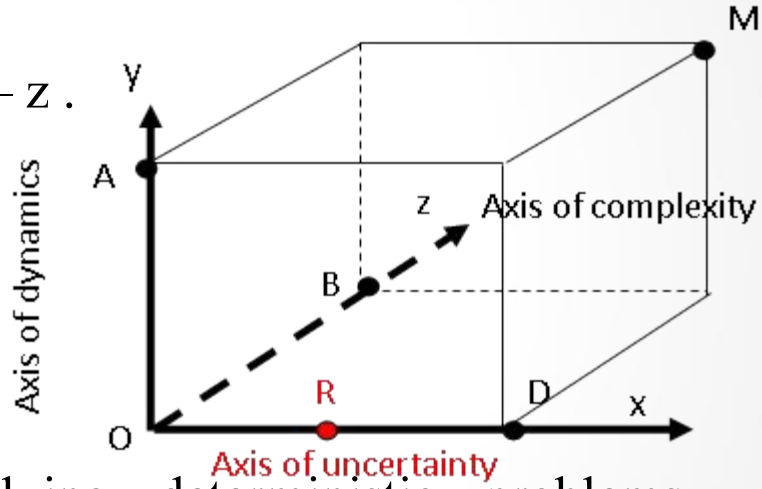
•Expert Systems

2. Classification of Decision Making Methods – 3D - Classification

It is known a lot of types of classification, but the simplest is the classification by Howard ([2] Jozef KOZIELECKI)

Classification is a cube in space, which has the axises (3d - **Classification**):

- Axis of uncertainty (measure (level) of uncertainty) - x,
- Axis of dynamics (measure of dynamics) – y
- Axis of complexity (measure of complexity) – z .

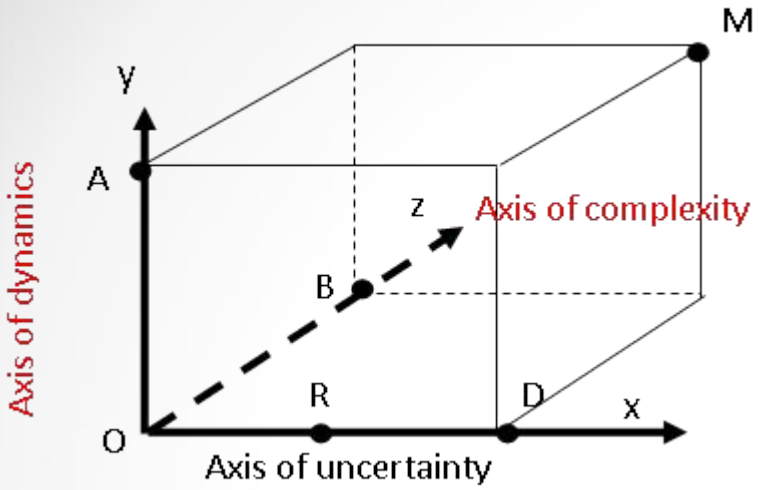


Extent of uncertainty - Axis x .

At point O, we have methods for solving deterministic problems - decision-making in certainty

At point R - we know the law of the probability distribution of the random variable, such as problem in risk R (decision-tree)

At point D - we don't know the law of the probability distribution of the random variable. We have methods for solving uncertainty problems - decision-making in uncertainty (for example, minmax-criteria Vald, Savage, Hurwitz and Laplace etc)

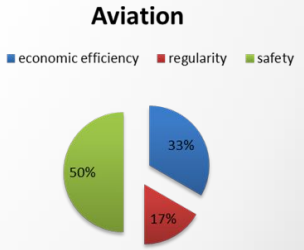


Extent of dynamics – Axis y

At point O, we have methods for solving one-step decision-making problem, such as linear programming.
At point B, we have methods for solving many-step decision-making problem, such as dynamic programming.

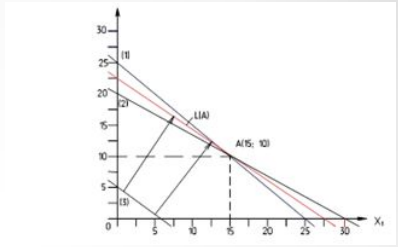
Extent of complexity – Axis z

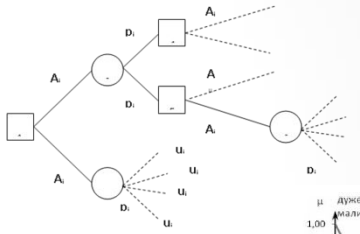
At point O, we have methods for solving **decision-making** tasks with a one-criterion problems
At point B, we have methods for solving **decision-making** tasks with multi-criteria problems

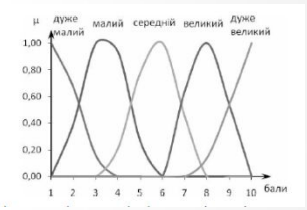


According with the variables types, constraints and objective function type there are following main methods:

- Decision making under certainty (LP, DP, NLP, etc)
- Decision making under risk (decision-tree)
- Decision making under uncertainty (minimax)
- Game Theory
- Fuzzy-logic
- Neural Networks, etc







But!

One of the methods for solving multi-criteria decision problems - **Expert Judgment Method** for define the quantitative values of quality indicators – after **Decomposition** (more - less, complex - simple, difficult - easy).

3. Expert Judgment Method

The main steps of Expert Judgment Method

0. Questionary for experts –

1. **Matrix of individual preferences** – R_i
2. **Matrix of group preferences** – R_{ij}
3. **Experts' group opinion** (sample average, arithmetical mean) - R_{grj}
4. **Coordination** of experts' opinion for each factor:
   - Dispersion for each factor – D_j
   - Square average deviation – σ_j
   - Coefficient of the variation for each factors – v_j
5. **Coordination** of experts' opinion for all factors (Kendal's coordination coefficient) – W
6. **Spirman's correlation** coefficient – R_s
7. **The significance of the calculations:**
   W , criterion - χ^2 χ^2
   R_s – Student's t – criterion t
8. **Weight coefficients** w_i
9. **Graph** of results of calculation

Examples. Matrix of individual preferences

Number of expert, m≥30

Methods for building Matrix of individual preferences :

✔**of paired comparisons method**

✔**ranking method**

Example 1: Estimation of the sources of the projects financing, criteria – efficiency

Estimate ***r*** is equal:

If $\omega_i * >> \omega_i$ (it is more difficult), r = 1

If $\omega_i * << \omega_i$, (less difficult), r = 0

If $\omega_{i*} \approx \omega_i$ (are equal on the difficult), r = 0,5

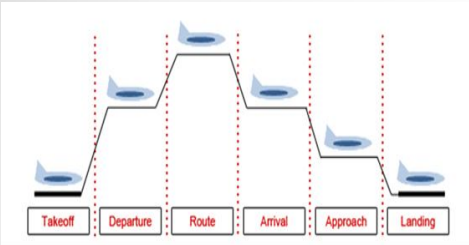
$$W_1 = R_j, R_m \succ R_s \succ R_{cr}$$

Sources	Credit	Self-financing	Joint stock ompany	Mixed	∑M	R	R
Credit		0	0	0,5	0,5	4	4
Self-financing	1		0	0,5	1,5	3	3
Joint stock company	1	1		0	2	1;2	1,5
Mixed	0.5	0.5	1		2	1;2	1,5

Matrix 2. Estimation of the approach systems, criteria - efficiency

	ILS	VOR/DM	GNSS (GPS)	GPS /EGNOS	∑M	R
ILS		1	1	1	3	1
VOR/DME	0		1	0,5	2,5	2
GNSS (GPS)	0	0		0	0	4
GPS /EGNOS	0	0,5	1		1,5	3

Matrix 3. To determine the significance (complexity) of the phases of flight of the aircraft



Methods:

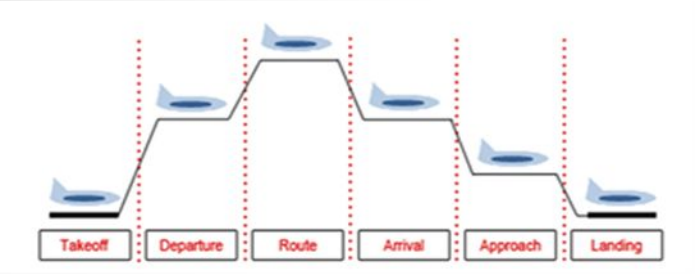
- ***paired comparison method***
- ***method of ranking***

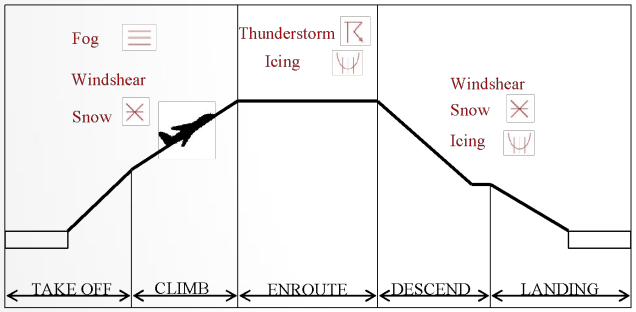
	Take-off	Departure	Route (horizontal flight)	Descend	Landing	$\sum r$	**R**
Take-off		1	1	1	0	3	2
Departure	0		1	1	0	2	3
Route (horizontal flight)	0	0		1	0	1	4
Descend	0	0	0		0	0	5
Landing	1	1	1	1		4	1

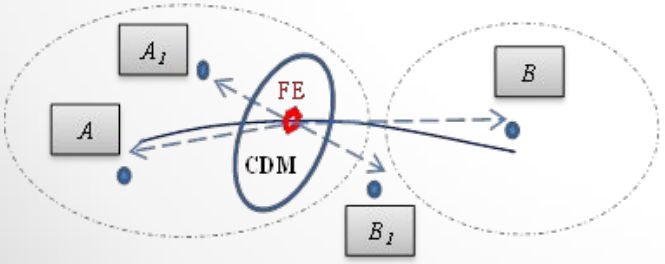
Take-off 2 places
Departure 3 places
Route (horizontal flight) 4 places
Descend 5 places
Landing 1 places

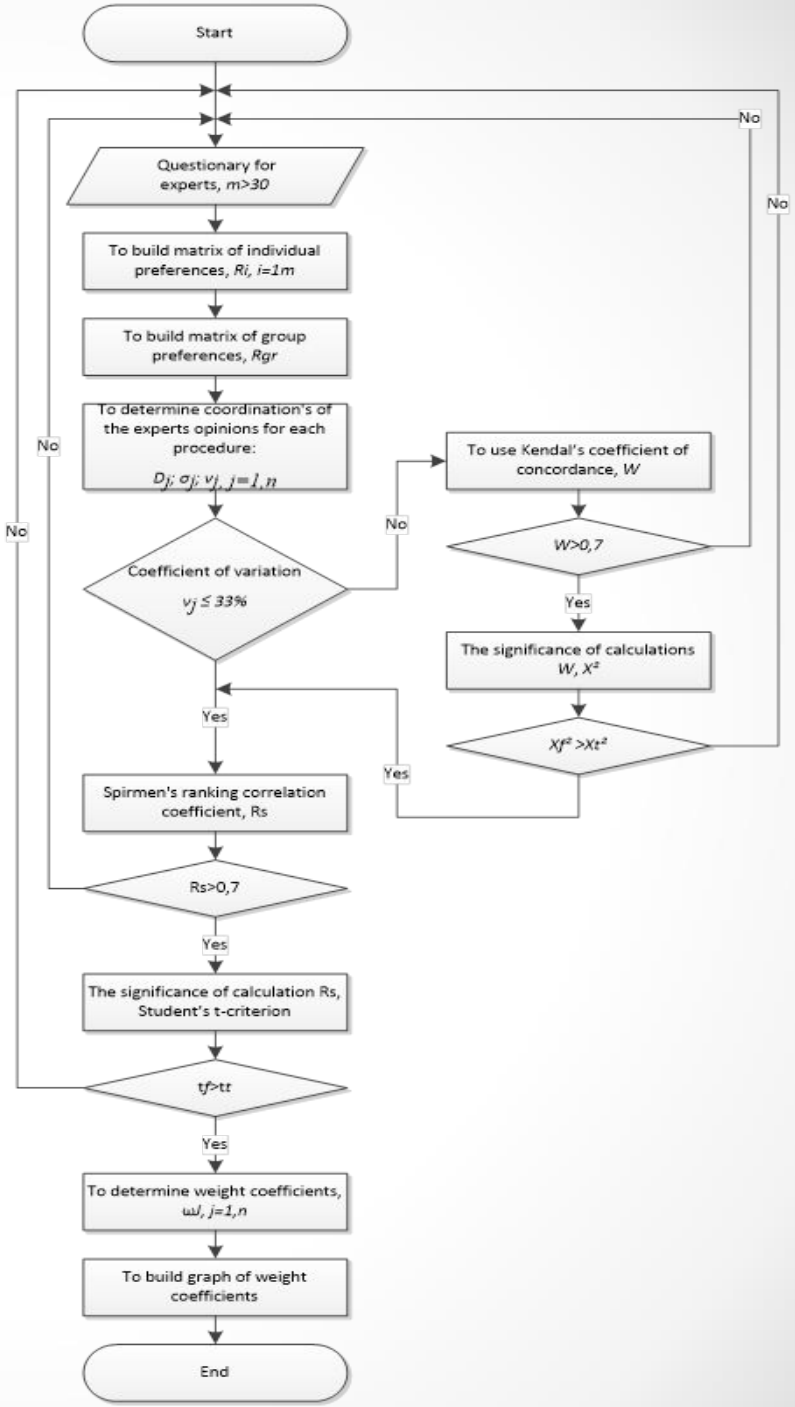
System of preferences expert №1 $S_1 = R_5 \succ R_1 \succ R_2 \succ R_3 \succ R_4$

Algorithm of Expert Judgment Method









National Aviation University
Department of Airnavigation system

Lecture 3:
”Algorithm of Expert Judgment Method (EJM). Example for using EJM. Estimation the difficulty of procedures of ATCO for aircrafts control”

1. *Algorithm of Expert Judgment Method*
2. *Example of Expert Judgment Method.*

Professor Shmelova T.

1.Algorithm of Expert Judgment Method

0. Questionary for experts

1. Matrix of individual preferences - determine opinion of the experts and their systems of individual preferences, R_i , i=1,…m

2. Matrix of group preferences R_{ij}, i=1,…m, j = 1,n

m - number of expert, m≥30

n - number of factors for expert estimates.

3. Determine the experts' group opinion (sample average, arithmetical mean) - R_{grj}:

$$R_{grj} = \frac{\sum_{i=1}^{m} R_i}{m}$$

m - number of expert, m≥30

4. Determine the coordination of experts' opinion:

4.1 Dispersion for each factors (procedure, phases of flight of the aircraft,…):

$$Dj = \frac{\sum_{i=1}^{m} \left(R_{grj} - R_i\right)^2}{m-1}$$

In statistics, dispersion also called variability, scatter, or spread.

4.2 Determine square average deviation (Squared deviations):

$$\sigma_j = \sqrt{D_j}$$

Determine coefficient of the variation for each each factors (procedure, phases of flight of the aircraft,…):

$$\nu_j = \frac{\sigma_j}{R_{grj}} \bullet 100\%$$

If coefficient of a variation is $\nu_j < 33\%$ - opinion of the experts coordinated
If coefficient of a variation is $\nu_j > 33\%$ - opinion of the experts don't coordinated

5.For evaluation of coordination on all procedures it is necessary to use Kendal's coefficient of concordance or to provide interrogation of the experts again.

$$W = \frac{12S}{m^2(n^3 - n) - m\sum_{j=1}^{m} T_j},$$

If coefficient of concordance *is* $W > 0,7$ *- opinion of the experts coordinated*
If coefficient of concordance *is* $W < 0,7$*- opinion of the experts don't coordinated*

We must to provide interrogation of the experts again

6 . Compare opinion of the group of experts and expert №1 by helping of rating correlation coefficient R_s (Spirmans correlation coefficient)

$$R_{s_I} = 1 - \frac{6\sum_{I=1}^{n}(x_I - y_I)^2}{n(n^2 - 1)}$$

7. The significance of the calculations W , criterion - χ^2:

$$\chi_\phi{}^2 = \frac{S}{\frac{1}{2}m(n+1) - \frac{1}{12(n-1)}\sum_{j=1}^{m} R} > \chi_t{}^2$$

8. The significance of the calculations R_s , Student's t – criterion

$$t_\phi = r_s\sqrt{\frac{n-2}{1-r_s^2}} > t_{st}$$

9. Weight coefficients

$$\omega_i = \frac{C_i}{\sum_{I=1}^{n} C_j},$$

Where

$$C_i = 1 - \frac{R_{ij} - 1}{n}$$

10. Graph

2. Example N1 of using Expert Judgment Method. Definition the difficulty of procedures of ATCO for aircrafts control

Method of EXPERT ESTIMATES for definition of difficulty of aircraft service and definition the workload of ATCO for TOWER

For TOWER we have next procedures:

1. Take-off,
2. Landing
3. Taxiing
4. Coordination

1.Matrix of individual preferences.

Procedures	Take-off , ω_1	Landing,ω_2	Taxiing,ω_3	Coordination,ω_4	∑r	R	R
Take-off, ω_1		1	1	1	3	1	1
Landing, ω_2	0		1	1	2	2	2
Taxiing, ω_3	0	0		0,5	0,5	3;4	3,5
Coordination, ω_4	0	0	0,5		0,5	3;4	3,5

2.Matrix of group preferences

Experts	Procedures			
	Take-off , w_1	Landing,w_2	Taxiing,w_3	Coordination,w_4
	R1	R2	R3	R4
1	1	2	3,5	3,5
2	1,5	1,5	3,5	3,5
3	1,5	3,5	1,5	3,5
4	1	2	3	4
5	1,5	1,5	3,5	3,5
ΣR_{ij}	6,5	10,5	15	18
R_{rp}	1,3	2,1	3	3,6
R'_{rp}	1	2	3	4
D_i	0,075	0,675	0,75	0,05
σ_i	0,27386	0,8215838	0,8660254	0,223606798
υ_i, %	21,0663	39,12304	28,867513	6,211299937

- if variation is less than $\upsilon \leq 33\%$ - opinion of experts are coordinated.
- if variation is more than $\upsilon > 33\%$ - opinion of experts are not coordinated.

$var(\omega_1) = 21{,}06625 < 33\%$

$\mathbf{var(\omega_2) = 39{,}12304 > 33\%}$

$var(\omega_3) = 28{,}86751 < 33\%$

$var(\omega_4) = 6{,}21129994 < 33\%$

3 Definition of Kendal's coordination coefficient

$$W = \frac{12S}{m^2(n^3 - n) - m\sum_{j=1}^{m} T_j}$$

$\bar{R} = \Sigma\Sigma R_{ij}/4 = 12{,}5$

$$T_j = \sum (t_i^3 - t_i) = (2^3 - 2) + 2*(2^3 - 2) + 0 + 2*(2^3 - 2) = 42$$

$$S = \sum (\sum_{i=1}^{m} R_{ij} - \bar{R})^2 = (6{,}5 - 12{,}5)^2 + (10{,}5 - 12{,}5)^2 + (15 - 12{,}5)^2 + (18 - 12{,}5)^2 = 76{,}5$$

$$\mathrm{W} = \frac{12S}{m^2(n^3 - n) - m\sum^{m} T_j} = 1\frac{12*76{,}5}{5^2*(4^2 - 4) - 5*42} = 0{,}711628$$

Kendal's coordination coefficient varies in the range $0 < W < 1$, and $W = 0$ – fully uncoordinated, $W = 1$ – fully coordinated; $W = 0{,}6 \ldots 0{,}8$ – coordinated.

4 Correlation coefficient of Spirman r_S

		Procedure			
Ranks		Takeoff	Landing	Taxiing	Coordination
Ranks of group, Rgr	xi	1,3	2,1	3	3,6
R1-ranks of expert N2	yi	1,5	1,5	3,5	3,5
n	4	0,04	0,36	0,25	0,01
r_{si}	0,934				

$$r_{s_i} = 1 - \frac{6\sum_{i=1}^{n}(x_i - y_i)^2}{n(n^2-1)} = 1 - \frac{6*((1{,}3-1{,}5)^2 + (2{,}1-1{,}5)^2 + (3-3{,}5)^2 + (3{,}6-3{,}5)^2)}{4(4^2-1)} = 1 - \frac{6*0{,}66}{4*15} = 0{,}934$$

$0 \le r_S \le 1$

Our result is 0.934. So, the coordination of opinions of the group and expert 2 **is high.**

The significance of the calculations:

Significance W , for using criterion - χ^2

The next step was to determine the Criterion χ^2 according the following formula:

$$\chi_{\phi}^{\ 2} = \frac{S}{\frac{1}{2}m(n+1) - \frac{1}{12(n-1)}\sum_{j=1}^{m} T} > \chi_{t}^{\ 2}$$

$$\chi_{\phi}^{\ 2} = \frac{S}{\frac{1}{2}m(n+1) - \frac{1}{12(n-1)}\sum_{j=1}^{m} T_j} = \frac{76{,}5}{\frac{1}{2} * 5(4+1) - \frac{1}{12*(4-1)} * 42} = 6{,}75$$

$\chi_{\phi}^{\ 2} > \chi_{t}^{\ 2} \rightarrow 6{,}75 > 0{,}5$

m	5
n	4
S	76,5
Tj	42
χ^2	6,75

Significance Rs , for using Student's t – criterion

For the calculation of Student's t – criterion the following formula is applied:

$$t_{\phi} = r_s \sqrt{\frac{n-2}{1-r_s^2}} > t_{st}$$

$$t_{\phi} = 0{,}934 * \sqrt{\frac{4-2}{1-0{,}934^2}} = 3{,}69$$

It is necessary to have the table with t_{st} in order to compare with calculated result.

National Aviation University
Department of Airnavigation system

Lecture 4: Expert Judgment Method. Weight coefficients

1. *Algorithm of Definition the weight coefficients*
2. *Definition of ATCO's loads for using weight coefficients*

Professor Shmelova T.

1. Definition the weight coefficients / Multi-criteria decision problems

Algorithm
Of Definition the weight coefficients

1. Determine the experts' group opinion - ranks R_{grj}, j=1...n, for each *j* procedures using "EJM"

1 method

1. Determine weight coefficient w_j of important. Weight coefficient is defined by using the formula: $\omega_I = \frac{C_I}{\sum_{I=1}^{n} C_j}$,

For example, difficult **of procedures** for service an aircraft:

$$\omega_I = \frac{C_o}{\sum_{o=1}^{n} C_j},$$

where, $C_o = 1 - \frac{R_{ij} - 1}{n}$ - estimates;

Rij - rank *j* - procedure for *i* expert ($R_{i\ gr}$ - ranks of group).

The method is based on the assumption about linear dependence between a rank *Rgr* and relative value of an efficiency parameter C_j.

2 method

Estimates *Cj* are determining by helping experts, from 1 to 0, descending importance rank

Task. Definition of importance coefficient workloads for a controller's on Tower

ω_1 - Take-off;
ω_2 Landing;
ω_3 - Taxiing;
ω_4 - Coordination.

$$F_{\Sigma} = \sum_{I=1}^{4} \omega_I \lambda_j \tau,$$

$$\omega_I = \frac{C_I}{\sum_{I=1}^{n} C_j},$$

$$C_I = 1 - \frac{R_{ij} - 1}{n}$$

1 method (linear dependence between a rank, Estimates and weight coefficients)

Procedure	Rank R_{grj}	C_i	ω_i		Total load
Take-off, $\omega_1^{\lambda_j}$	1	1	0,4	7	2,8
Landing, ω_2	2	0,75	0,3	3	0,9
Taxiing, ω_3	3	0,5	0,2	10	2
Coordination, ω_4	4	0,25	0,1	5	0,5
Σ		2,5	1	25	6,2

C_1=1- (1-1) /4 = 1
C_2=1- (2-1) /4 = 0,75
C_3=1- (3-1) /4 = 0,5
C_4=1- (4-1) /4 = 0,25
ΣC_j = 1 + 0,75 + 0,5 + 0,25 = 2,5

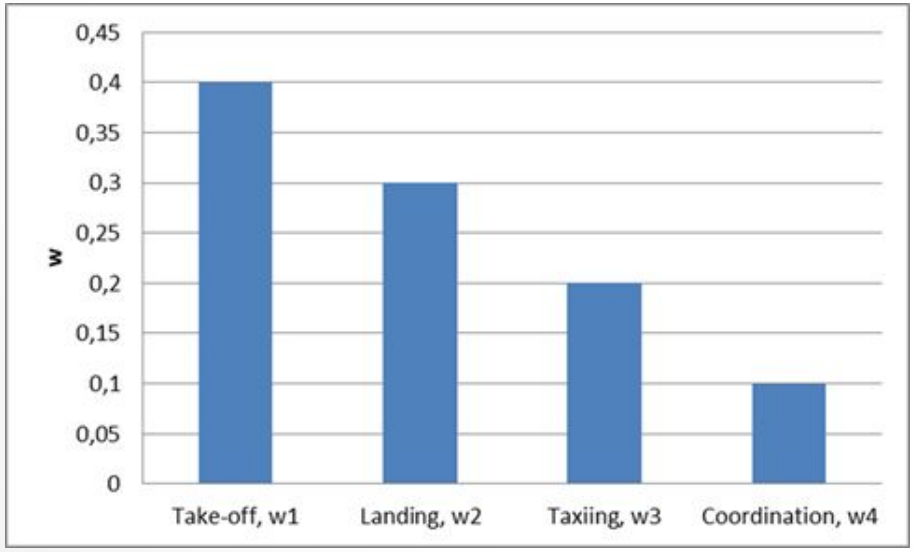
ω_1 = 1/2,5 = 0,4
ω_2 = 0,75/2,5 = 0,3
ω_3= 0,5/2,5 = 0,2
ω_1 = 0,25/2,5 = 0,1
$\Sigma\omega_j$ = 0,4 + 0,3 + 0,2 + 0,1 = 1

Thus, total loads for ATC for the certain time interval τ ($\tau = 1$h):

$$F_{\Sigma} = \sum_{I=1}^{4} \omega_I \lambda_j \tau,$$

Where λ_j - intensity of flights on types of carried out procedures. The given total workloads:

$$F_{\Sigma} = 0{,}4 \cdot 7 + 0{,}3 \cdot 3 + 0{,}2 \cdot 10 + 0{,}1 \cdot 5 = 6{,}2 \text{ aircraft\hour}$$



2 method

Estimates C_j are determining by helping experts, from 1 to 0, descending importance rank from more importance to less importance value

Procedure	Rank R_{grj}	C_i	$\omega_ı$		Total load
Take-off, w_1	1	1	0,35	7	2,5
Landing, w_2	2	0,9	0,32	3	0,96
Taxiing, w_3	3	0,7	0,25	10	2,5
Coordination, w_4	4	0,2	0,071	5	0,36
Σ		2,8	1	25	6,32

Thus, total loads for ATC for the certain time interval τ ($\tau = 1$h):

$$F_\Sigma = \sum_{ı=1}^{4} \omega_ı \lambda_j \tau,$$

Where, λ_j - intensity of flights on types of carried out procedures. The given total workloads:

$$F_\Sigma = 6{,}32 \text{ aircraft\hour}$$

The second method is more accurate method

The accounts can be made with the help of Excel:

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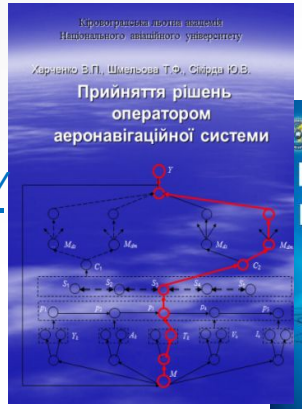
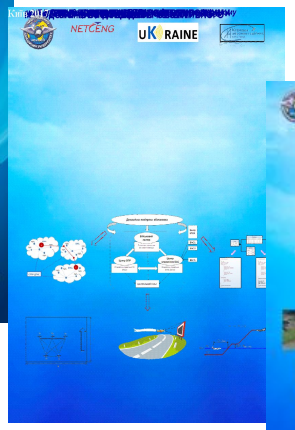
Books about DM of H-O in ANS: DM of ATC; pilot of AC/ UAV; engineer; flight dispatch etc.

Ukraine

http://er.nau.edu.ua/

2020





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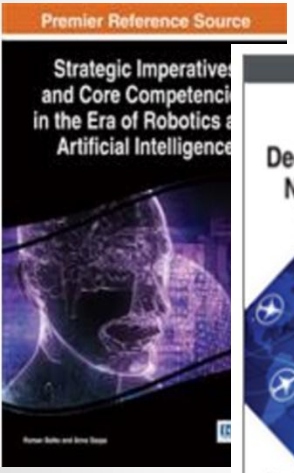
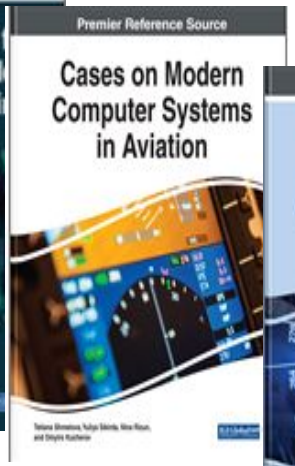
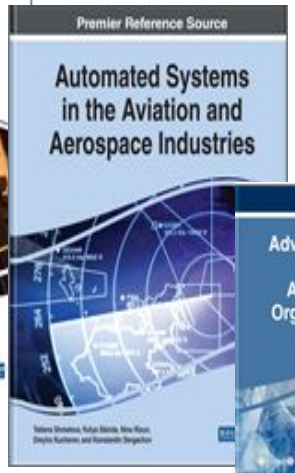
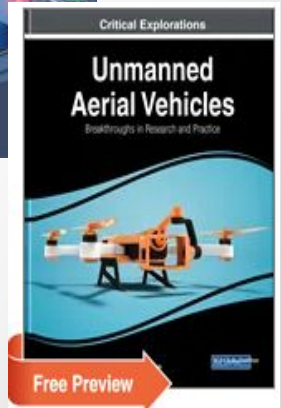








2017

2018

2019

Homework:

1. Choose a **multi-criteria problems:**
   Remark:

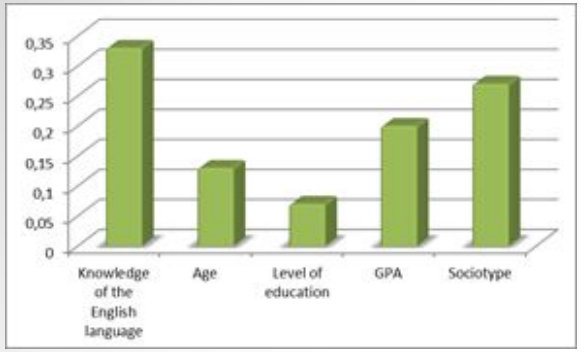
1. Choosing a telecommunication system
2. Choosing a product marketing strategy
3. Choosing Software
4. Cross-Browser Website Testing
5. **Aviation:** Quantitative estimation of the complexity of the stages the aircraft flight; Quantitative estimation of the complexity of the navigation parameters of flight; Air Craft Landing system (GNSS, ILS, GNSS +EGNOS,VOR,…); Quantitative estimation of the complexity procedures operators during working process; Quantitative estimation of the Human factor problem; Aviation Safety (safety, regularity, economic efficiency)
6. Management of enterprise
7. Select the best Smart Phone
8. Select of the sources of projects financing

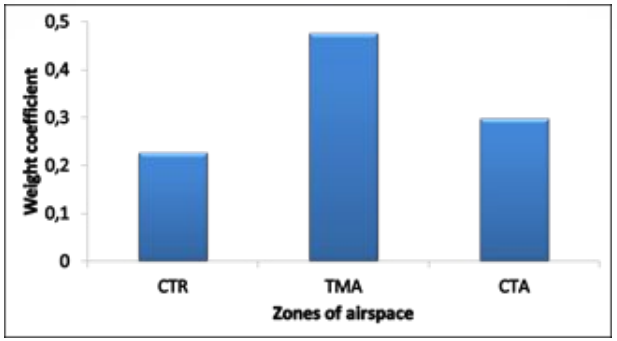
Individual research work (RW) for course IDM.
Application EJM for building "Expert system"

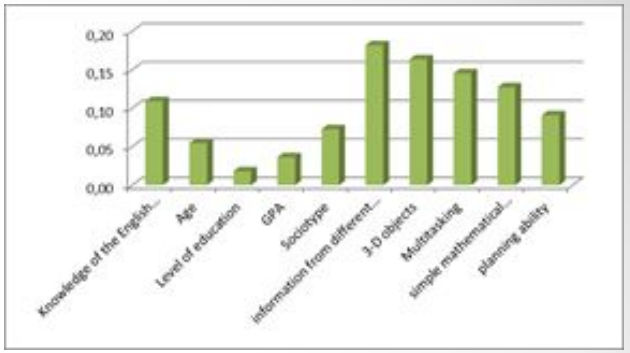
Algorithm

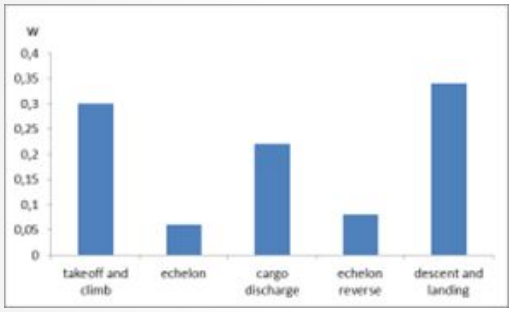
1. **PREPARING.** To choose the topic of the system (process, technology, etc.) of research work (RW)
   a. *Quantitative estimation of the complexity of the stages the aircraft flight;*
   b. *Quantitative estimation of the complexity of the navigation parameters of flight;*
   c. *Aircraft Approach system (GNSS, ILS, VOR,…);*
   d. *Quantitative estimation of the procedures of operators during working process;*
   e. *Quantitative estimation of the Human factor problem;*
   f. *The significance of the procedures performed by the dispatcher – Air Traffic Controller (ATC)*
   g. *Sources of projects funding projects.*
   h. *Criteria for assessing the skills.*
   i. *The importance of individual psychological factors influencing the Decision Making (DM)*
   j. *The importance of social and psychological factors influencing the decision*
   k. *Definition the difficult of procedures for aircraft control of ATC*
   l. *Aviation Safety (safety, regularity, economic efficiency, etc.*
2. **INTRODUCTION**
   a. Describing the system (link on literature need - [1; 2])
   b. Building main components of ES: Users interface; Database; Base Knowledge (figure).
   c. System analysis of the system as a complex system. Decomposition of complex systems on subsystems:
      i. *Definition subsystems for expert estimation of their significance and description of the characteristics of subsystems.*
      ii. *Definition of criteria estimation (3-5 criteria) and description of criteria features.*
      iii. *Definition of criteria estimation and description of criteria features.*
3. **Algorithm of EXPERT JUDGEMENT METHOD (EJM)**
4. **EJM for *estimation of subsystems in system*** by criterion and obtaining weight coefficients of subsystem significance by criterion.
   a. Estimation of subsystems using EJM by criterion №1 and obtaining weight coefficients of subsystem significance by criterion №1
   b. The analogical calculation for the next criteria.
5. **Aggregation subsystems in systems.**
   a. Additive aggregation of subsystems
   b. Multiplicative aggregation of subsystems
6. **Graphical presentation** of the significance of subsystems in Expert System.
7. **CONCLUSION**
8. **REFERENCES**
9. **Presentation and report**

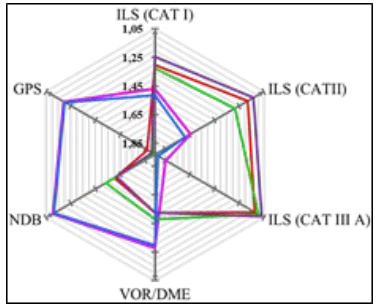
Examples (results – weights coefficients of subsystems):

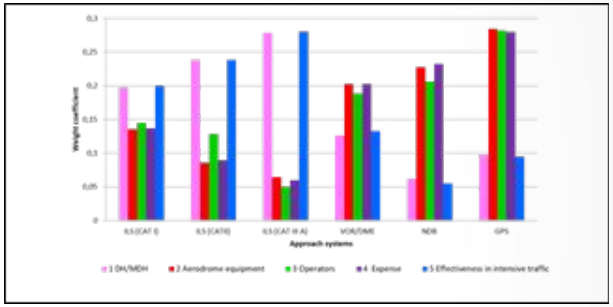


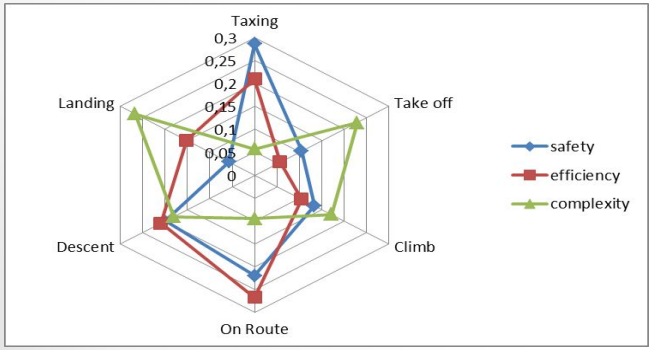


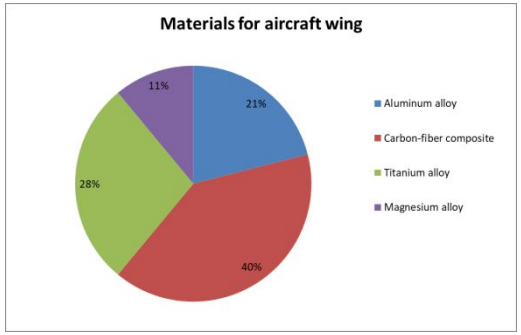


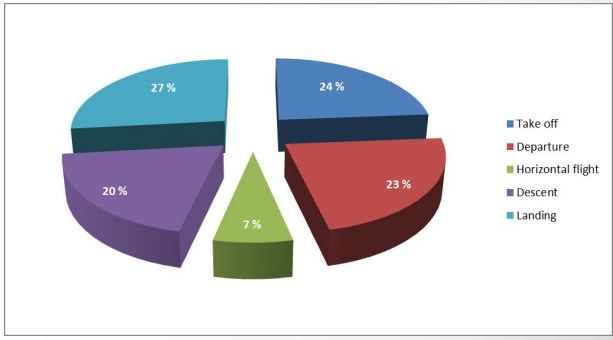












Індивідуальна науково-дослідна робота (РГР) для курсу IDM. Застосування EJM для побудови "Експертної системи"

Алгоритм

1. **ПІДГОТОВКА.** Вибрати тему роботи (система, процес, технологія тощо) науково-дослідної роботи (РГР)
   - а. Кількісна оцінка складності етапів польоту літака;
   - б. Кількісна оцінка складності навігаційних параметрів польоту;
   - с. Система наближення літаків (GNSS, ILS, VOR,...);
   - г. Кількісна оцінка процедур операторів під час робочого процесу;
   - е. Кількісна оцінка проблеми людського фактора;
   - f. Значення процедур, які виконує диспетчер - диспетчер повітряного руху (УВД)
   - г. Джерела проектів, що фінансують проекти.
   - год. Критерії оцінювання вмінь.
   - і. Важливість окремих психологічних факторів, що впливають на прийняття рішень (DM)
   - j. Важливість соціальних та психологічних факторів, що впливають на рішення
   - к. Визначення складності процедур управління літаками АТС
   - л. Авіаційна безпека (безпека, регулярність, економічна ефективність, тощо.
2. **ВСТУП**

а. Опис системи (посилання на літературу - [1; 2])

б. Побудова основних компонентів ES: інтерфейс користувача; База даних; Базові знання (рисунок).

с. Системний аналіз системи як складної системи. Декомпозиція складних систем на підсистемах:

- і. Визначення підсистем для експертної оцінки їх значущості та опису характеристик підсистем.
- іі. Визначення оцінки критеріїв (3-5 критеріїв) та опис особливостей критеріїв.
- ііі. Визначення оцінки критеріїв та опис особливостей критеріїв.

3. **АЛГОРИТМ МЕТОДУ ЕКСПЕРТНОГО ОЦІНЮВАННЯ (МЕО)**
4. **Оцінка підсистем з використанням МЕО** за критеріями та отримання вагових коефіцієнтів значущості підсистеми за критеріями.
   - а. Оцінка підсистем за допомогою методу експертного судження (EJM) за критерієм №1 та отримання вагових коефіцієнтів значущості підсистеми за критерієм №1
   - б. Аналогічний розрахунок для наступних критеріїв.
5. **Агрегування системи.**
   - а. Адитивна агрегування підсистем
   - б. Мультиплікативна агрегування підсистем
6. **Графічне представлення значення підсистем у Експертній системі.**
7. **ВИСНОВОК**
8. **ЛІТЕРАТУРА**
9. **Презентація та звіт**

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«INFORMATICS OF DECISION MAKING»

METHOD OF EXPERT ESTIMATES

QUANTITATIVE ESTIMATION OF FUEL JET-A1 COMPONENTS

« INDIVIDUAL WORK »

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INTRODUCTION

Aviation fuel is a specialized type of petroleum-based fuel used to power aircraft. It is generally of a higher quality than fuels used in less critical applications, such as heating or road transport, and often contains additives to reduce the risk of icing or explosion due to high temperature, among other properties.

Most current commercial airlines and military aircraft use jet fuel for maximum fuel efficiency and lowest cost. These aircraft account for the vast majority of aviation fuel refined today, which is also used in diesel aircraft engines. Other aviation fuels available for aircraft are kinds of petroleum spirit used in engines with spark plugs (e.g., piston and Wankel rotary engines).

Jet fuel is a mixture of a large number of different hydrocarbons. The range of their sizes (molecular weights or carbon numbers) is defined by the requirements for the product, such as the freezing or smoke point. Kerosene-type jet fuel (including Jet A and Jet A-1) has a carbon number distribution between about 8 and 16 (carbon atoms per molecule); wide-cut or naphtha-type jet fuel (including Jet B), between about 5 and 15.

Composition of Jet A-1

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1. EXPERT JUDGEMENT METHOD ALGORITHM

Expert Judgment is a term that refers specifically to a technique in which judgment is made based upon a specific set of criteria and/or expertise that has been acquired in a specific knowledge area, or product area, a particular discipline, an industry, etc.

To proceed with the method it is recommended to stick to the algorithm that is given in the table below:

1.	Select a criteria for estimation
2.	Undertake a survvey among experts
3.	Create a matrix of individual preferences R_{ij}, $i=1,\dots m$
4.	Create a matrix of group preferences R_{ij}, $i=1,\dots m$, $j = 1,n$ **m** - number of expert, m>30 **n** - number of factors for expert estimates
5.	Determine the experts' group opinion (sample average, arithmetical mean) R_{gj} as well as coordination of their opinion by estimating (for each factor): • Dispersion D_j • Squire average deviation σ_j • Coefficient of variation v_j
6.	Evaluate coordination of experts' opinion by calculating Kendal's coefficient W
7.	Compare opinion of the group of experts and expert №1 by

2. MATRICES OF INDIVIDUAL PREFERENCES

During the survey stage, experts were asked to complete their own matrix of individual preferences. They had to decide which component would be the best option to choose for aircraft's fuel Jet-A1. The results are performing in the tables below (table 2.1-2.5).

Component:	Carbon	Hydrogen	Sulphur	Nitrogen	∑r	R
Carbon		0	0	1	1	3
Hydrogen	1		1	1	3	1
Sulphur	1	0		1	2	2
Nitrogen	0	0	0		0	4

Table 2.1. Matrix of individual preferences of the expert №1

Component:	Carbon	Hydrogen	Sulphur	Nitrogen	∑r	R
Carbon		0	0	0.5	0.5	3.5
Hydrogen	1		1	1	3	1
Sulphur	1	0		1	2	2
Nitrogen	0.5	0	0		0.5	3.5

Table 2.2. Matrix of individual preferences of the expert №2

Component:	Carbon	Hydrogen	Sulphur	Nitrogen	∑r	R
Carbon		0	0.5	1	1.5	2.5
Hydrogen	1		1	1	3	1
Sulphur	0.5	0		1	1.5	2.5
Nitrogen	0	0	0		0	4

Table 2.3. Matrix of individual preferences of the expert №3

Component:	Carbon	Hydrogen	Sulphur	Nitrogen	∑r	R
Carbon		0	0	1	1	3
Hydrogen	1		1	1	2	1
Sulphur	1	0		1	3	2
Nitrogen	0	0	0		0	4

Table 2.4. Matrix of individual preferences of the expert №4

Component:	Carbon	Hydrogen	Sulphur	Nitrogen	∑r	R
Carbon		0	0.5	1	1.5	2.5
Hydrogen	1		1	1	3	1
Sulphur	0.5	0		1	1.5	2.5
Nitrogen	0	0	0		0	4

Table 2.5. Matrix of individual preferences of the expert №5

3. MATRIX OF GROUP PREFERENCES

According to the algorithm, the next step in the process is consolidation of obtained data in one single matrix of group preferences (table 3.1).

Expert, m	Component , n			
	Carbon	Hydrogen	Sulphur	Nitrogen
1	3	1	2	4
2	3.5	1	2	3.5
3	2.5	1	2.5	4
4	3	1	2	4
5	2.5	1	2.5	4

Table 3.1. Matrix of group preference

4. DETERMINATION OF EXPERTS' GROUP OPINION AND STATISTICAL PARAMETERS

Experts' group opinion can be calculated as sample average, using the

Below is the example for Carbon;

$$D_j = \frac{(2.9-3)^2+(2.9-3.5)^2+(2.9+2.5)^2+(2.9-3)^2+(2.9-2.5)^2}{5-1} = 0.175$$

Next is determination of square average deviation using the formula 4.3.

$$\sigma_j = \sqrt{D_j} \tag{4.3}$$

Example for Carbon is:

$$\sigma_j = \sqrt{D_j} = 0.41833$$

Also, we calculated coefficient of variation for all materials in accordance with the formula 4.4.

$$v_j = \frac{\sigma_j}{R_{gj}} \cdot 100\% \tag{4.4}$$

Example for Carbon is;

$$v_j = \frac{0.4183}{2.9} \cdot 100\% = 14.43\%$$

5. CALCULATION OF KENDAL'S COORDIATION COEFFICIENT

Another step in determining the best component for aircraft's fuel Jet A-1 is identifying so-called Kendal's coordination coefficient W, which will help us determine whether experts reached at least minimum agreement or another survey needs to be held. To do this, we use formulas 5.1 – 5.3

$$W = \frac{12S}{m^2(n^3-n)-m\sum_{j=1}^{n} T_j} \tag{5.1}$$

$$S = \sum_{i=1}^{n}\left(\sum_{i=1}^{m} R_{ij} - R\right)^2 \tag{5.2}$$

$$R = \sum\sum R_{ij}/4 \tag{5.3}$$

Below are the examples of the calculations:

$$R = \frac{1}{4}(3+1+2+4+3.5+1+2+3.5+2.5+1+2.5+4+3+1+2+4+2.5+1+2.5+4) = \frac{72}{4} = 12.5$$

$$S = (14.5-12.5)^2+(5-12.5)^2+(11-12.5)^2+(19.5-12.5)^2 = 111.5$$

$$W = \frac{12 \times 111.5}{5^2(4^3-4)-5 \times 18} = 0.9489$$

Due to the fact that coefficient W > 0.7, experts' group opinion is considered to be coordinated.

6. CALCULATION OF SPEARMAN'S COEFFICIENT

At this step we will compare opinion of the group of experts with opinion of expert 1. For this we will use formulas 6.1 – 6.2

$$x_0^2 = \frac{S}{\frac{1}{2}m(n+1)\sum_{i=1}^{n} T_j} > x_t^2 \tag{6.1}$$

$$\tau_{xy} = r_s\sqrt{\frac{n-2}{1-r_s^2}} > \tau_{xt} \tag{6.2}$$

In my case, n=5, m=4, T=18, so after calculating $\chi 2$ in Excel

$\chi 2 = 13.9375$ and it is greater that the table value of 3.35 which means that opinions are well coordinated.

The same conclusion applies to Student's coefficient that after calculation equals t = 12.85178 and is greater than the table value of 0.22.

7. WEIGHT COEFFICIENTS CALCULATION

One of the last steps in the process of expert judgment method application is determining weight coefficients in accordance with the following formulas 7.1-7.2

$$\omega_i = \frac{C_i}{\sum_{i=1}^{n} C_i} \tag{7.1}$$

Where: $$C_i = 1 - \frac{x_{ij}}{n} \tag{7.2}$$

Here is the example of calculations for Carbon:

$$C_i = 1 - \frac{2.9-1}{4} = 0.525$$

$$\omega = \frac{0.525}{2.5} = 0.21$$

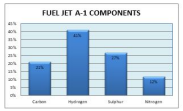
8. RESULTS OF CALCULATIONS

In this part of the work I created a generic table that clearly depicts all the values, previously calculated in Microsoft Excel (table 8.1)

Expert:	Component:				T	R	S	$\sum C_i$
	Carbon	Hydrogen	Sulphur	Nitrogen	$\sum r_{ij}$			
1	3	1	2	4	6			
2	3.5	1	2.5	3.5	6			
3	2.5	1	2.5	4	6			
4	3	1	2	4	6			
5	2.5	1	2.5	4	6			
R_{gj}	2.9	1	2.5	3.9				
D	0.175	0	0.075	0.05				
σ	0.4183	0	0.2738	0.22360	18	12.5	111.5	2.5
ϑ	14.43	0	12.45	5.73				
$\sum_{i=1}^{n} R_{ij}$	14.5	5	11	19.5				
$\left(\sum_{i=1}^{n} R_{ij} - \frac{\sum_{i=1}^{n} R_{ij}}{n}\right)^2$	4	56.25	2.25	49				
ω_i	0.525	1	0.7	0.275				
ω_i %	20	41	27	12				
χ^2	13.9375							
t	12.85178							
W	0.94858							
R_{xy}	0.994							

9. GRAPHICAL REPRESENTATION

In the following plot, we can see that the expert judgement method helped us to determine that Hydrogen is the best component for the elaboration of aircraft's fuel Jet A-1.



CONCLUSION

While doing this Individual Work was investigate the details of expert judgment method as a tool for decision making. As a topic I chose the components of the aircraft's fuel Jet A-1.

After that were made all necessary matrices of individual preferences, then I consolidated obtained data into one single matrix of group preferences and started analyzing it.

Then the following parameters were determined: sample average, dispersion and variation as well coordinated according of expert's opinion; also I calculated significance of expert's opinion by identifying Spearman rs and Student's coefficients. The estimate weight coefficients were calculated and after multiply by 100 to get the results in percentage.

Finally with all the information I got I was able to plot a graphic with the results and identify that Hydrogen is the best component for the elaboration of aircraft's fuel Jet A-1.

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Thank you for your attention