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ДОПУСТИТИ ДО ЗАХИСТУ

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д-р техн. наук, проф.

В.Ю. Ларін

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ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

ЗА ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ

«ОБСЛУГОВУВАННЯ ПОВІТРЯНОГО РУХУ»

Тема: «*Порівняльний аналіз завантаженості диспетчерського складу методами експертної оцінки*»

Виконала: __________ **Т.В.Голубцова**

Керівник: д-р техн. наук, проф. __________ **О.М.Алексєєв**

Нормоконтролер __________**Г.Ф.Аргунов**

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Institute: *Educational and Research Institute of Air Navigation, Electronics and Telecommunications*

Department: *Air Navigation Systems Department*

Educational degree: *Master*

The specialty: *272 "Aviation Transport"*

Educational Professional Program: *Systems of Air Navigation Service*

APPROVED BY

Head of the Department

_____________ V. Larin

"____" _____________2020

Master's Thesis Assignment

Student`s name: Holubtsova Tetiana Volodymyrivna

1. The thesis theme: ***" Comparative analysis of air traffic controllers workload with expert judgment methods"***

   approved by the Rector's order *of "29" September 2020 № 1815/cm.*

2. The thesis should be performed from : *5.10.2020 to 13.12.2020*

3. Initial data: *Statistical data about flight performances, expert judgment methodology, data about procedures of air traffic control.*

4. The content of the explanatory note (the list of problems to be considered): Sector load, ATCO activity, program of possible workload analysis

5. The list of mandatory graphic materials*: 49 Figures, 17 graphs, 45 tables, questionnaire. Microsoft office Excel, Power Point should be used to provide graphic support and presentation.*

6. Calendar Schedule of Performing the Master's thesis.

Tasks	Period of works execution	execution note
Analysis of documents connected with ATCO work	1.09.20 – 11.09.20	
Choise of method of analysis	11.09.20- 12.09.20	
Analysis of existing sources of monitoring the ATCO work	13.09.20 – 17.09.20	
Research of AI in aviation systems	18.09.20 – 25.09.20	
Data mining	26.09.20– 26.10.20	
Built of a model	27.10.20 – 04.11.20	
Arrangement of the explanatory note and illustrative material	31.10.20 – 22.11.20	
Preliminary defense of the thesis	10.12.20 – 11.12.20	

8. Date of issue: «___»_____________ 2020.

Supervisor of master's thesis __________________ _________________

Excepted the task __________________ _________________

ABSTRACT

The master thesis assignment to diploma work "Comparative analysis of air traffic controller`s workload with expert judgment methods" contain 95 pages, 49 illustrative figures, 17 graphs and 45 tables.

Investigation object is amount of aircraft, performing the flights via the controlled airspace per unit of time.

Investigation subject-existing and possible workload on an air traffic control specialist during its worktime.

Purpose of investigation- determination of workload on a specialist using the data about flights from the surveillance system, founding the sectors that are recommended to enforce with human resources using the expert judgment methodology and trying to predict possible future workload peaks.

Methods of investigation- Expert Judgment Method (type- Method of Nominal Expert group); Correlation and regression analysis; Modeling.

In this diploma work are investigated the amount of flights via the sectors using the average data of 13 hr everyday surveillance from the system Flightradar 24 and developed the program of prediction of possible workload peaks based on the obtained analysed data. Also was developed a user-friendly expert system prototype that can show the biggest and the lowest workload in a sector.

CONTENT

MAIN TERMS AND ABBREVIATIONS, CONNECTED WITH THE WORK

ACC-Area Control Center

ACRT-Aircraft

AI-Artificial Intelligence

APP-Approach control

ATC-Air Traffic Control

ATCS-Air Traffic Control Service

ATCO-Air Traffic Control Officer

ATFCM-Air Traffic Flow-Capacity Management

ANS-Air Navigation System

CRA-Correlation and Regression Analysis

CTA-Control Area

CTR-Control Zone

D-M-Decision Making

DSS-Decision Support System

EUROCONTROL-European Organization for the Safety of Air Navigation

FIR-Flight Information Region

FIS-Flight Information Service

TMA-Terminal Area

TWR- Tower

TOF-Take-off

LAN-Landing

Aerodrome control tower. A unit established to provide air traffic control service to aerodrome traffic.

Aircraft. Any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface.

Air traffic. All aircraft in flight or operating on the manoeuvring area of an aerodrome.

Air traffic advisory service. A service provided within advisory airspace to ensure separation, in so far as practical, between aircraft which are operating on IFR flight plans.

Air traffic control clearance. Authorization for an aircraft to proceed under conditions specified by an air traffic control unit.

Air traffic control service. A service provided for the purpose of:

a) preventing collisions:

1) between aircraft, and

2) on the manoeuvring area between aircraft and obstructions;

and

b) expediting and maintaining an orderly flow of air traffic.

Air traffic control unit. A generic term meaning variously, area control centre, approach control unit or aerodrome control tower

Air traffic flow management (ATFM). A service established with the objective of contributing to a safe, orderly and expeditious flow of air traffic by ensuring that ATC capacity is utilized to the maximum extent possible, and that the traffic volume is compatible with the capacities declared by the appropriate ATS authority.

Air traffic management (ATM). The dynamic, integrated management of air traffic and airspace including air traffic services, airspace management and air traffic flow management — safely, economically and efficiently — through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions.

Air traffic management system. A system that provides ATM through the collaborative integration of humans, information, technology, facilities and services, supported by air and ground- and/or space-based communications, navigation and surveillance.

Air traffic service (ATS). A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service).

Air traffic services airspaces. Airspaces of defined dimensions, alphabetically designated, within which specific types of flights may operate and for which air traffic services and rules of operation are specified.

Approach control service. Air traffic control service for arriving or departing controlled flights.

Approach control unit. A unit established to provide air traffic control service to controlled flights arriving at, or departing from, one or more aerodromes.

Appropriate ATS authority. The relevant authority designated by the State responsible for providing air traffic services in the airspace concerned.

Area control centre (ACC). A unit established to provide air traffic control service to controlled flights in control areas under its jurisdiction. Area control service.

Air traffic control service for controlled flights in control areas.

ATS route. A specified route designed for channelling the flow of traffic as necessary for the provision of air traffic services.

Computer. A device which performs sequences of arithmetical and logical steps upon data without human intervention.

Control area. A controlled airspace extending upwards from a specified limit above the earth.

Controlled airspace. An airspace of defined dimensions within which air traffic control service is provided in accordance with the airspace classification.

Controlled flight. Any flight which is subject to an air traffic control clearance.

Control zone. A controlled airspace extending upwards from the surface of the earth to a specified upper limit.

Data processing. A systematic sequence of operations performed on data.

Decision Support System. an interactive computer system for support the different types of activity during the Decision Making.

Estimated elapsed time. The estimated time required to proceed from one significant point to another.

Estimated off-block time. The estimated time at which the aircraft will commence movement associated with departure.

Estimated time of arrival. For IFR flights, the time at which it is estimated that the aircraft will arrive over that designated point, defined by reference to navigation aids, from which it is intended that an instrument approach procedure will be commenced, or, if no navigation aid is associated with the aerodrome, the time at which the aircraft will arrive over the aerodrome. For VFR flights, the time at which it is estimated that the aircraft will arrive over the aerodrome.

Expected approach time. The time at which ATC expects that an arriving aircraft, following a delay, will leave the holding fix to complete its approach for a landing.

Flight information centre. A unit established to provide flight information service and alerting service.

Flight information region (FIR). An airspace of defined dimensions within which flight information service and alerting service are provided.

Flight information service. A service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights.

Flight path monitoring. The use of ATS surveillance systems for the purpose of providing aircraft with information and advice relative to significant deviations from nominal flight path, including deviations from the terms of their air traffic control clearances.

Flow control. Measures designed to adjust the flow of traffic into a given airspace, along a given route, or bound for a given aerodrome, so as to ensure the most effective utilization of the airspace.

Human performance. Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations.

IFR. The symbol used to designate the instrument flight rules.

IFR flight. A flight conducted in accordance with the instrument flight rules.

Movement area. That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the manoeuvring area and the apron(s).

Terminal control area (TMA). A control area normally established at the confluence of ATS routes in the vicinity of one or more major aerodromes.

INTRODUCTION

Nowadays the Artificial Intelligence methods are used in all sphere of life. It supports a human in all the activities that are potentially important when the question is about safety.

Aviation is one of the prospective branches of science development, that gives a possibility of fast and economically efficient transportation. However, the most important thing in aviation always remains safety. To provide safety in this case is not only to reach final point of destination, but to make that without disproportionate costs of human lives.

For the safety needs were taken in consideration developed such important things like team work, skills formation and risk assessment. Also was significantly developed technical base- new systems that help a human operator to prevent collision risks. But to obtain a strong Safety Management System, a big amount of factors from different sights should be taken into account. It mean, that the complex environment research of the aviation enterprises conditions should be provided. And a lot of internal and external factors were analyzed and classified to see the significance of a factor on aviation.

Aviation safety management should form and provide the safety flight goals rationally, without waste of resources, whether it be labor resources or material. Every factor that can affect the aviation can affect all the Decision Making process.

The Artificial intelligence is a fast spreading in transportations technologies. The AI has a strong potential to be used in aviation, in particular-in ATM, when decision-making in uncertainty should be provided and the precision with limited information is necessary to be obtained. The AI system is able to forecast the ATCO actions with the accuracy of 70% ,using the data about previous flights.

The most easily the AI software was used in the expert systems and the ICAO recommended to use the Intelligent Expert Systems as ATCO decision making support.

CHAPTER 1. ANALYSIS OF CONTROLLED AIRSPACE CONDITIONS

1.1 Airspace classification

The division of airspace into classes is an integral part of air traffic management. Depending on the load on the sector and the capabilities of the air traffic controller, the airspace is divided into classes A to G. In Ukraine, classes C, D and G are used as optimal.

ICAO recommends that the following factors be followed in order to build airspace:

-type of service- Air Traffic Control (ATC), Flight Information Service (FIS), Alerting Service (ALS)

-flight rules

-intensity and regularity of air traffic

-technical characteristics of aircraft

-technical characteristics of the equipment of radio navigation aids and ATS

-possibilities of the air traffic controller officer (ATCO).

Aircraft flight requirements are set for each class and include:

-application of instrument flight rules (IFR) and / or visual flight rules (VFR)

-need for separation of aircraft

-type of air traffic service provided for the aircraft

-need to obtain an ATC clearance

-presence of restrictions (speed, visibility, minimum distance from clouds)

-existence of two-way radio communication

Class A requires IFR separation of all aircraft, two-way radio communication and dispatch permit. No speed limit is implemented. ATC service is provided.

Class B requires separation of IFR and VFR, two-way communication and ATC permission. Speed limit is not implemented.ATCS is provided.

Class C requires separation of IFR and VFR and two-way radio communication, ATC service is provided, speed limits are introduced in the case of VFR flights. For flights in this class, a control permit is required. In Ukraine, TMA (Terminal Area) and CTA (Control area) are represented. It stretches from 2900 m and above.

Class D requires two-way radio communication and a dispatch permit. Separation in the case of IFR flights has been introduced, ATC service and information on IFR flights are provided. There are also speed limits. In Ukraine, the class stretches from 1500 m to 2900 m. CTR (Control zone) is presented.

Class E requires IFR separation, control clearance and speed limitation. ATC service and information service, if possible, on VFR flights are provided

Class F requires IFR separation, two-way radio communication. There is a speed limit. Information service is provided.

Class G does not require two-way radio communication in the case of VFR flights and control clearance. When flying in this class, flight information service is used, separation is not introduced. There are speed limits. In Ukraine, class G extends from the earth's surface to 1500 m, which significantly complicates the process of observation and increases the load on the human operator in conditions of high intensity of air traffic. [2]

Classes C and D are the main classes where high-intensity flights are operated in Ukraine.

1.2 Controlled airspace

Controlled airspace is a part of the airspace within which air traffic control is provided in accordance with the established classification of airspace. Air traffic control must monitor the location of the aircraft in the horizontal and vertical planes.

Coordination between sectors is also important during the aircraft flights control,because it facilitates the control of aircraft flight in conditions of traffic high intensity.

On a territory of Ukraine the airspace is divided onto 3 classes-C, D and G. (Figure 1.1)

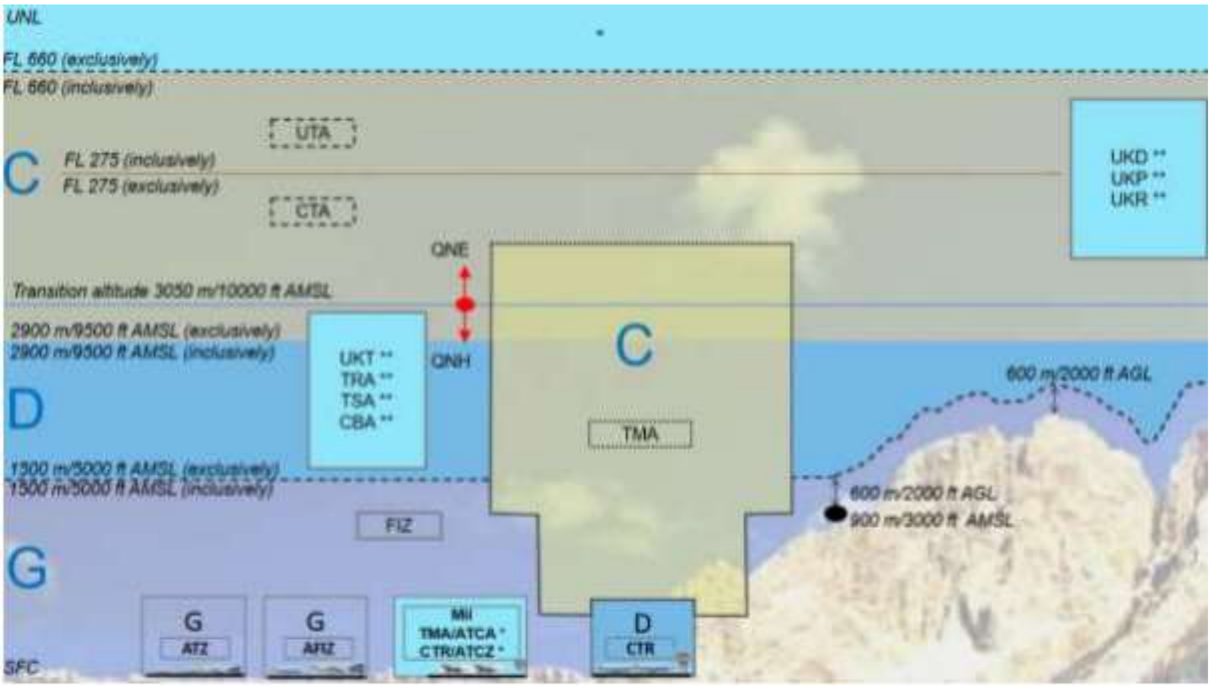


Figure 1.1 An airspace structure of Ukraine

The controlled airspace is divided onto controlled zone CTR, terminal area (approach area) TMA and control area CTA.

A CTR (Figure 1.2) is a controlled space, usually near an airport, that extends from the earth's surface to an established upper limit. It is installed at airports with high air traffic intensity, designed to provide ATCS during take-off and landing.

Figure 1.2 CTR location relative to the ground

Typically, the radius of CTR is approximately 9-18 km (5-10 nautical miles), but this size may vary, increasing in the direction of take-off and landing of IFR-operating aircraft.

CTR can contain several aerodromes situated closely.If CTR is situated in the limites of lateral borders of Control Area,it extends up to the lowest boundary of higher CTR.

CTR is a responsibility area of a TWR controller.

The TMA is a controlled area established at the points of convergence of ATS routes around one or more major aerodromes, the area of responsibility of approach controllers.(Figure 1.3)

Given the high intensity of flights can be divided into several parts, which implements the Approach Control Service (APP).

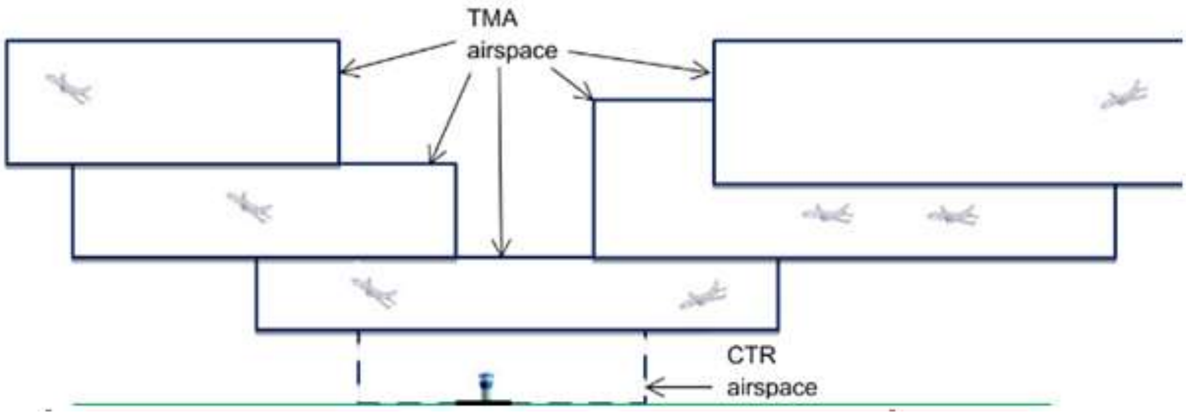


Figure 1.3. - TMA airspace location relative to CTR

Lower boundary of TMA is installed at 300 m height over the ground level. Higher boundary can reach a boundary of lower airspace.

CTA is a controlled airspace extending from the set lower limit to the set upper limit.

CTA is a main part of a controlled airspace. Its boundaries can reach 150-170 km.

A CTA can be formed by:

- Terminal control areas (TMA) of sufficient size to contain the controlled traffic around the busier aerodrome
- Interconnecting airways
- Area-type control areas for which specific ATS routes have been defined for the purpose of flight planning and which provide for the organization of an orderly traffic flow
- In the case of oceanic airspace, control areas may be achieved by the establishment of one or more route structures serving specific traffic flows

In the CTA an Area control is provided.

CTR, TMA and CTA, due to its functions features, should be located in certain way. (Figure 1.4)

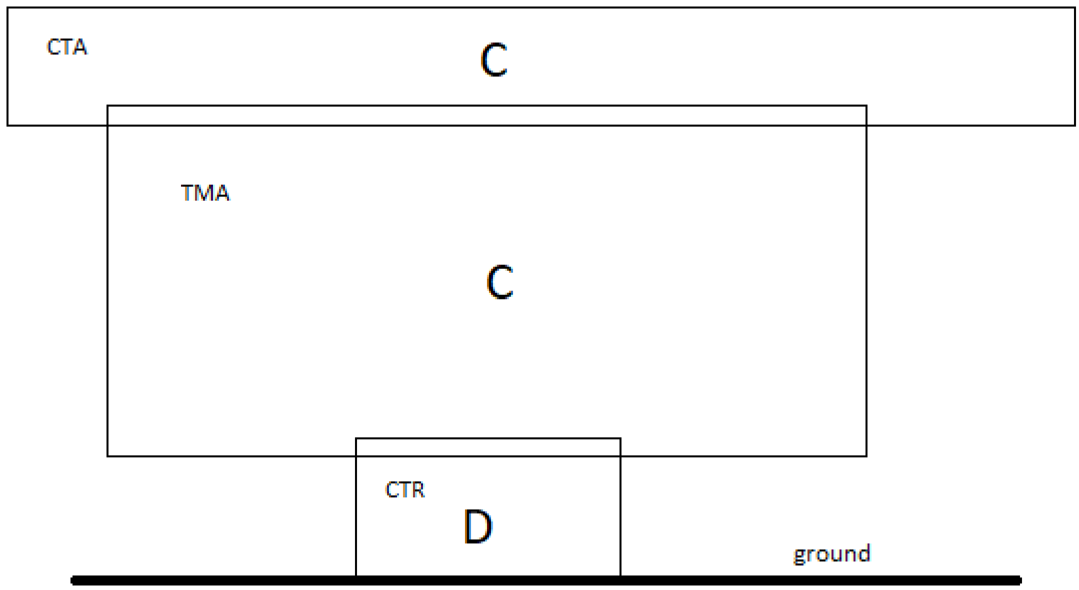


Figure 1.4. - CTR,TMA,CTA interrelation

FIR is an airspace within which flight information service and alerting service are provided. Lower boundary is a ground, upper boundary can be established if Upper Information Region is provided. If no UIR, so upper boundary is absent.

A body that is related to FIR is Flight Information Center.

1.3 An Air Traffic Controller activity in controlled airspace

Depending on a sector of an airspace, an ATCO duties varies. For different traffic zones different ATC units are intended. It can be Tower and Ground control at CTR boundaries, Approach Control at TMA and Area control at CTA.

In any case, without depending on area of responsibility, at a controlled airspace is provided alerting service (or emergency notification). It is provided with notice of appropriate organizations about the aircraft in need with search, rescue and aid. Alerting service is provided for all aircraft provided with an ATCS, all aircraft that provided the Flight Plan or which flights are known to the ATC, and for all aircraft that are suspected to be unlawfully interferred.

Flight Information Center and Area Control Center are main units for collection of flight information about emergency state of aircraft that perform flights in boundaries of a certain FIR or controlled airspace part, and transmit this information to the appropriate Rescue Coordination Center.

Necessity of search and rescue activity is determined by an ATCO due to stages of emergency markers.

Flight information service is also provided in every part of Flight information region permanently. In case of FIS provision an air traffic controller can not to see a sign of aircraft on a screen and even can not hear them. During FIS an aircraft is provided with information about state of aerodrome, about dangers in flight or collision hazard, meteorological information, radiotechnical means state, information transmission.

An information can be transmitted for one aircraft only (and be confirmed about receiving), for all aircraft and with the broadcast (ATIS, OFIS). Information for all aircraft can be transmitted if it is necessary to inform about dangerous conditions or some sudden changes that can influence the safety of flight significantly.

Air Traffic Control Service is provided for all flights that are performed in a controlled airspace. Providing this type of service, an air traffic controller can watch on a screen a sign of an aircraft or maintain visual contact (in case of Tower). ATCO can communicate with the aircraft and rule them with the help of clearances. Task of an Air Traffic Control Service is to prevent collisions between aircraft and obstacles, coordinate the traffic flow and order it for provision of efficiency.

ATCS includes, depending on area of responsibility, Aerodrome control service, Approach control service and Area control service.

At CTR an ATCO provides aerodrome control, intended for provision of aircraft

Also it is intended for the service of aircraft, performing VFR flights in the vicinity of aerodrome traffic zone and aircraft in the maneuvering area in cases when VFR flights and visual approach are performed. An ATCO provides information and clearances intended for safe and order traffic in the vicinity of the aerodrome, prevention of collision between aircraft performing VFR flights in aerodrome zone, aircraft performing take-off and landing, aircraft in a taxiing area and between aircraft and artificial obstacles on a maneuvering area.

At TMA an ATCO provides approach control. An Approach control is a medium service between the aerodrome control service and area control service.This service controls aircraft approaching to the aerodrome and assists in instrument approach and final approach.

An aerodrome of approach control can be situated as in controlled airspace as in an airspace beyond its boundaries. In the first case an ATCO should provide separation between aircraft performing IFR flights and aircraft performing VFR flights. In the second case an ATCO provides separation between aircraft performing IFR flights.

Coordination between the adjacent Area sector control and Aerodrome sector control units is also important. ATCO should provide to area control information about the aircraft performing IFR flights about the lowest flight level in a holding area that is possible to use for area control unit, about the time interval that is minima for final approach between two aircraft, about clarified estimated time of approach, when exists 5 minute deviation from estimated time, about coming of aircraft to holding area, if 3 minute deviation from estimated time exists, about going around in case of route change, about aircraft time of departure and about the aircraft being late.

At CTA an ATCO, as a part of Area Control Center, provides control in sectors beyond the limits of CTR and TMA. The controlled area of ATCO includes airways in upper and lower airspace, flight routes, TMA within FIR.

An Area Control Center coordinates with Approach control to exchange information about the aircraft leaving one area and coming to another,not later than in 15 minutes before taking under control.

Depending on intensity of air traffic, CTA can be divided on several sectors, that serve certain airways. These sectors can be separated with height and communication on different channels.

1.3 Airspace loading problem

One of the global aviation tasks is a safety during the flight. For the purposes of safety the controlled airspace was equipped with the modern devices, that help to obtain as much information as possible in a real time mode and developed a system of work for each specialist connected with the aviation. However, nowadays a problem of airspace loading exists and it can have a serious influence on an air traffic control officer. This problem is an airspace overloading or insufficient loading. Example of over and insufficient load can be seen on a European part of airspace Eurocontrol data. (Figure 1.5)

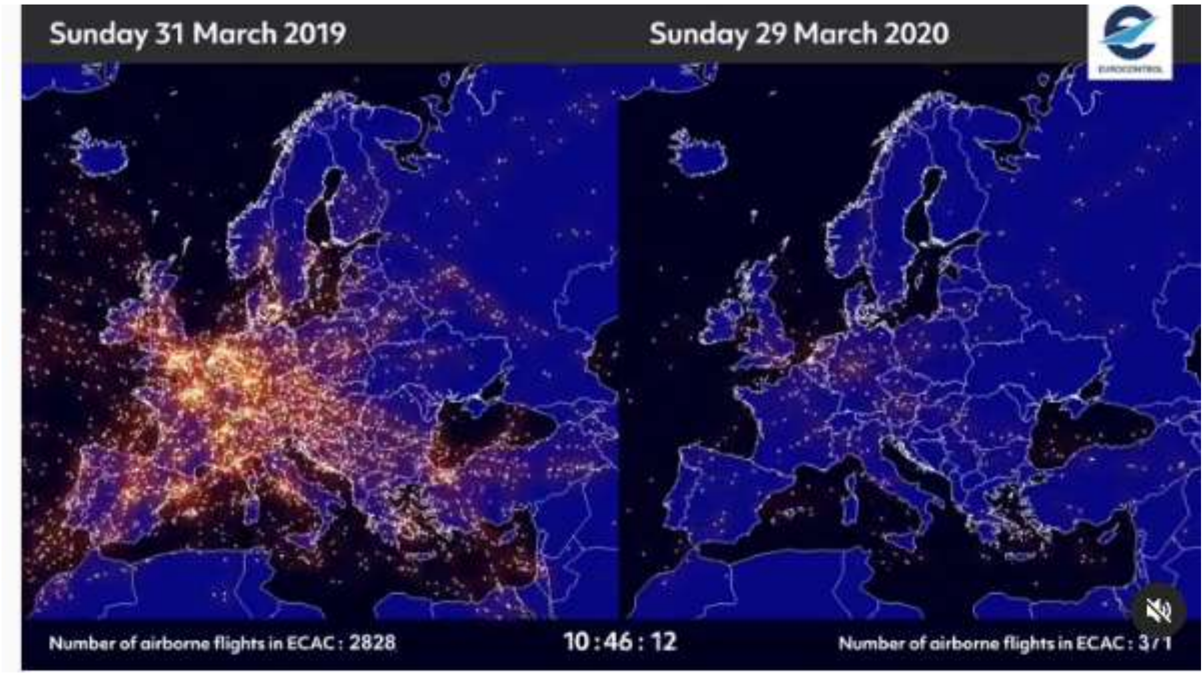


Figure 1.5. *Eurocontrol data about traffic on 2019 and 2020 years*

For the purposes of solving the problem of traffic distribution, the ATFCM (Air traffic flow and capacity management) was provided.

1.3.1 Overload

An overload is a problem of international airports. It can be easily seen if to look at traffic over the Europe. For the protection from overload is implemented an ATFCM, to prevent the entrance of aircraft to the sector where an ATC capacity can be exceeded. Also, the slots, level-capping and route changes can be actively used for prevention of a problem.

However, despite all the measures intended to protect and ATCO from the over traffic, that can`t be handled in safe way, more aircraft than had been planned regularly enter the sectors, that can exceed the sector capacity more than 10%. Such the situations mostly are the result of not flying at the initial requested flight level (RFL),departing at times different from the original estimated off block time (EOBT) or calculated take off time (CTOT),deviating from their original planned route; often direct routeing (DCT).

Possible reasons for non-adherence are multiple and vary from inefficient turnover process, weather problems, lack of trust in load figures, under estimation of the network effects and pressure to make up lost time.

The harmful impact of the overload can lead to non-used potential capacity in other sectors, distrust to the accuracy of forecast traffic counts, protective capacity reduction, increased workload, stress or working conditions such that the ability of ATC controller may be significantly impaired and thus a safety issue.

1.3.2 Insufficient load

An insufficient load has a negative impact as in economic as in safety of aviation. From the economic side, it is the waste of the airspace and workloads, which can influence the traffic efficiency. From the side of safety, an insufficient load have the negative impact at the ATCO (Air Traffic Control Officer/Operator) skills. Also it can cause the unwillingness of a human operator to a rapid increase of traffic flow.

1.3.3 An influence of the airspace load on an air traffic controller

An airspace load plays an important role on an air traffic controller`s personal efficiency and, that way, have a great influence on a safety of flights.

In conditions of overload or sudden increases of traffic, an ATCO can suffer from distress, and can`t rule the traffic in safe way, as required with regulations.

While operating in area with stable air traffic, human-operator uses possible resources of attention and readiness, that significantly decrease hazard of dangerous situation on the ATCO`s fault.

CONCLUSION FROM CHAPTER 1

Correctly distributed in controlled airspace traffic is one of the most important part of safety provision in air traffic control. So the air traffic controllers of each zone should obtain uniformly distributed traffic flow to ensure its safety and order.

CHAPTER 2.METHODS OF RESEARCH FOR ANALYSIS OF THE AIR TRAFFIC CONTROLLER WORKLOAD

2.1 Methods of Decision making. Expert Judgment Method.

Decision making is a choice of an optima variant among the several alternate.

Expert Judgment method is a method of decision making that allows to forecast and evaluate the future steps and their result, using the experts opinion.

For the usage of expert judgment method should be defined a group of experts, that should contain professionals with different type of cognition and world perception. The purpose of expert questioning is to choose main criteria of problem evaluation. Experts freely say their opinion. They should answer the questionnaire that is connected with a problem in details and then make a short report for the other experts.

For the expert group should be chosen people who demonstrate a strong knowledge of the problem and have a fast thinking to orientate in fast discussion flow. Also the expert should have a possibility to say shortly and main things, that will allow to save time and hear the opinion of all experts. And main criteria of expert choice is impartiality-any variant of solving the problem should be chosen only in interests of solving efficiency. Also it should be taken into account the expert`s professional status.

So, to use the expert judgment method, group should be prepared to provide the precise designation of task and aim, expert independent and competent choice, negotiation of a problem in expert group or, otherwise, an exception of contact among the experts to provide the full independency, provision of results free access for expert group, choice of conclusions handling methods and accurate formulations of conclusions in the end of expert poll.

An Expert Judgment Method is used for the forecasting of an event with the help of coordinated expert opinion. If the experts` opinions are not coordinated, the experts whose opinion differs from the majority should explain their point of view for other experts.

Using the Expert Judgment method (EJM) it should be taken data about the situation on different levels of the management-lower and higher.

Information on lower level is typically collected from the "link leaders"-chiefs, leaders or foremen-and ordinary workers. It is intended for efficiency growth of production and finding the inefficient resources usage reasons to eliminate them.

Information of higher level is about the relationship of the investigated processes. Usually this information is taken from the experts of higher level, that are deeply recognizing the problem.

The analysis that is based on the expert estimation results can be performed on several stages:

1) Definition of aim
2) Estimation of needed expert group number
3) Expert group appointment
4) Poll type determination
5) Questionnaire and control program drafting
6) Poll
7) Analysis of information, taken from expert answers
8) Generalization of results and making the development of possible variants of problem solving.

All the expert methods can be divided onto the individual and group.

Individual methods is the expert`s own point of view, when the expert doesn`t have any contact with other experts. The form of organization of such methods can be interviewing every expert or fulfilling the questionnaire.

The form of interview is a conversation between an expert and the analyst. An analyst asks the key questions concerning the problem, solving variants, wasted resources, direction of efficiency increase, etc.

The form of questionnaire implies a fulfilling the blank with the key questions.

Individual methods advantages are simplicity of survey, understanding and possibility to use the acquired knowledge and experience of each expert. The disadvantages are in knowledge limitation and lack of experience of related branches experts.

Group methods allow to avoid the disadvantages of individual methods. Being based on the experts cooperation, they allow to estimate the general experts` opinion.

Among the group methods of decision making are allocated the method of commission, Delphi method, ideas conference, remote evaluation, etc.

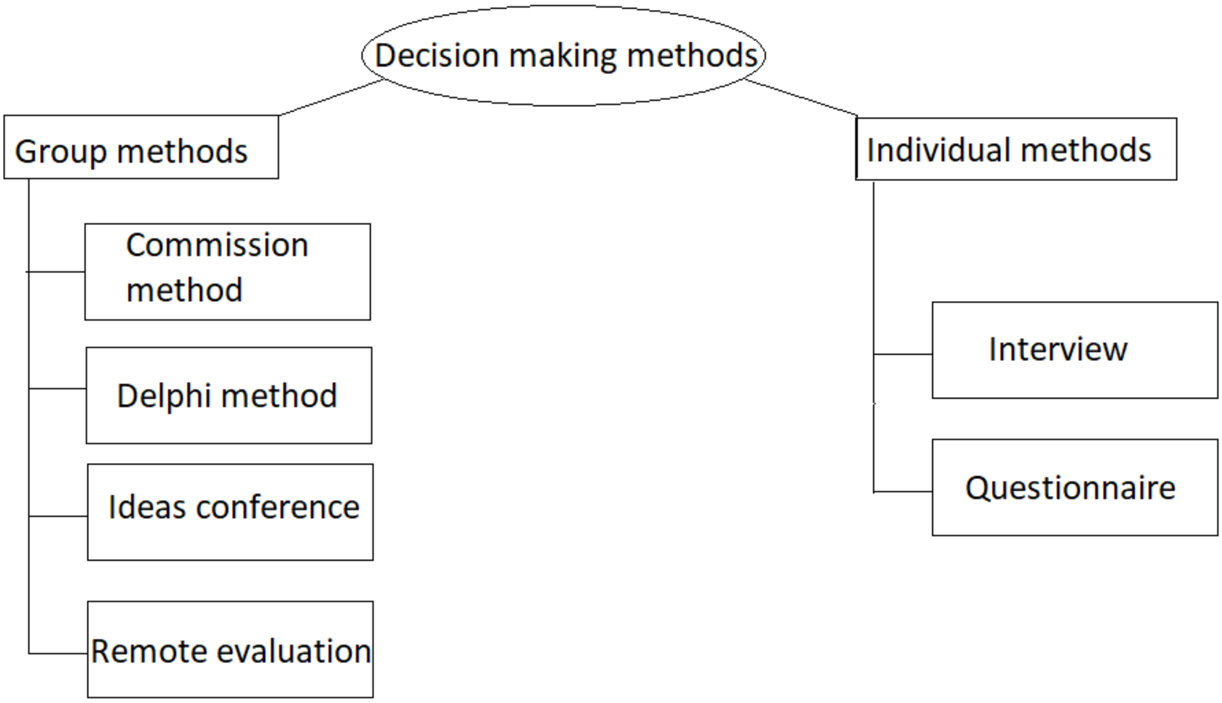


Figure 2.1. Classification of decision making expert methods

Method of commission is a best variant choice made by the expert commission after the discussion, taking into account all the expert`s point of view.

Advantages are possibility of invitation experts from different fields of activity, connected with the problem and possibility to see the problem from all the sides. Disadvantage-subjective point of perception the problem and stereotypes, that have already existed for experts; propensity of expert group to find a compromise.

Delphi method is the survey of the expert group in several rounds to determine the best decision among all the offered variants.

The aim of Delphi method use is to coordinate the group opinion without the contact between the experts, providing anonymity of thoughts and opinions and arguments in favor of one or another variant.

When the Delphi method is used, experts are suggested to express their mind as for problem and argument them. Before the next round of questioning experts obtain the results of the last survey about independent agreements and disagreements of experts` ideas. This process is continues until the full coordination of group opinion. After that the opinions that differs from majority are exuded.

The Ideas Conference is similar to the brainstorm method, but differs with the pace of meetings and allowed positive critique of ideas in form of remarks and comments.

Remote evaluation is also choice of optima variant among offered by experts on a meeting, but the organization differs: firstly the experts suggest the ideas and then discuss all of them.

2.2 Data mining. Statistical data analysis. Correlation-Regression analysis.

Correlation-Regression Analysis (CRA) can show the relationship or its absence between two parameters. This method can be applied in different spheres, including aviation, for the forecast future parameters behavior. Parameter that shows the way in which 2 values are dependent or independent one from another is correlation coefficient r.

The CRA method need the previous data mining to analyse the dependence between parameters.

After the data collection, correlation analysis starts. Correlation shows the strength and way of the variables relationship.

The correlation coefficient r should be in bounds between -1 and 1.If r=0, correlation between variables doesn`t exist. If r=1 or r=-1, than correlation is strong and straight. If r=0.7.. 0.8 then the correlation of variables is good (and it is the most spread in reality result). (Formulae 1)

$$r = \frac{\sum xy - \frac{1}{n}\sum x \sum y}{\sqrt{(\sum x^2 - \frac{1}{n}(\sum x)^2)(\sum y^2 - \frac{1}{n}(\sum y)^2)}}$$

Formulae 1.Determining of the correlation coefficient.

Determination of Regression (Formulae 2-4)

$$y = b_0 + b_1 x_1$$

Formulae 2.Equation of regression line

$$b_0 = \frac{\sum y \sum x^2 - \sum xy \sum x}{n \sum x^2 - (\sum x)^2}$$

$$b_1 = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2}$$

Formulae 3,4.Determination of regression line coefficients.

To prove the significance of evaluation,should be implemented Student`s (Formulae 5) and Fisher (Formulaes 6-8) criteria.

Student Criteria is evaluated with the help of r (correlation coefficient).

$$\hat{t} = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \geq t_{kp}(k;\alpha)$$

Formulae 5.Student Criteria

Fisher Criteria is based on coefficients σ_y^2 and $\hat{\sigma}_{y3}^2$.

$$\sigma_y^2 = \frac{\sum y_y^2 - \frac{1}{n}(\sum y)^2}{n-1}$$

$$\hat{\sigma}_{y3}^2 = \frac{\sum (y-\hat{y})^2}{n-2}$$

$$\hat{F} = \frac{\sigma_y^2}{\hat{\sigma}_{y3}^2}$$

Formulaes 6,7,8. Determination of significance using Fisher criteria

The CRA should be used according to the following algorithm. (Figure 2.2)

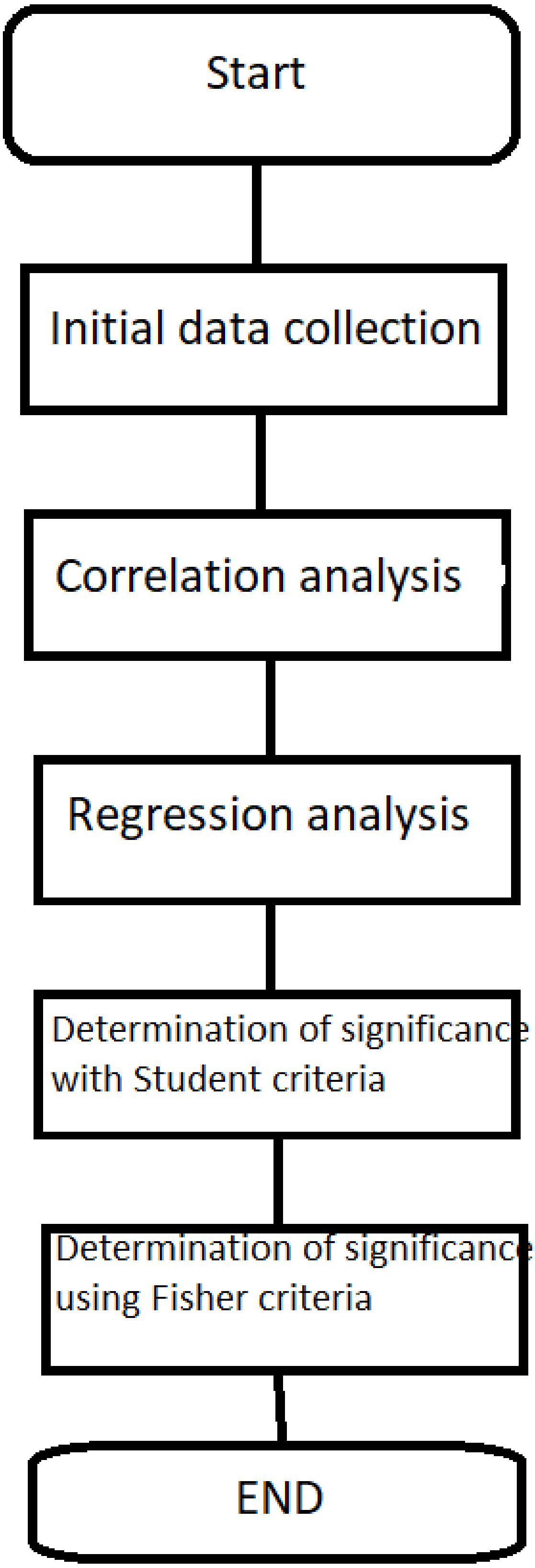


Figure 2.2. Algorithm of CRA

The CRA method can be used for prediction of future workload on the controlled sector.

2.3 Methods of AI in air navigation systems.

An Artificial intelligence is a modeling of the human cognition process with the computer systems, simulation and the apparatus. Its algorithm includes:

-information collection and rules of its usage (learning)

-using the rules of data processing to obtain the approximate results (reasoning, estimation, model building)

-estimation of an obtained model (self-correction)

-parts of Expert System (particular cases)

-Decision Support Systems

-Automated systems

-other systems, that can be helpful as the addition for safety control

The AI system differs from the another systems with the ability to self-learning, improving and prediction. Via the self-learning, the AI system is able to make the conclusions and, using this knowledge, solve the problems that hadn`t been appeared before.

In AI the ES is a system that simulates the human way of thinking.

For the education of aviation personals in AI developed training, such as:

-Expert Judgment Method (EJM) / Multi-criteria decision problems.

- Deterministic models. Network planning. D-M in an emergency conditions.
- Stochastic models. D-M in Risk. D-M in an emergency.
- Game Theory. D-M in uncertainty. Optimal aerodrome of landing.
- Dynamic programming (DP) and GRID analyzes of the problem. The DP method to solve the problem of minimal cost, climbing an aircraft.

The Decision Support System consists on the Database (where the status and relationship of analysed object is reflected), Model Base (where performed a set of logic,mathematic,linguistic models for future possible comparative analysis of decision) and User Interface.

The Aeronautical Decision Making is a DM proceeding in a unique environment, so it need the own DSS, that will be based on the AI algorithms.

Problems of D-M in organizational management have such the common features,as:

-unique D-M situation;

-difficult assess of possible alternatives;

-uncertainty of the actions and their consequences;

-big amount of factors that need to be taken into account during the D-M process

-the presence of a person or expert group responsible for D-M.

The main methods of analytical modelling to support DM are:

-Factor Analysis "cause- consequence "- change of the values and relationships of some factors (variables) for the investigation of values changes of other (dependent) variables.

-Optimization analysis – obtaining the best value of the objective function taking into account restrictions from the selection of variables.

-Correlation and regression analysis - determining the type of relations between the dependent variables and factors.

-Trend Analysis - predicting the dynamics of the control object by building trends - segments of numerical series;

-Control system models base;

-The user`s interface - the way of user interaction with the system.

Building a DSS should ensure implementation of its important properties:

-Interactivity of DSS means that the system can respond various types of influence on computation process (from the user`s side). Human and system information exchange performs with the speed of processing information by human.

-Integrity of DSS - is complex of system component for data management and the communication with users during decision support.

-Power of DSS means the ability of a system to respond to the most significant question or question that needs to use a lot of data.

-Availability of DSS - the ability to provide answers to the user requests in the right form and at the right time.

-Flexibility of DSS describes the possibility of adapting to needs and situations changing.

-Reliability of DSS means the ability of the system to perform the required functions for a given long period.

-Robustness of DSS - this is the system's ability to recover in case of error situations, both external and internal origin. For example, there are mistakes of the input data or malfunctioning hardware in a robust system. [Applications in Socio-Technical Systems]

White paper is a type of guide, that inform its user about the complex issue and help to understand an issue, solve a problem or make a decision. A white paper that redefining the collaborative air traffic management states the Collaborative Decision Making need to be developed to provide greater flexibility to the flight planners and best use of available airspace resources and capacity.

Also it tells about the already existed technologies, that can be classified as DSS:

-Aviation System Performance Metrics (ASPM)

-Terminal Aerodrome Forecast (TAF)

-Airport Decision and Support Tool (ADEST)

-PERTI Analysis of Traffic Management Initiatives History (PATH)

An ASPM is a database supported by FAA, that contain everyday data of 77 airports. These data contain information about delays, departure and arrival cancellations, average taxi-out times, departure delays, number of airborne holding events and holding minutes, going around and completion rate.

TAF is a weather report, that forecast weather at an airport every 6 hours. It is applied to a 24 or 30 hr period and acts within 5 statute miles (approximately 8 km) from the centre of airport.

ADEST is a tool that can provide a rate of arrival, adressing such the variables as, for example, fleet mix, braking action or other factors of environmental possible impact. ADEST builds an arrival rate to an airport based on airport configuration, TAF and specific set of business rules intended only for the analysed airport. This tool is supported with TAF so the time of work of this system depends from TAF mainly (24-30 hr period).The ADEST goal is to generate arrival rates at 34 of the busiest airports in the National Airspace System.

The PATH tool is a new addition of tools available to the PERTI team. PERTI is a part of strategic analysis of disruptive events. Each letter represents one of the five key points of the mission – Plan, Execute, Review, Train and Improve. For realization PERTI objectives and strategy was founded a PERTI Evaluation Team (PET). PET uses the data collection on the expert consortium and “lesson-learned” metodology, based on collected information about the incidents. After the D-M PET process, PERTI provides the results, based on the expert PET data.

The PATH tool help an air traffic manager to search historical ground delay program data, compare it to similar historical constraints and use this information to predict the airspace system performance.

CHAPTER 3. MODELING OF LOAD OF ATCS AND SECTOR

3.1 Flight stages and ATC bodies connected with them

During the flight the aircraft passing such stages: Taxiing, Take-Off, Climb, En-route, Descend and Landing .

Take off stage is a stage from the start of ACRT moving on RWY until the velocity that will provide the lift off the ground and reaching the 10,7 m.

Take-off and Climb (partially) stages are performed at CTR. Responsible for the traffic within the CTR are Ground and Tower control.

Ground control is a service that is responsible for maneuvering area and areas free from the airlines or other lessees. Their area of responsibility includes taxiways, inactive runways, holding areas and transition aprons or intersections where the landed aircraft arrives after the RWY vacation, or departure gate. Local documents and agreements regulate the ground control areas of responsibility. Any subject moving via the ground control area should obtain the clearance from GND. Usually the channels VHF/UHF are used, but in case of transceiver breakage or absence the light signals or other vehicles that have the transceiver can be used. In case of poor visibility or at night GND ATCO can use the Surface Moving Radar (SMR).

Ground control is very important for the continuous airport operation, because of its impact on the sequence of departured aircraft, affecting the safety and efficiency of the airport's operation.

Tower Control is responsible for the movement control on the active runways. It allows the take-off and landing, providing the safe interval between the aircraft. If TWR ATCO detects any potentially dangerous conditions, it can be used go-around procedure for the approaching aircraft. For the successful activity of this ATCO body should be provided and well-organized coordination between sectors and communication. In particular, TWR control and Ground control should strictly coordinate their actions. CRM (or TRM) is often implemented to ensure the procedure is safe and efficient. Also TWR and GND control can be complemented.

Approach control is a service that is responsible for the Terminal Area.APP ATCO acts usually in bounds of 56-93 km from the airport. Their activity is intended to control the approaching and departing aircraft, during Descent and Climb stages. An ATCO of APP ensure the provision of maintaining the appropriate altitudes while handing off and suitable rate for landing. The consolidated Terminal Control center can provide APP in case of several airports situated closely one to other.

Area control provides an ATCS in the Controlled area. The ACC monitor the aircraft during En-Route stage and are responsible for the separation provision and climbing the aircraft until its assigned altitude. When the aircraft approaches the destination point, the ACC is responsible for provision of instructions to pilots about altitudes restrictions at certain points, and providing destination airports with a traffic flow, which prevents all of the arrivals from being groupped together. The ACC work can be significantly affected with the cross traffic, weather conditions, special missions for which are used big airspace volumes and traffic density.

3.2 Criteria of analysis

To make analysis of ATCO workload on each sector are chosen the following criteria of analysis:

-air traffic intensity

-air traffic density

-flights regularity

-potential flight safety

-capacity of the controlled airspace part

Intensity is a number of aircraft arrived to the airspace or its part per unit of time. Its value strictly depends on the capacity of the ATC bodies. Usage of Automated Systems of ATM leads to increase of the amount of aircraft.

Density is a number of aircraft that are simultaneously in the airspace or its part. It is defined as ratio of aircraft amount and airspace volume. On practice, can be defined two significatives – mean value at the certain period and peak density.

Regularity is ratio of the performed flights to the planned. Departure is said to be regular when the take-off is performed not later than estimated take-off time (time that is established in the Flight Plan + time of taxiing and safety provision). If the delay of 15 min is present, departure is said to be regular if the aircraft arrived to the airport of the first landing on the flight route in the designated time. Flight is considered to be regular if the aircraft arrived to the airport of destination in time or with the lateness 10 min for less than 3 hr flights, 20 min for flights that lasts 3-6 hr and 30 min for flights over 6 hr.

Safety is a state of an aviation system or organization in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level [Safety manual].Main factors affecting the safety in the ATM system are:

-reliability of ATM organization

-route planning

-division of airspace

-professional level and discipline of operators

General designators of safety are mean amount of flights per one incident and mean amount of flight hours per one incident.

Capacity is amount of aircraft that can be provided with the air traffic service in a part of airspace with one ATS body. Capacity depends on:

-established separation;

-ATM organization;

-aircraft speed;

-controlled airspace parts volumes ;

-ATCO.

Distinguished two types of sector capacity. Estimated (or theoretical) capacity is a capacity which reflect how many aircraft can be maximally provided with ATCS within the certain airspace part per unit of time.

To determine the theoretical capacity of ATC Sector the following data are used:

1) About airspace structure:

- Boundaries of ATC Sector.
- Routes structure.
- Data about traffic flow.
- Information about reported points
- About length of ATS routes.
- Number of flight levels (heights) for ATS routes within the ATC Sector.
- Areas of ATS routes with variable profile of airplanes flight.

2) The structure of the air traffic flow:

- Actual and predicted number of aircraft, which are (will be) involved in air traffic control service (per hour, per day) based on season.
- Actual or predicted distribution of air traffic flow directions, (ATS routes, flight levels).
- Actual or predicted ratio of different types of aircraft in the air traffic flow (the direction of movement, flight levels).
- Actual or estimated number of airplanes (that will conduct flights according to Visual flight rules (VFR) and which will be provided only with flight information service (FIS)).

3) Analysis of the structure of airspace and air traffic flow are recorded in the appropriate tables. These data, in future will be used to develop a scenario simulation of air traffic on dispatch simulator (mode Real-time Simulation) in order to determine the practical capacity of ATC Sector.

4) List and content of technological operations, on which the time spent by controller unit is based, according to the work manual of ATC unit.

In fact capacity reflects how many aircraft can be really provided with the ATCS

$$\mu = \frac{N_0}{t_0}$$

,where N_0 is amount of aircraft, provided with ATCS within the certain airspace part per unit of time t_0,

t_0 is the time period within which capacity is designated (usually it is taken 1 hr).

3.3 Analysis of ATCO workload on each sector

Before the start of data mining, with the analyst and experts should be clearly designated the boundaries of each analysed zone. For this purpose was used a Free Route Airspace chart of Kyiv FIR. (Figure 3.1, Figure 3.2)

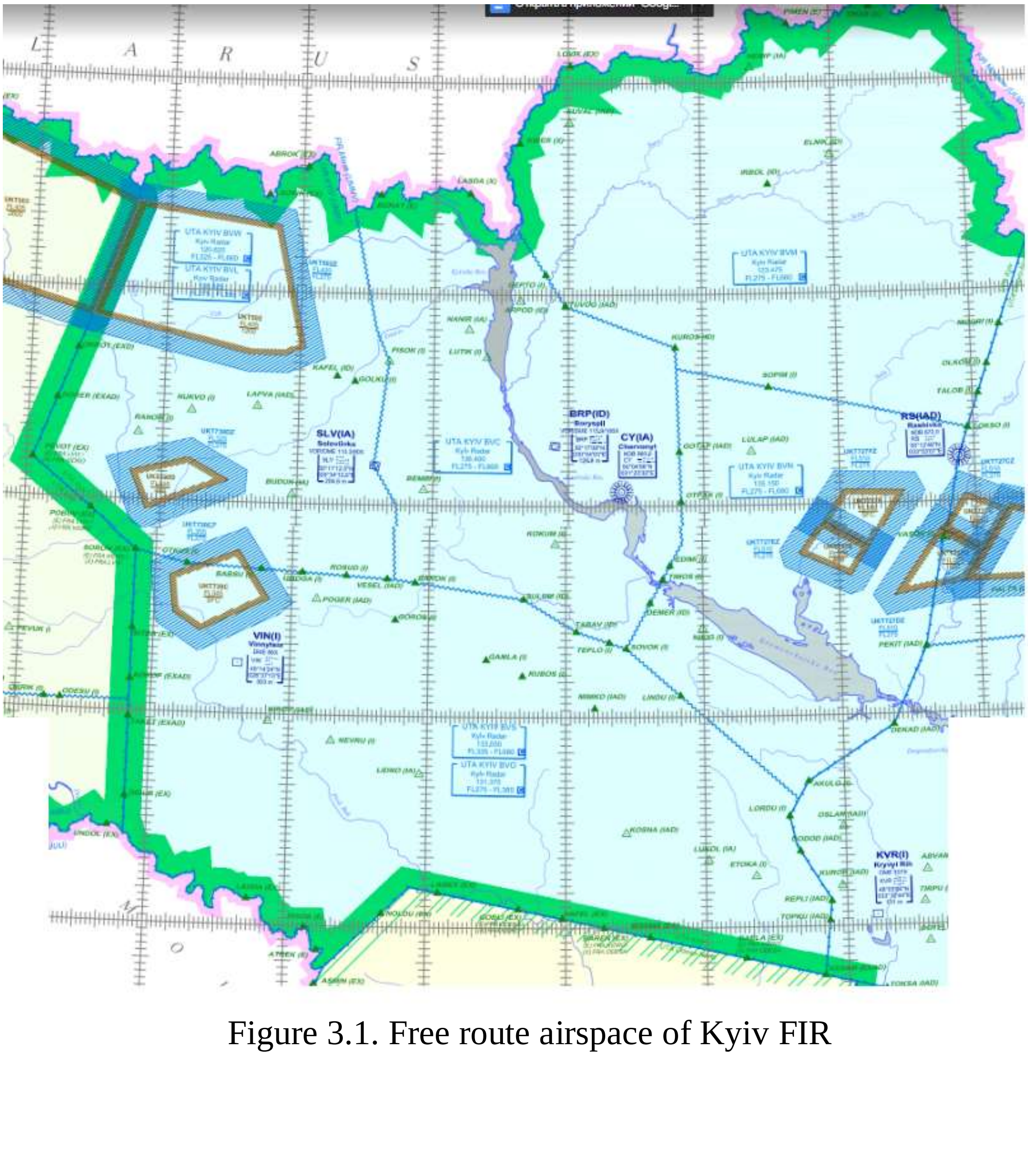


Figure 3.1. Free route airspace of Kyiv FIR

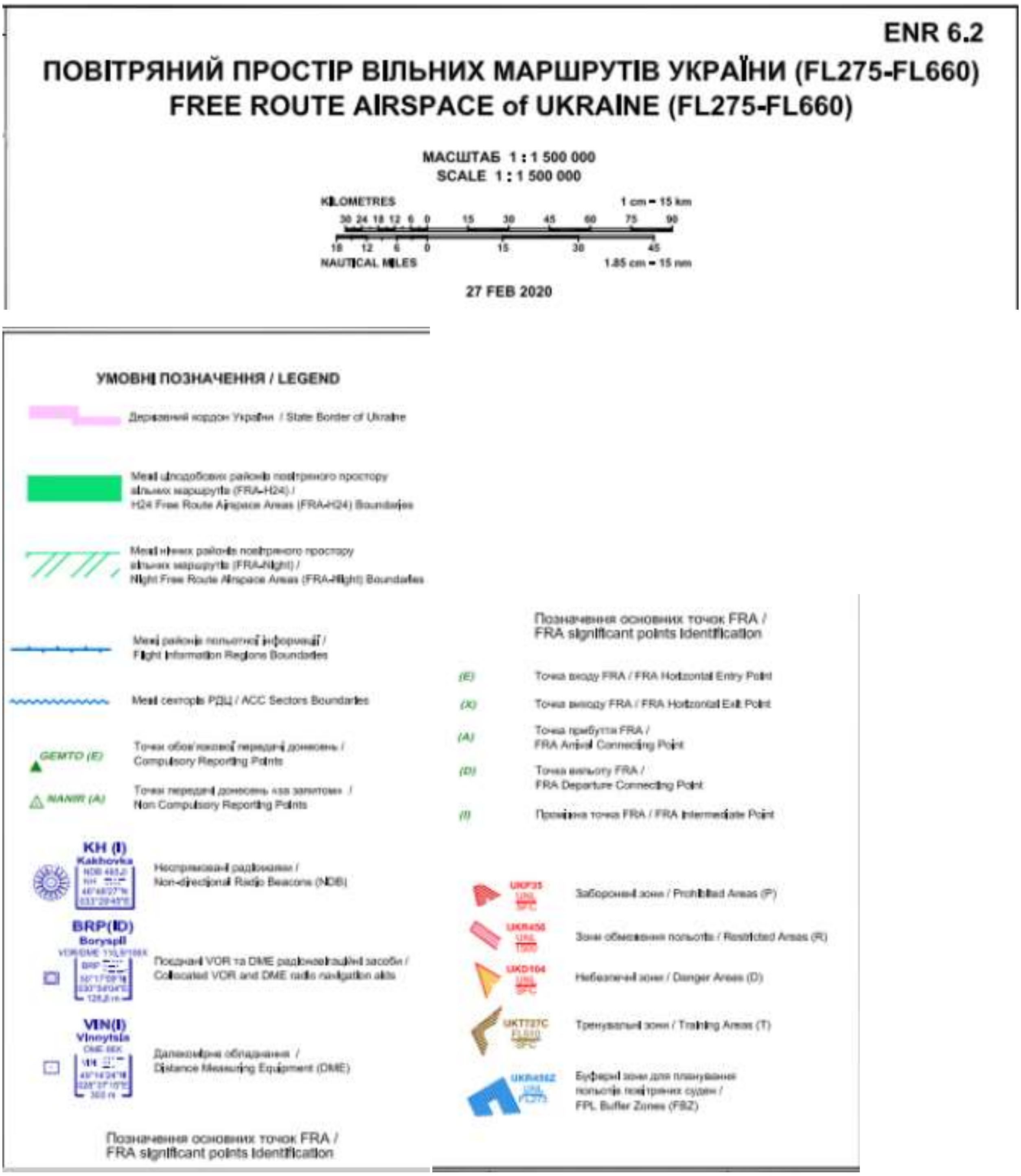


Figure 3.2 Legend of a Free Route Airspace Chart

Also was analysed traffic within Kyiv FIR. According to data obtained from Flight Radar 24, expectations are higher workload at Kyiv BVC and TMA Boryspil , less workload within Kyiv BVL and Kyiv BVS, the lowest at Kyiv BVM and Kyiv BVN.

Were analysed also charts about CTR of Boryspil and TMA of Boryspil,where was obtained information about its operational data. (Figure 3.3, Figure 3.4, Figure 3.5)

ДИСПЕТЧЕРСКІ ЗОНИ (CTR) / CONTROL ZONES (CTR)

Позначення / Designation	Вертикальні межі та клас повітряного простору / Vertical limits and airspace Class	Позивний, частоти та мови / Callsigns,frequencies (MHz) and languages
11 CTR Kyiv / Boryspil	900 / SFC Class D	Boryspil Tower RWY 18R/36L 119.650 ENG, RUS RWY 18L/36R 119.300 ENG, RUS

Figure 3.3 Information about analysed CTR

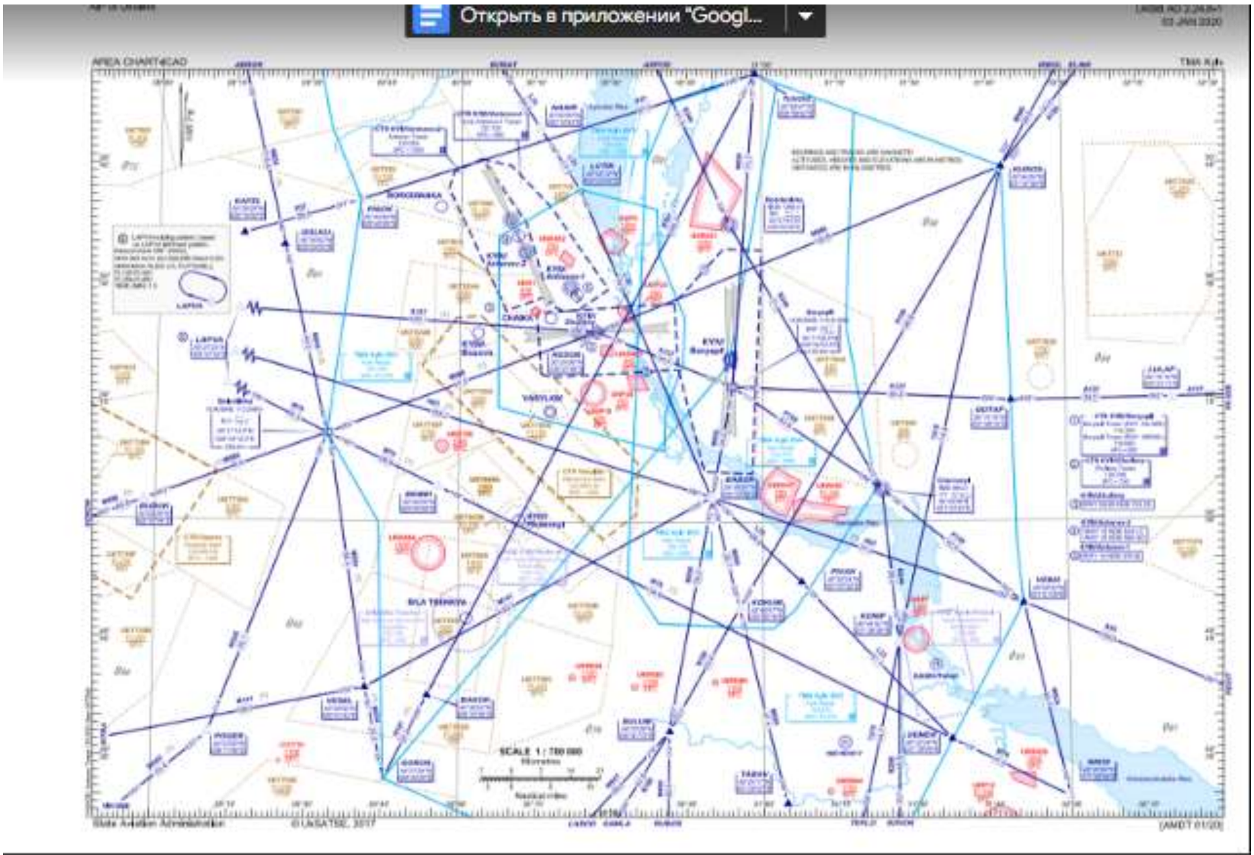


Figure 3.4 TMA chart

ВУЗЛОВІ ДИСПЕТЧЕРСЬКІ РАЙОНИ (TMA) / TERMINAL CONTROL AREAS (TMA)		
Позначення / Designation	**Вертикальні межі та клас повітряного простору / Vertical limits and airspace Class**	**Позивний, частоти та мови / Callsigns,frequencies (MHz) and languages**
11 TMA Kyiv BV 1	FL275 / 900 Class C	Kyiv Radar 127.725 ENG, RUS
12 TMA Kyiv BV 2	FL275 / 900 Class C	Kyiv Radar 124.675 ENG, RUS
13 TMA Kyiv BV 3	2900 / 450 Class C	Kyiv Radar 128.175 ENG, RUS
14 TMA Kyiv BV 4	2900 / 450 Class C	Kyiv Radar 122.775 ENG, RUS
15 TMA Kyiv BV 5	1650 / 400 Class C	Kyiv Radar 125.300 ENG, RUS

Figure 3.5 Information about TMA

Were analysed areas Kyiv BLV (Figure 3.6), Kyiv BVO (Figure 3.7), Kyiv BVC (Figure 3.8), Kyiv BVN (Figure 3.9) and Kyiv BVM (Figure 3.10)

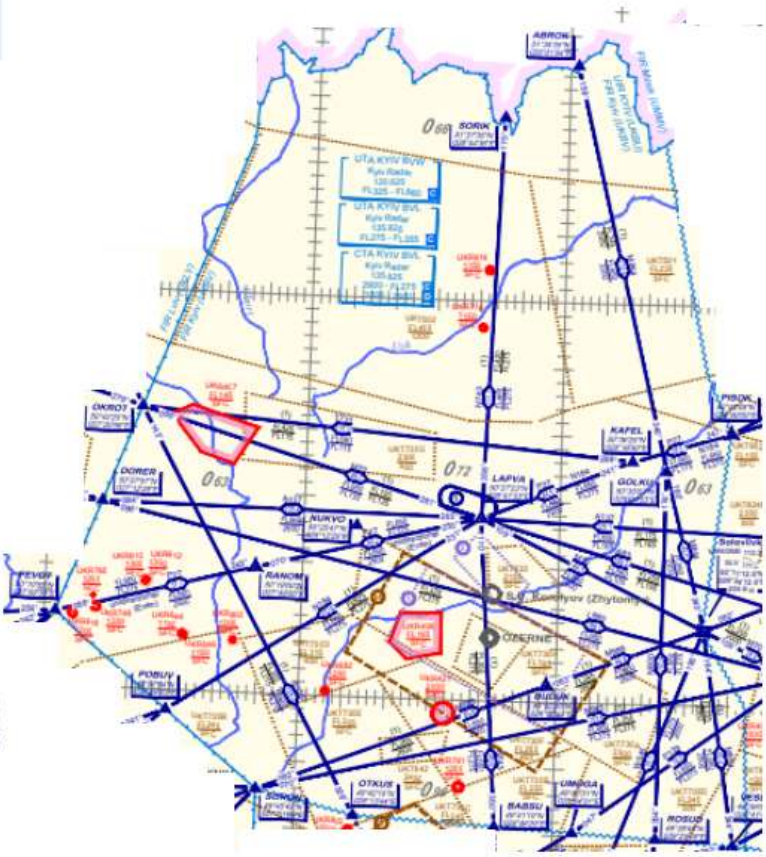


Figure 3.6 CTA 1 (Kyiv LIV)

CTA Kyiv BVL extends from 1500 m till FL275 and exists in two classes-D (1500-2900 m) and C (2900m-FL275). Also exists Upper area, that extends from FL275 and lays in a class C. Points of entry to the area- ABROK, SORIK (from the North), OKROT, DORER, PEVOT, POBUV (from the West), SORON, OTKUS,BABSU, UMOGA, ROSUD, VESEL (from the South), Soloviivka, GOLKU, PISOK (from the East). Within the BVL area are 13 routes, 3 (significant) restriction area, 12 training areas.

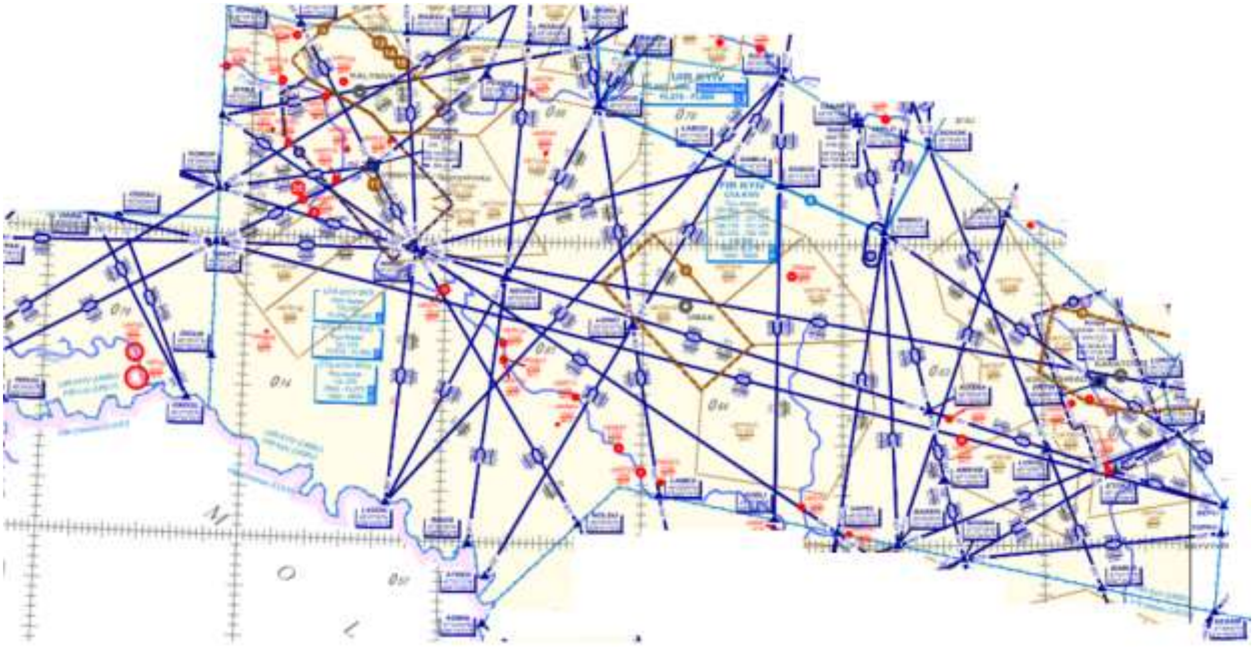


Figure 3.7 CTA 2 (Kyiv BVO)

CTA Kyiv BVO is also lays in classes D and C. Its vertical limits are 1500-2900 m (D class) and 2900-FL275 (C class). BVO is limited with the reporting points SORON, OTKUS, BABSU, UMOGA, ROSUD, VESEL, BAKOK, SULUM, TABAV, TEPLO, SOVOK, LINDU (from the North), SITBA, KOROP, TAKET, DIDUR (from the West), LAVDA, RIXOS, ATREK,NOLDU, LAMEX, GOBLI, VAPEL, BAREN, BOGMA, BABLA,KESAM (from the South), TOPKU, REPLI,GODOD, LORDU (from the East). 5 significant restriction areas, more than 15 routes, more than 15 training zones.

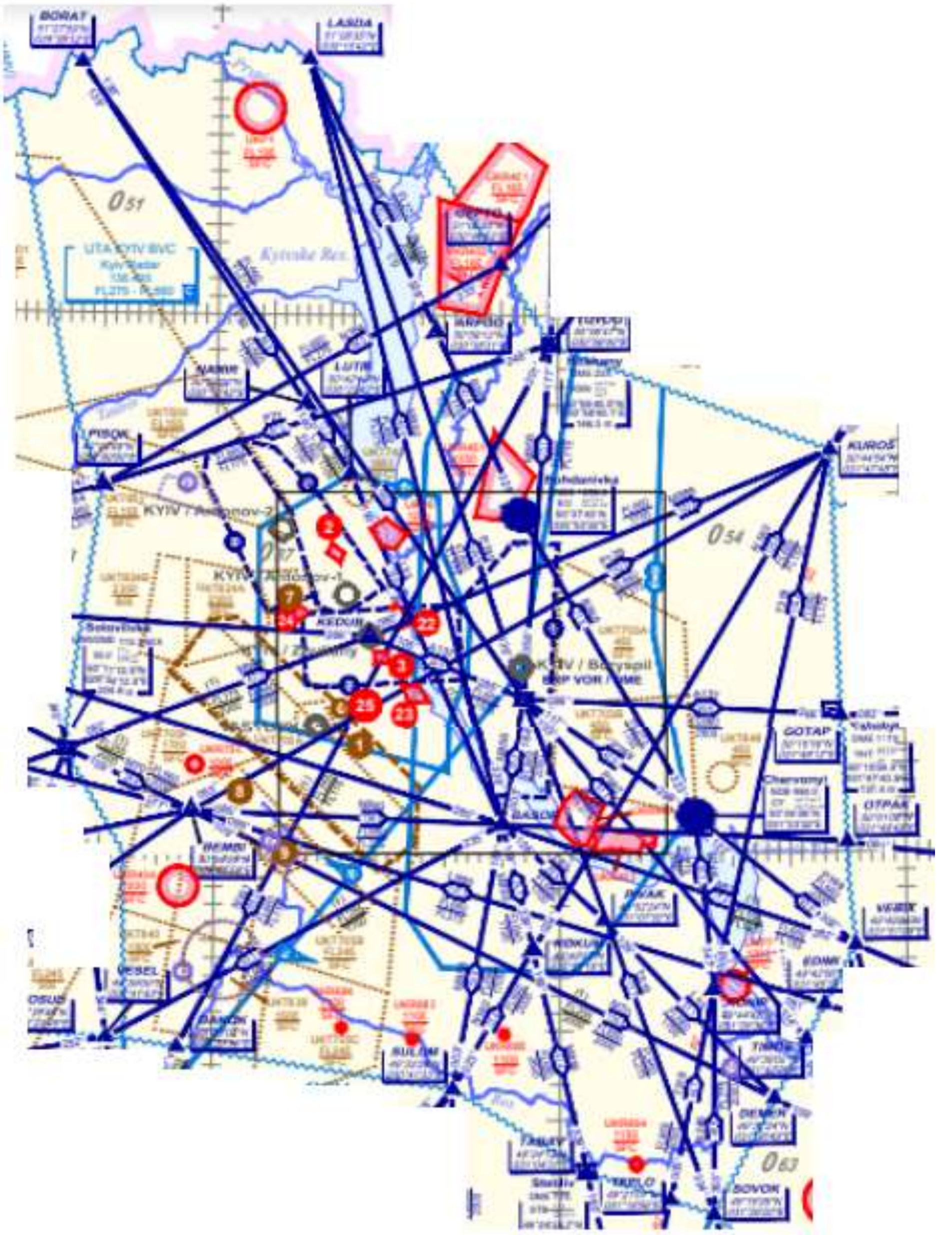


Figure 3.8 CTA 3 (Kyiv BVC)

Kyiv Centre CTA (BVC) is limited with the points ABROK, BORAT and LASDA from the North, GEPTO,TUVOG, KUROS, GOTAP,OTPAK, VEBIX, EDIMI, TIMOS, DEMER from the East, SOVOK, TEPLO, TABAV, SULUM, BAKOK from the South, Soloviivka, PISOK from the West.

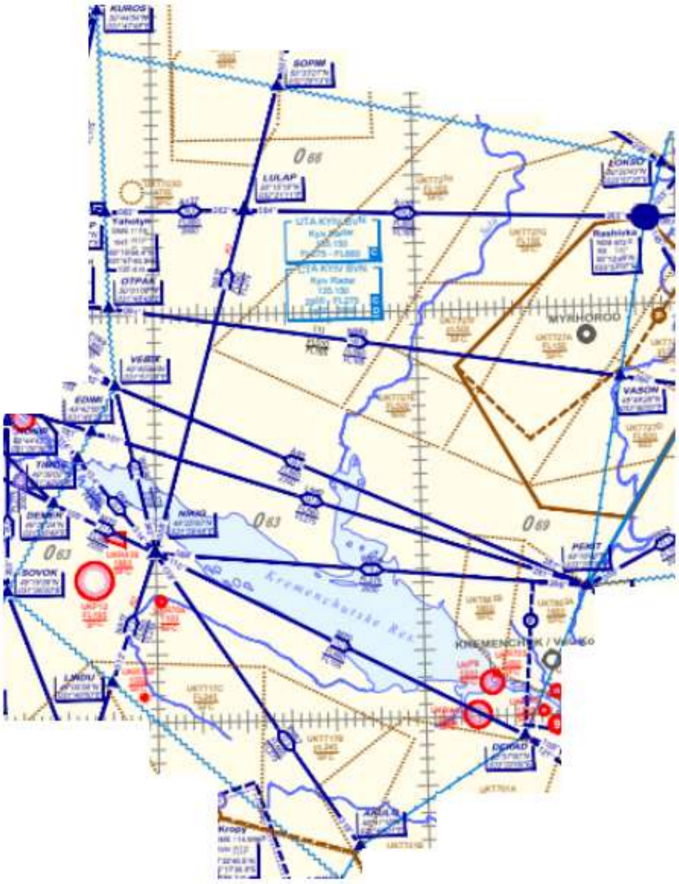


Figure 3.9 CTA 4 (Kyiv BVN)

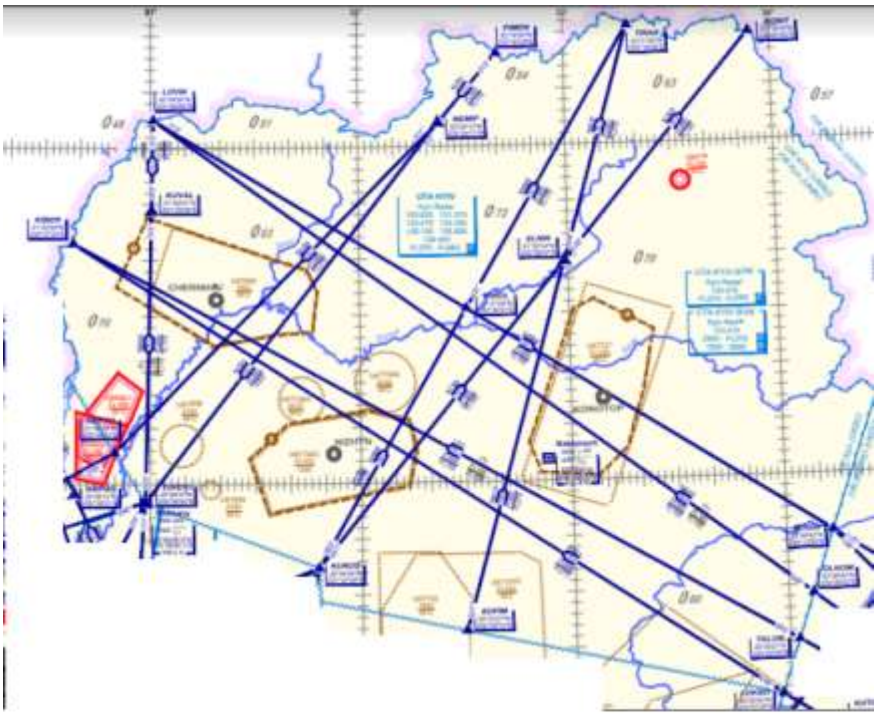


Figure 3.10 CTA 4 (Kyiv BVM)

Due to the low amount of flights, Kyiv BVM and Kyiv BVN were analysed as one zone in questionary.

CTA Kyiv BVM lays at D (1500-2900m) and C(2900m-FL275) classes. It is bounded with the points LOVIK, PIMEN, TIRAS, RONIT (from the North), KIBER, GEPTO (from the West), TUVOG,KUROS,SOPIM,LOKSO (from the South), MOGRI, OLKOM, TALOB (from the East).

CTA Kyiv BVN lays at D and C classes and has the same vertical limits as BVM. It is bounded with the points SOPIM, LOKSO (from the North), GOTAP, OTPAK, VEBIX, EDIMI, TIMOS, DEMER (from the West), SOVOK, LINDU, AKULO, DEKAD, PEKIT (from the South), VASON, Rashivka (from the East).
For the analysis purposes was used an en-route chart of ICAO [] and analysed its legend. (Figure 3.11)

Figure 3.11 Map legend (Pic 11-14)

The first step of the workload analysis is collection of the information about the intensity of a traffic in an airport sector.

For this purpose several experts were asked using with a following blank-matrix of individual expert preferences. (Table 3.1)

Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4
CTR						
TMA						
CTA1						
CTA2						
CTA 3						
CTA 4						

Table 3.1. Questionnaire about expected workload analysis in a certain controlled airspace sector

The questionnaire should be fulfilled with the 0 (zero),1(one) or 0,5 (one point five). 0 is designated less expected intensity,1 more and 0,5 equal.

The second stage was Ranging of the results, that helped to build a system of individual expert`s preferences. (Table 3.2)

Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sum r	R
CTR								
TMA								
CTA1								
CTA2								
CTA3								
CTA4								

Table 3.2. Matrix of individual preferences

Then the matrix of group preferences (Table 3) should be built and system of group preferences should be defined (Formulae 9)

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

Formulae 9. Mean ranges of group opinion

The forth step is analysis of expert coordination. To determine it, should be defined variation coefficient(Formulae 10),Kendall concordation coefficient and Spirman`s criteria. If the variation coefficient is less than 33%, expert opinion is coordinated, if more than 33%, should be provided new poll or used Kendall concordation coefficient to determine coordination for each the parameter.

$$var = \frac{\sigma_j}{R_{gr}} * 100\%$$

Formulae 10. Variation determination

To determine variation coefficient first need to obtain mean square deviation of opinion ranks (Formulae 11, Formulae 12, Formulae 13) and provided several additional calculations (Formulae 14, Formulae 15) necessary for the Formulae 13 calculation.

$$\sigma_j = \sqrt{D}$$

Formulae 11. Mean square deviation determination

$$D = \frac{\sum_{i=1}^{m}(R_{gr} - R_i)^2}{m-1}$$

Formulae 12. Dispersion of experts` opinions

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

Formulae 13. Kendall concordation coefficient

,where S is the sum of the squares of the deviations of all assessments of the ranks of each object of examination from the mean;

n is the number of experts;

m is the number of objects of expertise.

$$S = \sum\sum_{j=1}^{m}(R_{ij} - \bar{R})^2$$

Formulae 14.Determination of sum of the squares of the deviations of all assessments of the ranks of each object of examination from the mean value

$$T_j = \frac{1}{12}\sum({t_i}^3 - t_i)$$

Formulae 15. Determination of connected ranks indicator

Kendall concordation coefficient shows expert coordination on all the criteria. It is used when the experts determine two factors as equal important. If it is more than 0,6 opinions of experts are coordinated. Otherwise it should be provided another poll.

Spirman`s criteria shows coordination of general experts opinion with one of them. (Formulae 16)

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

Formulae 16. Spirman`s criteria

Where x_I – ranks of group opinion;

y_I – ranks of expert K;

n-number of experts.

Spirman`s criteria is also lay in bounds of 0 and 1 and the higher it is, the better experts opinions are coordinated.

Next step is evaluation of calculation significance. To calculate significance of coordination evaluation, were used χ criteria for W-coefficient (Formulae 17) and Student criteria for R_S coefficient (Formulae 18).

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

Formulae 17. Significance of Kendall concordation coefficient

$$t = r_s\sqrt{\frac{n-2}{1-{r_s}^2}} > t_s$$

Formulae 18. Significance of Spirman`s criteria, using comparison with Student coefficient

Then should be designed and fulfilled a matrix of individual preferences that is a consolidated experts` opinion representation. (Table 3.3)

Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4
Expert 1						
Expert 2						
Expert 3						
Expert 4						
Expert 5						
Expert 6						
Rav						
D						
SqDev						
Variation Coefficient						
Rest						
W						
$\chi\phi^2$			>	11,07050*		
R_S						

Table 3.3 Matrix of group preferences

*according to the table value of degrees of freedom k=m-1=4,level of significance α=0,05, the obtained $\chi\phi^2$ shouldn`t exceed the table value of 11,07050 to show the

Kendall coefficient (W) significance. If the obtained value is more than this value, so W value is a random and unreliable.

3.4 Modeling of sector load. Calculations using Microsoft Excel

The obtained results were ranged with the criteria of flights density in the sector. (Table 3.4, Table 3.5, Table 3.6, Table 3.7, Table 3.8, Table 3.9)

Expert 1 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0,5	1	0	1	1	3,5	3
TMA	0,5		1	1	0,5	1	4	1,5
CTA1	0	0		0	0	1	1	5
CTA2	1	0	1		0	1	3	4
CTA3	1	0	1	1		1	4	1,5
CTA4	0	0	0	0	0		0	6

Table 3.4 Matrix of individual preferences of expert 1

Expert 2 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0,5	1	1	0,5	1	4	2
TMA	0,5		1	1	1	1	4,5	1
CTA1	0	0		0	0	1	1	5
CTA2	0	0	1		0,5	1	2,5	4
CTA3	0,5	0	1	0,5		1	3	3
CTA4	0	0	0	0	0		0	6

Table 3.5 Matrix of individual preferences of expert 2

Expert 3 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		1	1	1	1	1	5	1
TMA	0		1	1	0	1	3	2
CTA1	0	0		0,5	0	1	1,5	5

CTA2	0	0	0,5		0,5	1	2	4
CTA3	0	0	1	0,5		1	2,5	3
CTA4	0	0	0	0	0		0	6

Table 3.6 Matrix of individual preferences of expert 3

Expert 4 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0,5	1	1	1	1	4,5	1,5
TMA	0,5		1	1	1	1	4,5	1,5
CTA1	0	0		0,5	0	1	1,5	5
CTA2	0	0	0,5		0,5	1	2	4
CTA3	0	0	1	0,5		1	2,5	3
CTA4	0	0	0	0	0		0	6

Table 3.7 Matrix of individual preferences of expert 4

Expert 5 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0,5	1	1	1	1	4,5	1,5
TMA	0,5		1	1	1	1	4,5	1,5
CTA1	0	0		0,5	0	1	1,5	5
CTA2	0	0	0,5		0,5	1	2	4
CTA3	0	0	1	0,5		1	2,5	3
CTA4	0	0	0	0	0		0	6

Table 3.8 Matrix of individual preferences of expert 5

Expert 6 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0	1	1	1	1	4	2
TMA	1		1	1	1	1	5	1
CTA1	0	0		0,5	0	1	1,5	5
CTA2	0	0	1		0	1	2	4
CTA3	0,5	0	1	1		1	3,5	3

CTA4	0	0	0	0	0		0	6

Table 3.9 Matrix of individual preferences of expert 6

Then the matrix of group preferences was fullfilled.

Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4
Expert 1	3	1,5	5	4	1,5	6
Expert 2	2	1	5	4	3	6
Expert 3	1	2	5	4	3	6
Expert 4	1,5	1,5	5	4	3	6
Expert 5	1,5	1,5	5	4	3	6
Expert 6	2	1	5	4	3	6
Rav	1,833333	1,416667	5	4	2,75	6
D	0,388889	0,118056	0	0	0,3125	0
SqDev	0,68313	0,376386	0	0	0,612372	0
Variation Coefficient	0,372616	0,265684	0	0	0,222681	0
RT	2	1	5	4	3	6
W	0,952496					
χф2	28,20024>11,0705					
Rs	0,9					

Table 3.10 Matrix of group preferences on density criteria

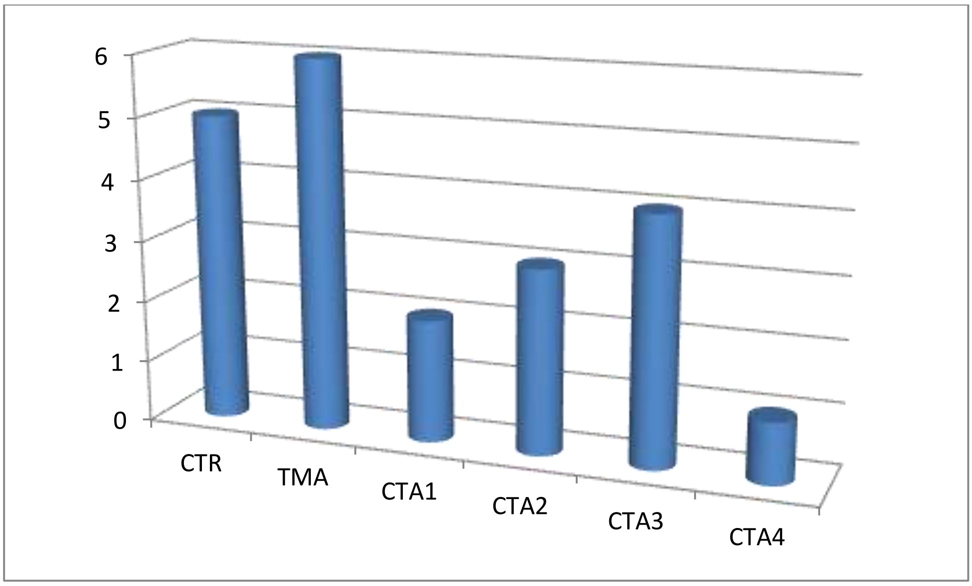
Coordination of expert group opinion and expert 1 using Spirman criteria (Table 3.11)

Expert 1(yi)	3	1,5	5	4	1,5	6
RT(xi)	2	1	5	4	3	6

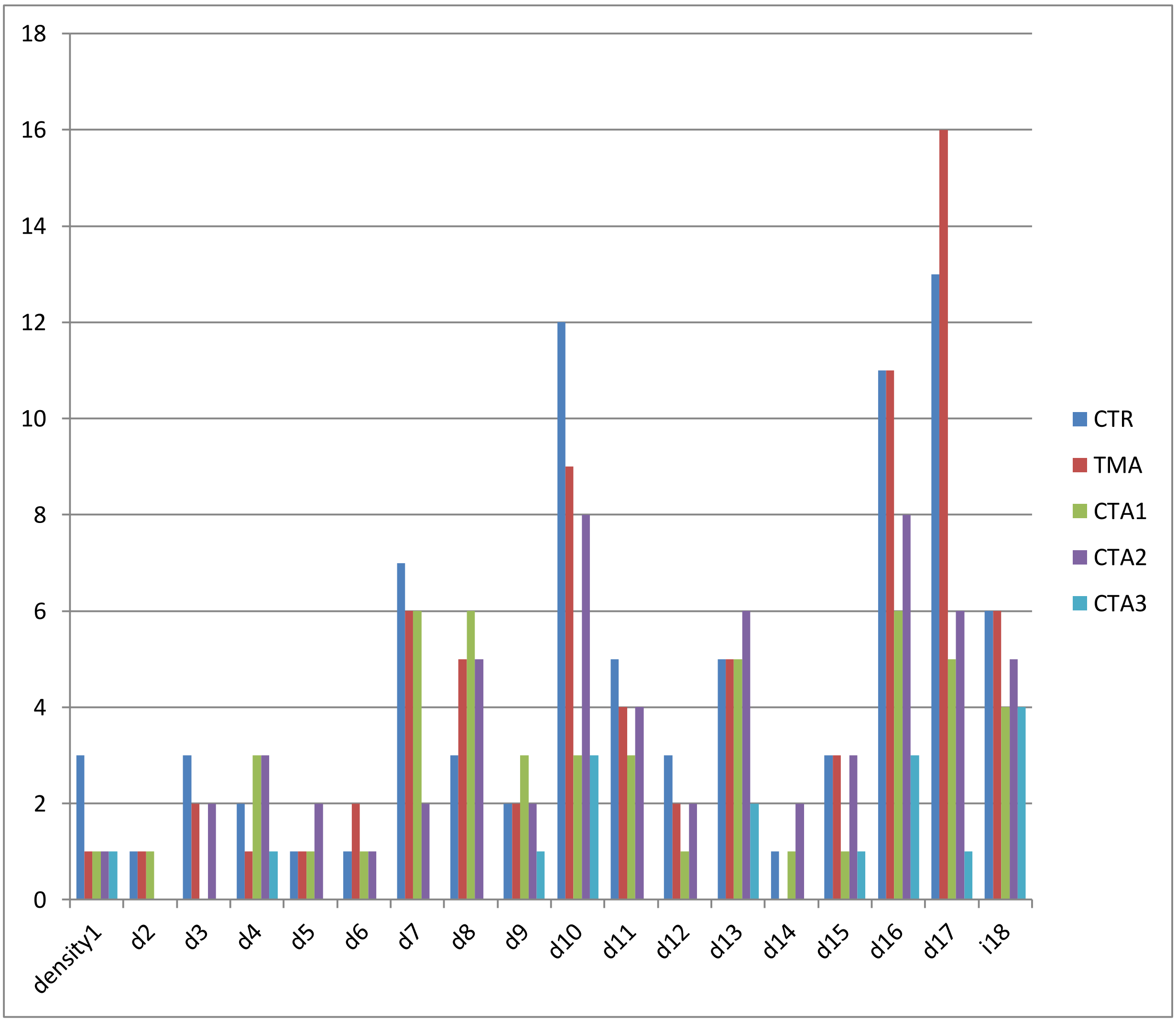
Table 3.11 Necessary data

$$Rs=1-\frac{6*(2-3)^2+(1-1,5)^2+0+0+(3-1,5)^2+0}{6*35}=0,9$$

After the calculation were obtained the results about density in each sector, that were represented in a graphs. (Graph 3.1, Graph 3.2)



Graph 3.1 .Expected workload on sectors based on density criteria according to expert data (5-the highest,0-the lowest)



Graph 3.2. Practical density at the sectors, based on Flight Radar 24 data

The obtained results were ranged with the criteria of flights intensity in the sector.

Expert 1 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0,5	1	1	1	1	4,5	1,5
TMA	0,5		1	1	1	1	4,5	1,5
CTA1	0	0		0,5	1	1	2,5	3,5
CTA2	0	0	0,5		1	1	2,5	3,5
CTA3	0	0	0	0		1	1	5
CTA4	0	0	0	0	0		0	6

Table 3.12 Matrix of individual preferences of Expert 1

Expert 2 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0	1	1	0,5	0,5	3	2
TMA	1		1	1	1	1	5	1
CTA1	0	0		0,5	1	1	2,5	3
CTA2	0	0	0,5		0	1	1,5	5
CTA3	0,5	0	0	1		1	2,5	4
CTA4	0,5	0	0	0	0		0,5	6

Table 3.13 Matrix of individual preferences of Expert 2

Expert 3 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0,5	1	0,5	1	0,5	3,5	2
TMA	0,5		1	1	1	1	4,5	1
CTA1	0	0		0,5	1	0,5	2	4,5
CTA2	0,5	0	0,5		1	1	3	3
CTA3	0	0	0	0		0	0	6
CTA4	0,5	0	0,5	0	1		2	4,5

Table 3.14 Matrix of individual preferences of Expert 3

Expert 4 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0	0,5	0,5	1	1	3	2,5
TMA	1		1	0,5	1	1	4,5	1
CTA1	0,5	0		0,5	1	0,5	2,5	4
CTA2	0,5	0,5	0,5		1	0,5	3	2,5
CTA3	0	0	0	0		1	1	5,5
CTA4	0	0	0,5	0,5	0		1	5,5

Table 3.15 Matrix of individual preferences of Expert 4

Expert 5 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0	0,5	1	1	1	3,5	2
TMA	1		1	1	0,5	1	4,5	1
CTA1	0,5	0		0,5	0	1	2	4
CTA2	0	0	0,5		0	1	1,5	5
CTA3	0	0,5	1	1		0,5	3	3
CTA4	0	0	0	0	0,5		0,5	6

Table 3.16 Matrix of individual preferences of Expert 5

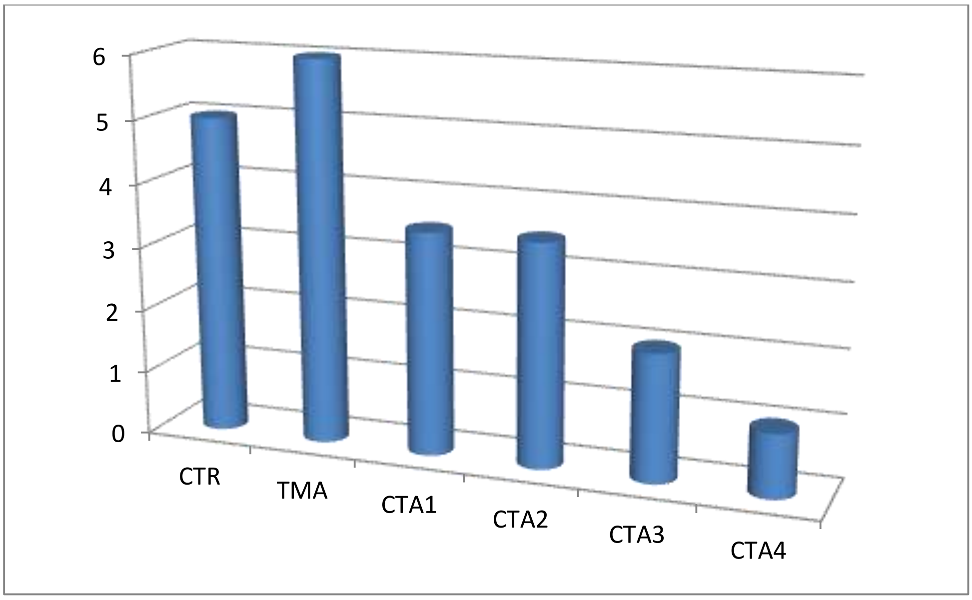
Expert 6 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0	1	1	0,5	1	3,5	2
TMA	1		1	1	1	1	5	1
CTA1	0	0		0,5	1	1	2,5	3,5
CTA2	0	0	0,5		1	1	2,5	3,5
CTA3	0,5	0	0	0		0	0,5	6
CTA4	0	0	0	0	1		1	5

Table 3.17. Matrix of individual preferences of expert 6

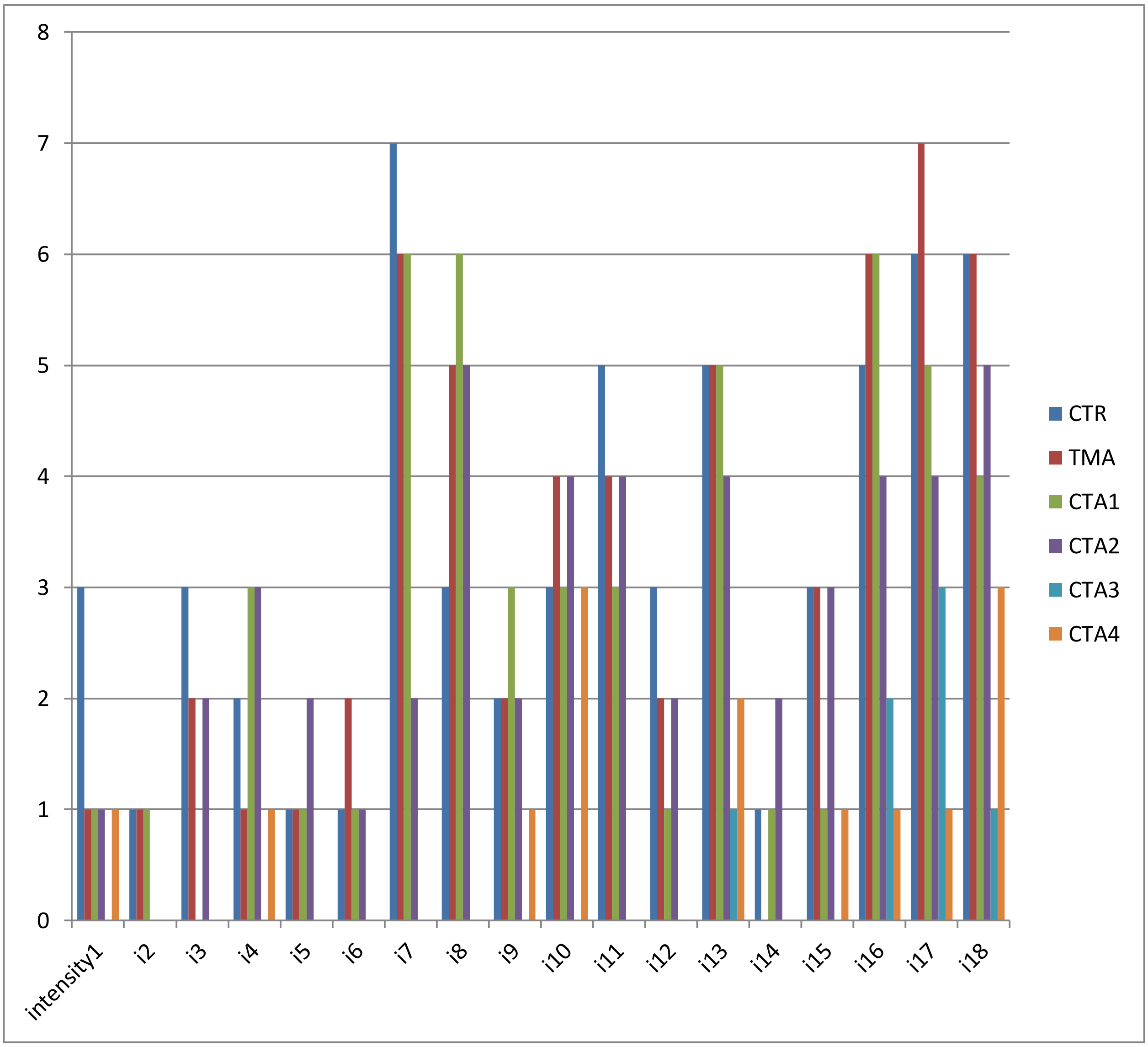
Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4
Expert 1	1,5	1,5	3,5	3,5	5	6

Expert 2	2	1	3	5	4	6
Expert 3	2	1	4,5	3	6	4,5
Expert 4	2,5	1	4	2,5	5,5	5,5
Expert 5	2	1	4	5	3	6
Expert 6	2	1	3,5	3,5	6	5
Rav	2	1,083333	3,75	3,75	4,916667	5,5
D	0,083333	0,034722	0,229167	0,895833	1,201389	0,333333
SqDev	0,316228	0,204124	0,524404	1,036822	1,200694	0,632456
Variation Coefficient	0,158114	0,188422	0,139841	0,276486	0,244209	0,114992
R	2	1	3,5	3,5	5	6
W	0,840722					
χф2	24,44887>11,0705					
Rs	0,728571					

Table 3.18 Matrix of group preferences on intensity criteria



Graph 3.3. Expected intensity according to experts data



Graph 3.4. Practical intensity according to the system data

The obtained results were ranged with the criteria of regular flights amount in the sector.(Amount of regular flights flying via the controlled airspace), were seen the prior routes to Hurgada and Sharm el Sheikh airport. (Table 3.19 – Table 3.24)

Expert 1 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0,5	0,5	1	1	1	4	2,5
TMA	0,5		0,5	1	1	1	4	2,5
CTA1	0,5	0,5		1	1	1	4	2,5
CTA2	0	0	0		1	1	2	4
CTA3	0	0	0	0		0,5	0,5	5,5
CTA4	0	0	0	0	0,5		0,5	5,5

Table 3.19 Matrix of individual preferences of Expert 1

Expert 2 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0,5	1	1	1	1	4,5	1,5
TMA	0,5		1	1	1	1	4,5	1,5
CTA1	0	0		0,5	1	1	2,5	4
CTA2	0	0,5	0,5		1	1	3	3
CTA3	0	0	0	0		0,5	0,5	5,5
CTA4	0	0	0	0	0,5		0,5	5,5

Table 3.20 Matrix of individual preferences of Expert 2

Expert 3 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0,5	1	1	1	1	4,5	1,5
TMA	0,5		1	1	1	1	4,5	1,5
CTA1	0	0		1	1	1	3	3
CTA2	0	0	0		1	1	2	4
CTA3	0	0	0	0		1	1	5

CTA4	0	0	0	0	0		0	6

Table 3.21 Matrix of individual preferences of Expert 3

Expert 4 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0,5	1	1	1	1	4,5	1,5
TMA	0,5		1	1	1	1	4,5	1,5
CTA1	0	0		1	1	1	3	3
CTA2	0	0	0		1	1	2	4
CTA3	0	0	0	0		0,5	0,5	5,5
CTA4	0	0	0	0	0,5		0,5	5,5

Table 3.22 Matrix of individual preferences of Expert 4

Expert 5 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0,5	1	1	1	1	4,5	1,5
TMA	0,5		1	1	1	1	4,5	1,5
CTA1	0	0		0,5	1	1	2,5	3,5
CTA2	0	0	0,5		1	1	2,5	3,5
CTA3	0	0	0	0		0,5	0,5	5,5
CTA4	0	0	0	0	0,5		0,5	5,5

Table 3.23 Matrix of individual preferences of Expert 5

Expert 6 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0,5	1	1	1	1	4,5	1
TMA	0,5		0,5	1	1	1	4	2
CTA1	0	0,5		0,5	1	1	3	3
CTA2	0	0	0,5		1	1	2,5	4
CTA3	0	0	0	0		0,5	0,5	5,5
CTA4	0	0	0	0	0,5		0,5	5,5

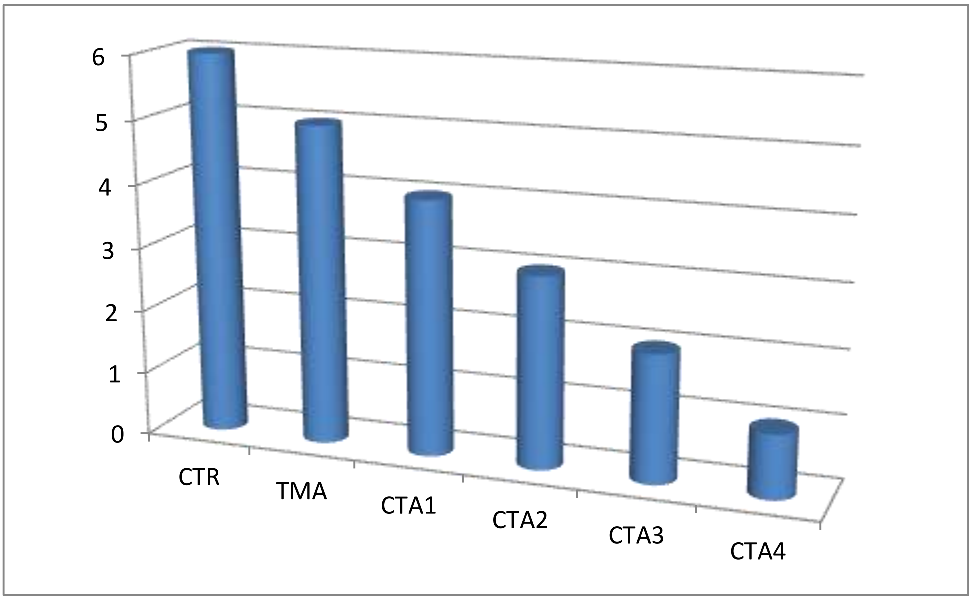
Table 3.24 Matrix of individual preferences of Expert 6

Was fulfilled the matrix of group preferences (Table 3.25)

Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4
Expert 1	2,5	2,5	2,5	4	5,5	5,5
Expert 2	1,5	1,5	4	3	5,5	5,5
Expert 3	1,5	1,5	3	4	5	6
Expert 4	1,5	1,5	3	4	5,5	5,5
Expert 5	1,5	1,5	3,5	3,5	5,5	5,5
Expert 6	1	2	3	4	5,5	5,5
Rav	1,583333	1,75	3,166667	3,75	5,416667	5,583333
D	0,201389	0,145833	0,222222	0,145833	0,034722	0,034722
SqDev	0,491596	0,41833	0,516398	0,41833	0,204124	0,204124
Variation Coefficient	0,310482	0,239046	0,163073	0,111555	0,037684	0,03656
Rest	1	2	3	4	5	6
W	0,922466					
$\chi\phi^2$	25,72883>11,07050*					
R_S	0,913095					

Table 3.25.Matrix of group preferences

Graphs of regular flights amount in sector was built (Graph 3.5)



Graph 3.5. Expected amount of regular flights at sector (based on expert opinion)

The obtained results were ranged with the criteria of flights safety in the sector.(How many incidents in the controlled airspace part were happened)(Table 3.26). The data about this criteria is better to analyse with a method of full expert group (33+ people) because of human factor, that have a strong influence on answering and lack of information about the incidents.

Expert 1 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0,5	0,5	1	0,5	0,5	3	2,5
TMA	0,5		0,5	0	0	0	1	6
CTA1	0,5	0,5		0,5	0,5	0,5	2,5	4,5
CTA2	0	1	0,5		0,5	0,5	2,5	4,5
CTA3	0,5	1	0,5	0,5		0,5	3	2,5
CTA4	0,5	1	0,5	0,5	0,5		3	2,5

Table 3.26 Matrix of individual preferences of Expert 1

Expert 2 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0	0	0	0,5	1	1,5	5
TMA	1		0	0	0	0	1	6

CTA1	1	1		0,5	0,5	0,5	3,5	2
CTA2	1	1	0,5		0,5	0	3	3,5
CTA3	0,5	1	0,5	0,5		0,5	3	3,5
CTA4	1	1	0,5	1	0,5		4	1

Table 3.27 Matrix of individual preferences of Expert 2

Expert 3 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0,5	0	0	0,5	1	2	5
TMA	0,5		0	0	0	0	0,5	6
CTA1	1	1		0,5	0,5	0,5	3,5	2
CTA2	1	1	0,5		0,5	0	3	3,5
CTA3	0,5	1	0,5	0,5		0,5	3	3,5
CTA4	1	1	0,5	1	0,5		4	1

Table 3.28 Matrix of individual preferences of Expert 3

Expert 4 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0,5	0,5	0,5	0,5	1	3	2,5
TMA	0,5		0	0	0	0	0,5	6
CTA1	0,5	1		0,5	0,5	0	2,5	4,5
CTA2	0,5	1	0,5		0,5	0	2,5	4,5
CTA3	0,5	1	0,5	0,5		0,5	3	2,5
CTA4	1	1	1	1	0,5		4,5	1

Table 3.29 Matrix of individual preferences of Expert 4

Expert 5 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		1	0,5	0,5	1	0	3	3,5
TMA	0		0	0	0	0	0	6
CTA1	0,5	1		0,5	0,5	0,5	3	3,5
CTA2	0,5	1	0,5		0,5	0	2,5	5

CTA3	1	1	0,5	0,5		1	4	1
CTA4	1	1	0,5	1	0		3,5	2

Table 3.30 Matrix of individual preferences of Expert 5

Expert 6 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0	0,5	1	0,5	0	2	4
TMA	1		0	0	0	0	1	6
CTA1	0,5	1		0,5	0,5	0	2,5	3
CTA2	0	1	0,5		0	0	1,5	5
CTA3	0,5	1	0,5	1		0	3	2
CTA4	1	1	1	1	1		5	1

Table 3.31 Matrix of individual preferences of Expert 6

Matrix of group preferences (Table 3.32)

Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4
Expert 1	2,5	6	4,5	4,5	2,5	2,5
Expert 2	5	6	2	3,5	3,5	1
Expert 3	5	6	2	3,5	3,5	1
Expert 4	2,5	6	4,5	4,5	2,5	1
Expert 5	3,5	6	3,5	5	1	2
Expert 6	4	6	3	5	2	1
Rav	3,75	6	3,25	4,333333	2,5	1,416667

D	1,0625	0	1,0625	0,388889	0,75	0,368056
SqDev	1,129159	0	1,129159	0,68313	0,948683	0,66458
Variation Coefficient	0,301109	0	0,347434	0,157645	0,379473	0,469115
Rest	4	6	3	5	2	1
W	0,766967					
$\chi\text{ф}^2$	21,39177>11,07050*					
R_S	0,846429					

Table 3.32 Matrix of group preferences

The obtained results were ranged with the criteria of capacity in the sector.(How many flights can be potentially provided with ATCS). This criteria is also better to analyse in a wide group because of human factor influence. (Table 3.33 – Table 3.38)

Expert 1 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	sumr	R
CTR		0,5	0	0	0,5	0,5	1,5	5
TMA	0,5		0	0	0	0	0,5	6
CTA1	1	1		0	0,5	1	3,5	2
CTA2	1	1	1		0,5	1	4,5	1
CTA3	0,5	1	0,5	0,5		0,5	3	3
CTA4	0,5	1	0	0,5	0,5		2,5	4

Table 3.33 Matrix of individual preferences of expert 1

Expert 2 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0,5	0,5	0	0,5	0	1,5	5

TMA	0,5		0	0	0	0	0,5	6
CTA1	0,5	1		0	0,5	0	2	4
CTA2	1	1	1		0	0	3	3
CTA3	0,5	1	0,5	1		0,5	3,5	2
CTA4	1	1	1	1	0,5		4,5	1

Table 3.34 Matrix of individual preferences of expert 2

Expert 3 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0,5	0,5	0	0	0	1	5
TMA	0,5		0	0	0	0	0,5	6
CTA1	0,5	1		0	0,5	0	2	4
CTA2	1	1	1		0	0	3	3
CTA3	1	1	0,5	1		0,5	4	2
CTA4	1	1	1	1	0,5		4,5	1

Table 3.35 Matrix of individual preferences of expert 3

Expert 4 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0,5	0,5	0	0,5	0	1,5	5
TMA	0,5		0	0	0	0	0,5	6
CTA1	0,5	1		0	0,5	0	2	4
CTA2	1	1	1		0	0	3	3
CTA3	0,5	1	0,5	1		0,5	3,5	2
CTA4	1	1	1	1	0,5		4,5	1

Table 3.36 Matrix of individual preferences of expert 4

Expert 5 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0,5	0,5	0	0,5	0	1,5	5
TMA	0,5		0	0	0	0	0,5	6
CTA1	0,5	1		0	0,5	0	2	4

CTA2	1	1	1		1	1	5	1
CTA3	0,5	1	1	0		1	3,5	3
CTA4	1	1	1	1	0		4	2

Table 3.37 Matrix of individual preferences of expert 5

Expert 6 results								
Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4	Sumr	R
CTR		0,5	0,5	0	0,5	0	1,5	5
TMA	0,5		0	0	0	0	0,5	6
CTA1	0,5	1		0	0,5	0	2	4
CTA2	1	1	1		0	0	3	3
CTA3	0,5	1	0,5	1		0,5	3,5	2
CTA4	1	1	1	1	0,5		4,5	1

Table 3.38 Matrix of individual preferences of Expert 6

Matrix of group preferences (Table 3.39)

Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4
Expert 1	5	6	2	1	3	4
Expert 2	5	6	4	3	2	1
Expert 3	5	6	4	3	2	1
Expert 4	5	6	4	3	2	1
Expert 5	5	6	4	1	3	2
Expert 6	5	6	4	3	2	1
Rav	5	6	3,66666	2,33333	2,33333	1,66666

			7	3	3	7
D	0	0	0,555556	0,888889	0,222222	1,222222
SqDev	0	0	0,816497	1,032796	0,516398	1,21106
Variation Coefficient	0	0	0,222681	0,442627	0,221313	0,726636
Rest	5	6	4	2,5	2,5	1
W	0,834921					
$\chi\phi^2$	25,04762>11,07050*					
R_S	0,771429					

Table 3.39. Matrix of group preferences

To forecast the intensity and density within the sector, the data from the Flight Radar 24 were analysed with the Correlation-Regression method.

Intensity analysis:

- Within the CTR

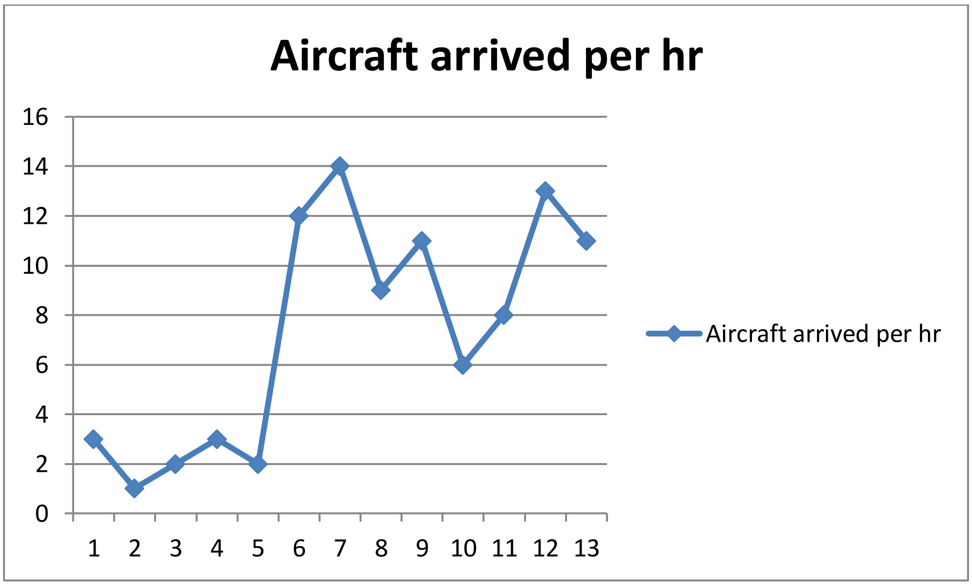
To make the intensity analysis were collected data about the traffic within the CTR. The following table (Table 3.40) contains the data about the aircraft that appeared within the CTR and time periods, within which these aircraft appeared.

Enumeration of a time period	Time	Amount of aircraft arrived to an airspace part per unit of time
1	00.00-01.00	3
2	01.01-02.00	1
3	02.01-03.00	2
4	03.00-04.00	3
5	04.00-05.00	2

6	05.00-06.00	12
7	06.00-07.00	14
8	07.00-08.00	9
9	08.00-09.00	11
10	09.00-10.00	6
11	10.00-11.00	8
12	11.00-12.00	13
13	12.00-13.00	11

Table 3.40 Data mining about traffic within the CTR

On basis of the collected data was obtained a graph of intensity behavior. (Graph 3.5)



Graph 3.5 Aircraft arrived within CTR

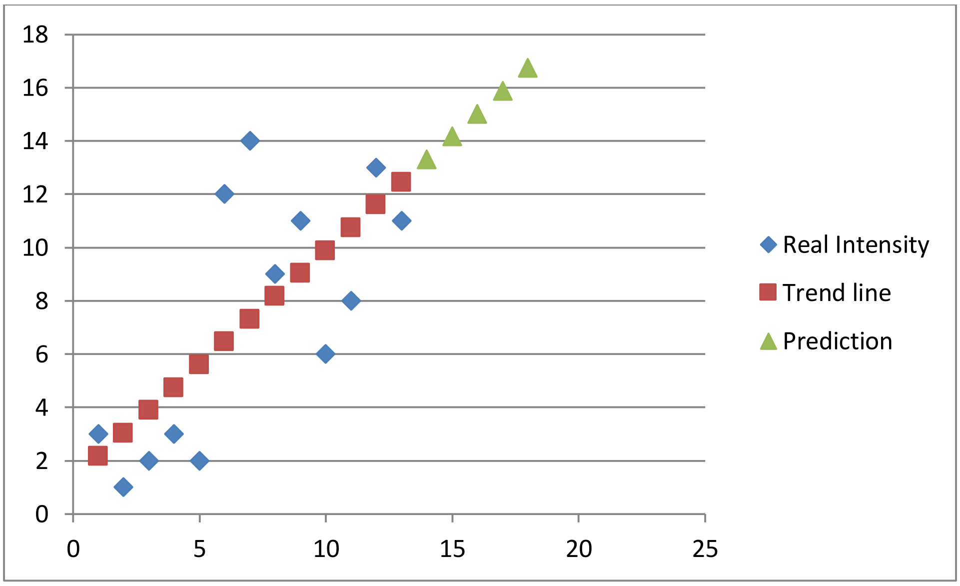
Using the Formulae 1, obtained the correlation coefficient r=0,71 (strong positive correlation).

To build the line of prediction, we need b0 and b1 coefficients from Formulae 3,4. For this we need make another calculations. (Figure 3.11)

	X	Y	X^2	Y^2	xy	x+y	(x+y)^2	x-xav	y-yav	(x-xav)^2	(y-yav)^2	(x-xav)*(y-yav)
	1	3	1	9	3	4	16	1	3	1	9	3
	2	1	4	1	2	3	9	2	1	4	1	2
	3	2	9	4	6	5	25	3	2	9	4	6
	4	3	16	9	12	7	49	4	3	16	9	12
	5	2	25	4	10	7	49	5	2	25	4	10
	6	12	36	144	72	18	324	6	12	36	144	72
	7	14	49	196	98	21	441	7	14	49	196	98
	8	9	64	81	72	17	289	8	9	64	81	72
	9	11	81	121	99	20	400	9	11	81	121	99
	10	6	100	36	60	16	256	10	6	100	36	60
	11	8	121	64	88	19	361	11	8	121	64	88
	12	13	144	169	156	25	625	12	13	144	169	156
	13	11	169	121	143	24	576	13	11	169	121	143
Sum	91	95	819	959	821	186	3420	91	95	819	959	821
xav	7	7,307692										

Figure 3.11 Additional calculations to obtain the coefficients for the trend line

After usage of data from the Figure 16,were obtained b0=1,3;b1=0,86. So the trend line will have a view of line y=0,86x+1,3.(Graph 3.6)



Graph 3.6 Line of intensity peak prediction within the CTR

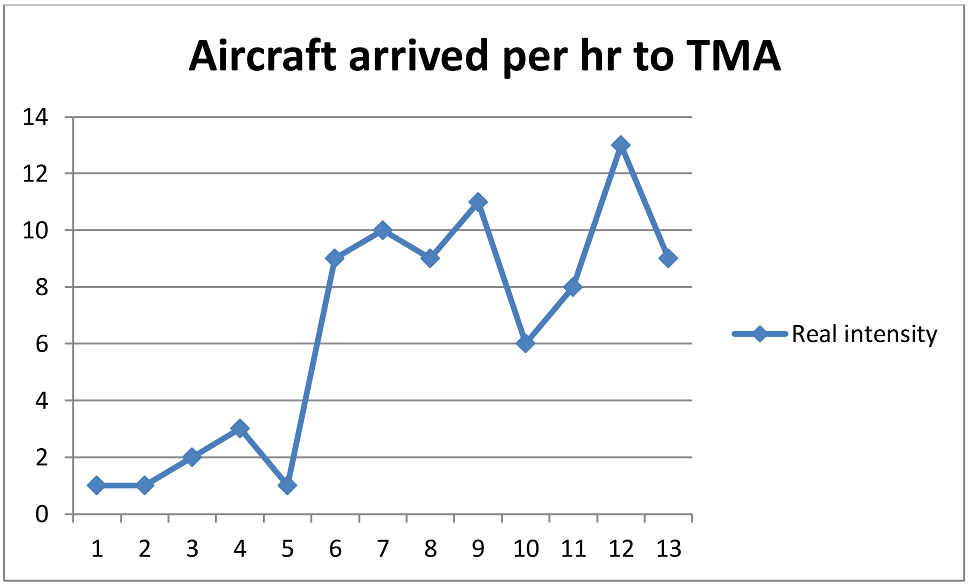
- Analysis of traffic within the TMA (Table 3.41)

Moment of time	Amount of aircraft
1	1
2	1
3	2
4	3
5	1
6	9
7	10
8	9
9	11

10	6
11	8
12	13
13	9

Table 3.41 Data about flights within TMA

Using the data about flights amount in the sector was built a graph of traffic behavior within the TMA. (Graph 3.7)



Graph 3.7 Intensity within TMA

Using the Formula 1, obtained correlation coefficient r=0,8.

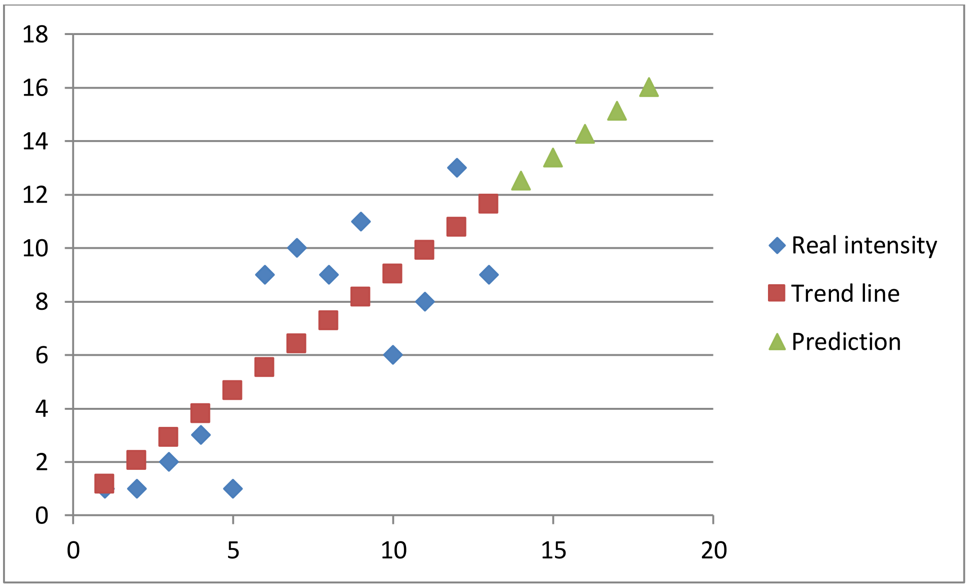
To build the line of prediction, we need b0 and b1 coefficients from Formulae 3,4.

For this we need make another calculations. (Figure 3.12)

	X	Y	X^2	Y^2	xy	x+y	(x+y)^2	x-xav	y-yav	(x-xav)^2	(y-yav)^2	(x-xav)*(y-yav)
	1	1	1	1	1	2	4	-6	-5,38462	36	28,99408	32,30769
	2	1	4	1	2	3	9	-5	-5,38462	25	28,99408	26,92308
	3	2	9	4	6	5	25	-4	-4,38462	16	19,22485	17,53846
	4	3	16	9	12	7	49	-3	-3,38462	9	11,45562	10,15385
	5	1	25	1	5	6	36	-2	-5,38462	4	28,99408	10,76923
	6	9	36	81	54	15	225	-1	2,615385	1	6,840237	-2,61538
	7	10	49	100	70	17	289	0	3,615385	0	13,07101	0
	8	9	64	81	72	17	289	1	2,615385	1	6,840237	2,615385
	9	11	81	121	99	20	400	2	4,615385	4	21,30178	9,230769
	10	6	100	36	60	16	256	3	-0,38462	9	0,147929	-1,15385
	11	8	121	64	88	19	361	4	1,615385	16	2,609467	6,461538
	12	13	144	169	156	25	625	5	6,615385	25	43,76331	33,07692
	13	9	169	81	117	22	484	6	2,615385	36	6,840237	15,69231
Sum	91	83	819	749	742	174	3052	0	-1,1E-14	182	219,0769	161
xav	7	6,384615										

Figure 3.12 Additional calculations to obtain coefficients for a trend line of TMA intensity

After the additional data analysis and usage formulas 3,4 were obtained coefficients b0=0, b1=1.So the trend line has the view of straight line y=x (Graph 3.9)



Graph 3.9 Line of intensity peak prediction within TMA

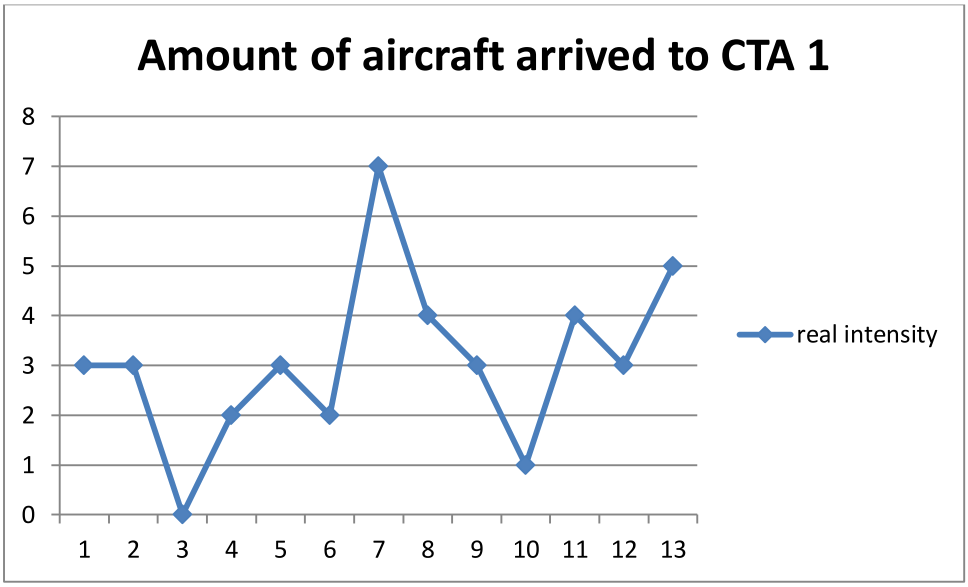
- Traffic analysis within the CTA 1(BVL)(Table 3.42),CTA 2(BVO)(Table 3.43),CTA 3 (BVC)(Table 3.44), CTA 4 (BVN+BVM) (Table 3.45)

Moment of time	Amount of aircraft within CTA1
1	3
2	3
3	0
4	2
5	3
6	2
7	7
8	4
9	3
10	1

11	4
12	3
13	5

Table 3.42 *Data mining about traffic within CTA1*

Using the collected data, was built graph of traffic behavior within the CTA 1. (CTA Kyiv BVL) (Graph 3.10)



Graph 3.10. Intensity within CTA1

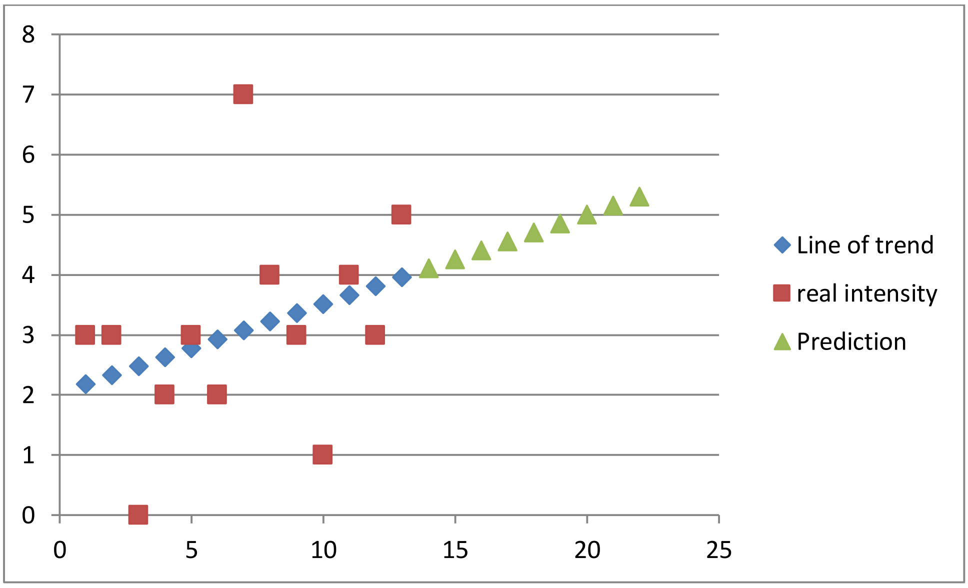
Using the formulae of correlation coefficient determination (Formulae 1), obtained the correlation coefficient r=0,32.

To build the line of prediction, we need b0 and b1 coefficients from Formulae 3,4. For this we need make another calculations. (Figure 3.13)

	X	Y	X^2	Y^2	xy	x+y	(x+y)^2	x-xav	y-yav	(x-xav)^2	(y-yav)^2	(x-xav)*(y-
	1	3	1	9	3	4	16	-6	-0,07692	36	0,005917	0,461538
	2	3	4	9	6	5	25	-5	-0,07692	25	0,005917	0,384615
	3	0	9	0	0	3	9	-4	-3,07692	16	9,467456	12,30769
	4	2	16	4	8	6	36	-3	-1,07692	9	1,159763	3,230769
	5	3	25	9	15	8	64	-2	-0,07692	4	0,005917	0,153846
	6	2	36	4	12	8	64	-1	-1,07692	1	1,159763	1,076923
	7	7	49	49	49	14	196	0	3,923077	0	15,39053	0
	8	4	64	16	32	12	144	1	0,923077	1	0,852071	0,923077
	9	3	81	9	27	12	144	2	-0,07692	4	0,005917	-0,15385
	10	1	100	1	10	11	121	3	-2,07692	9	4,313609	-6,23077
	11	4	121	16	44	15	225	4	0,923077	16	0,852071	3,692308
	12	3	144	9	36	15	225	5	-0,07692	25	0,005917	-0,38462
	13	5	169	25	65	18	324	6	1,923077	36	3,698225	11,53846
Sum	91	40	819	160	307	131	1593	0	0	182	36,92308	27
xav	7	3,076923										

Figure 3.13 Additional data necessary for calculation of trend line coefficients

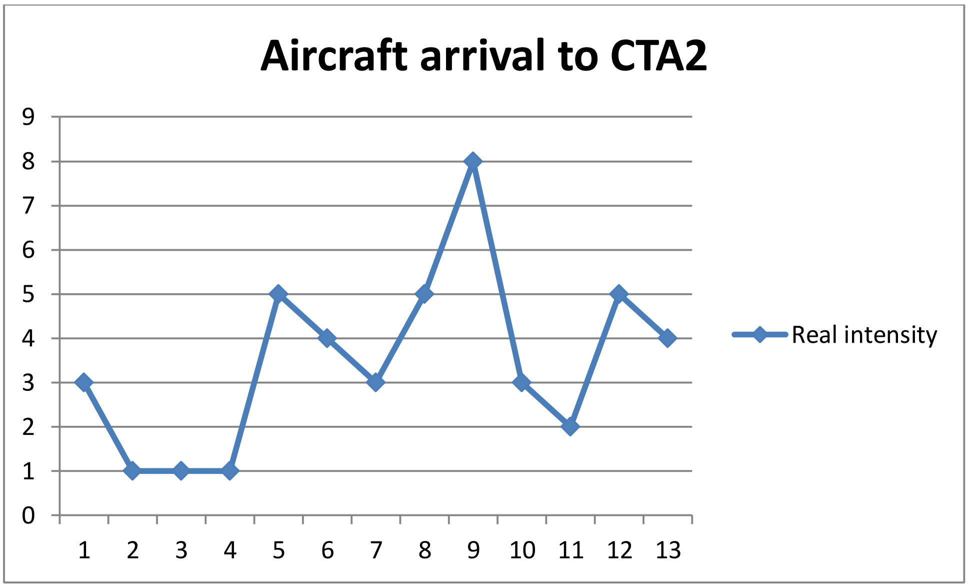
Using additional data from the table were calculated b0=2,038 and b1=0,14. So the trend line will have a view of a straight line y=0,14x+2,038. (Graph 3.11)



Graph 3.11.Line of intensity peak prediction within CTA1.

Moment of time	Amount of aircraft within CTA2
1	3
2	1
3	1
4	1
5	5
6	4
7	3
8	5
9	8
10	3
11	2
12	5
13	4

Table 3.43 Data about intensity within CTA2



Graph 3.12. Intensity within CTA2

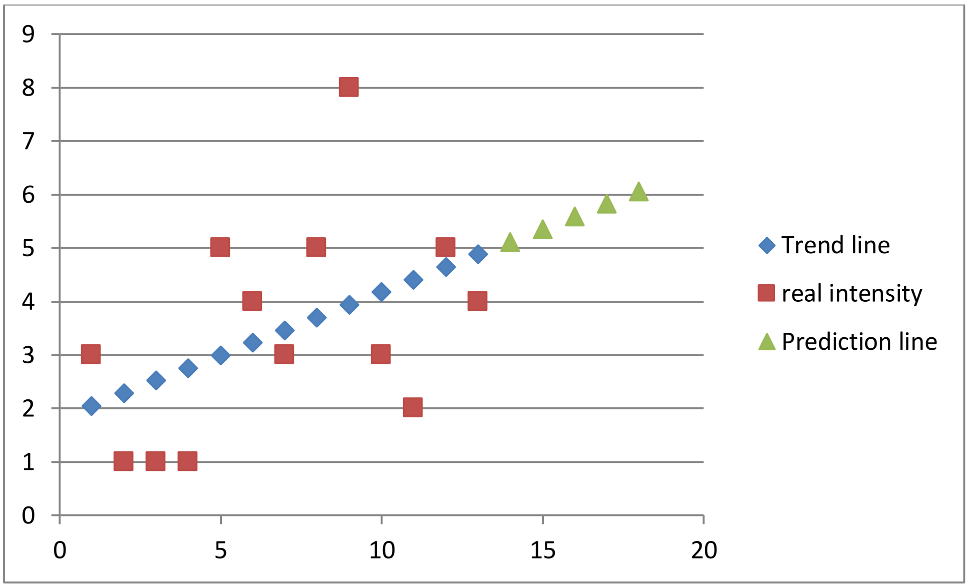
Obtained the correlation coefficient r=0,45.

To build the trend line, should be calculated coefficients b0 and b1, for this purpose need additional calculations. (Figure 3.14)

	X	Y	X^2	Y^2	xy	x+y	(x+y)^2	x-xav	y-yav	(x-xav)^2	(y-yav)^2	(x-xav)*(y-yav)
	1	3	1	9	3	4	16	1	3	1	9	3
	2	1	4	1	2	3	9	2	1	4	1	2
	3	1	9	1	3	4	16	3	1	9	1	3
	4	1	16	1	4	5	25	4	1	16	1	4
	5	5	25	25	25	10	100	5	5	25	25	25
	6	4	36	16	24	10	100	6	4	36	16	24
	7	3	49	9	21	10	100	7	3	49	9	21
	8	5	64	25	40	13	169	8	5	64	25	40
	9	8	81	64	72	17	289	9	8	81	64	72
	10	3	100	9	30	13	169	10	3	100	9	30
	11	2	121	4	22	13	169	11	2	121	4	22
	12	5	144	25	60	17	289	12	5	144	25	60
	13	4	169	16	52	17	289	13	4	169	16	52
Sum	91	45	819	205	358	136	1740	91	45	819	205	358
	7	3,461538										

Figure 3.14 Additional calculations necessary for trend line coefficients

Using the additional calculations obtained trend line coefficients b0=1,8 and b1=0,23. The line of trend will have a view of a straight line y=1,8+0,23x. (Graph 3.13)



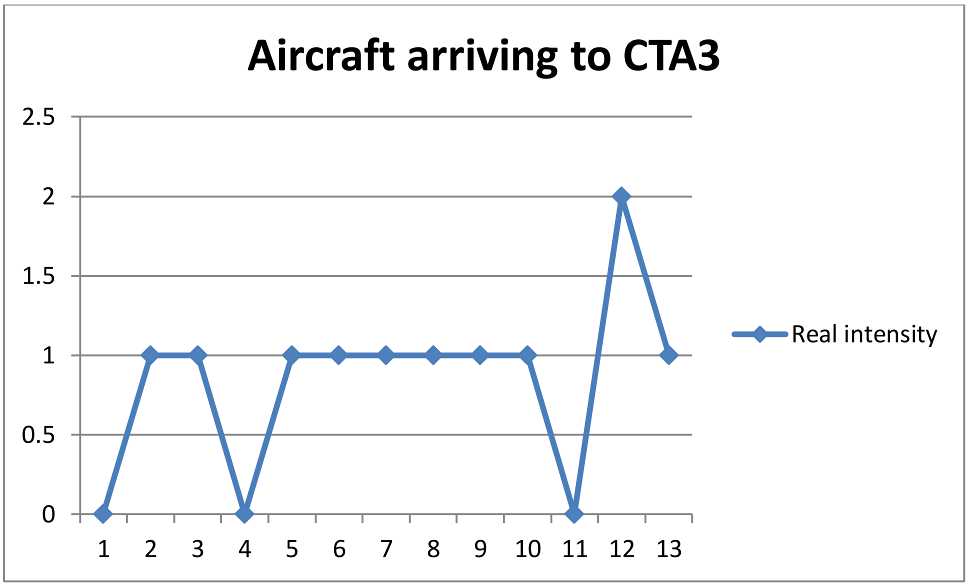
Graph 3.13. Line of intensity peak prediction within CTA2.

Moment of time	Amount of aircraft within CTA3
1	0
2	1
3	1
4	0
5	1
6	1
7	1
8	1
9	1
10	1
11	0
12	2
13	1

Table 3.44.Data about intensity within CTA3

Obtained correlation coefficient r=0,38.

Using the collected data was built a graph of traffic behavior within CTA3. (Graph 3.14)



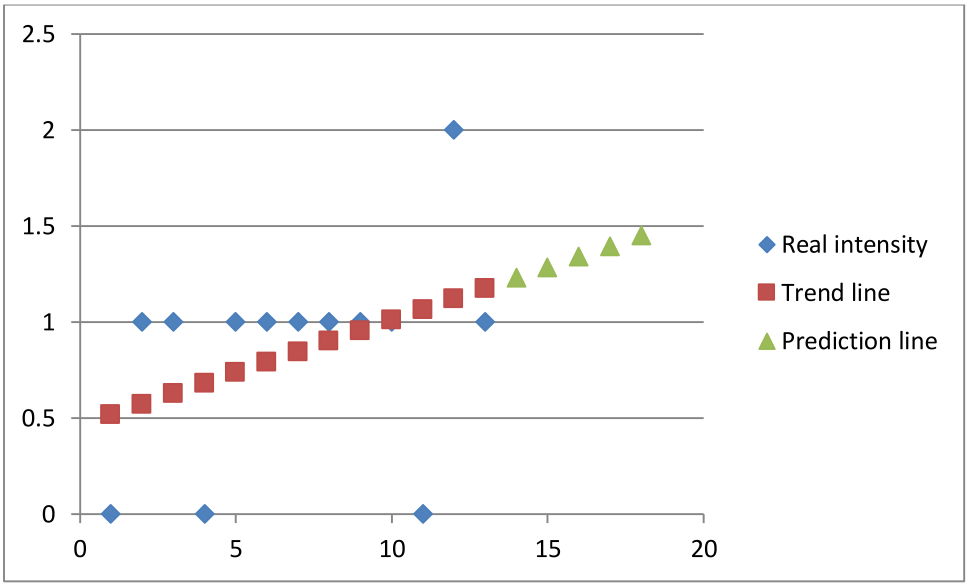
Graph 3.14. Intensity within CTA3

To build the trend line, should be calculated coefficients b0 and b1, for this purpose need additional calculations. (Figure 3.15)

	X	Y	X^2	Y^2	xy	x+y	(x+y)^2	x-xav	y-yav	(x-xav)^2	(y-yav)^2	(x-xav)*(y-yav)
	1	0	1	0	0	1	1	-6	-0,84615	36	0,715976	5,076923
	2	1	4	1	2	3	9	2	1	4	1	2
	3	1	9	1	3	4	16	3	1	9	1	3
	4	0	16	0	0	4	16	4	0	16	0	0
	5	1	25	1	5	6	36	5	1	25	1	5
	6	1	36	1	6	7	49	-1	0,153846	1	0,023669	-0,15385
	7	1	49	1	7	8	64	6	1	36	1	6
	8	1	64	1	8	9	81	6	1	36	1	6
	9	1	81	1	9	10	100	6	0	36	0	0
	10	1	100	1	10	11	121	6	0	36	0	0
	11	0	121	0	0	11	121	6	-4	36	16	-24
	12	2	144	4	24	14	196	6	1	36	1	6
	13	1	169	1	13	14	196	6	-1	36	1	-6
Sum	91	11	819	13	87	102	1006	83	10	343	23,73964	2,923077
	7	0,846154										

Figure 3.15 Additional data for calculation of trend line coefficients

Calculated coefficients b0=0,46; b1=0,06. So the trend line will have a view of a straight line y=0,46+0,06x. (Graph 3.15)



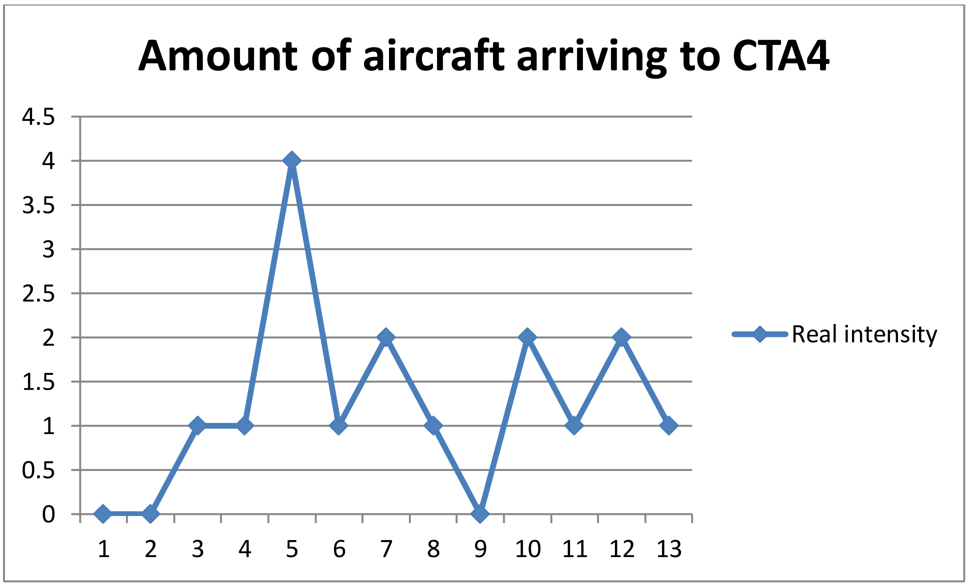
Graph 3.15. Line of intensity peak prediction within CTA3.

Moment of time	Amount of aircraft within CTA4
1	0
2	0
3	1
4	1
5	4
6	1
7	2
8	1
9	0
10	2
11	1
12	2
13	1

Table 3.45 Data about the intensity within CTA4

Obtained correlation coefficient r=0,21.

Using the collected data was built a graph of traffic behavior within CTA4. (Graph 3.16)



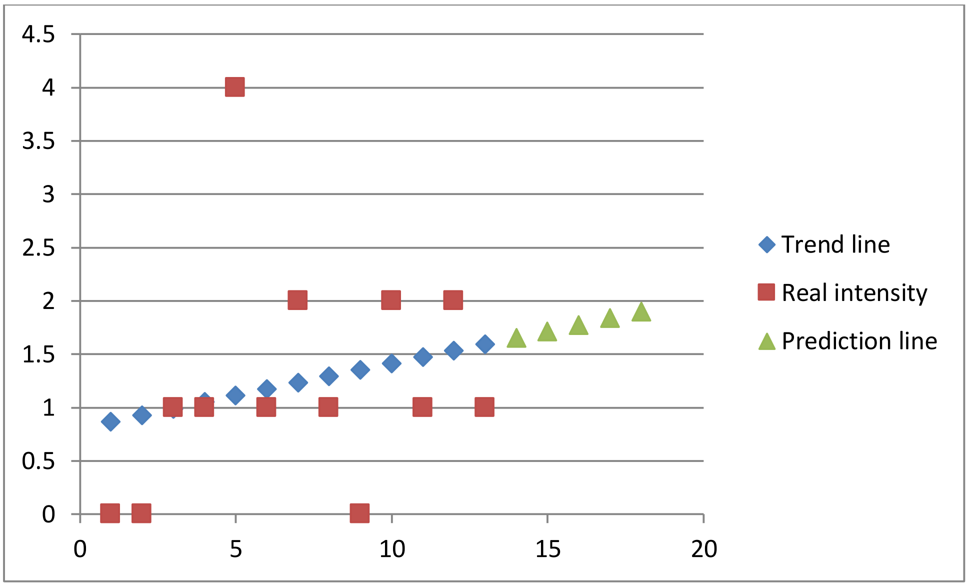
Graph 3.16. Intensity within the CTA4

To build the trend line, should be calculated coefficients b0 and b1, for this purpose need additional calculations. (Figure 3.16)

	X	Y	X^2	Y^2	xy	x+y	(x+y)^2	x-xav	y-yav	(x-xav)^2	(y-yav)^2	(x-xav)*(y-yav)
	1	0	1	0	0	1	1	1	0	1	0	0
	2	0	4	0	0	2	4	2	0	4	0	0
	3	1	9	1	3	4	16	3	1	9	1	3
	4	1	16	1	4	5	25	4	1	16	1	4
	5	4	25	16	20	9	81	5	4	25	16	20
	6	1	36	1	6	7	49	6	1	36	1	6
	7	2	49	4	14	9	81	7	2	49	4	14
	8	1	64	1	8	9	81	8	1	64	1	8
	9	0	81	0	0	9	81	9	0	81	0	0
	10	2	100	4	20	12	144	10	2	100	4	20
	11	1	121	1	11	12	144	11	1	121	1	11
	12	2	144	4	24	14	196	12	2	144	4	24
	13	1	169	1	13	14	196	13	1	169	1	13
Sum	91	16	819	34	123	107	1099	91	16	819	34	123
	7	1,230769										

Figure 3.16. Additional data for calculation of trend line coefficients

Calculated coefficients for the trend line b0=0,8 and b1=0,06. So the trend line will have a view of a straight line y=0,8+0,06x (Graph 3.17)



Graph 3.17. Line of intensity peak prediction within CTA4.

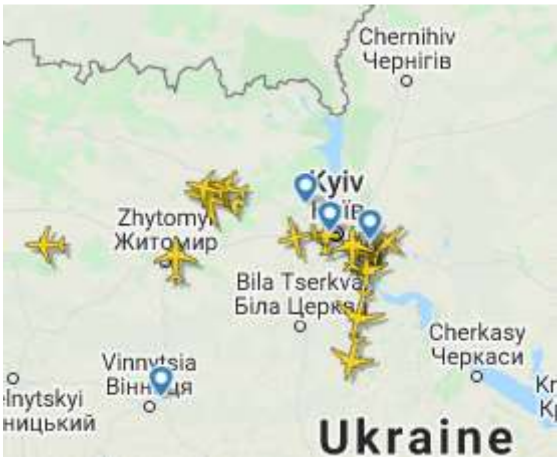


Figure 3.17 One from the peak intensities (8.20 am,16.11.2020)

CONCLUSION FROM THE CHAPTER 3

With expert methods were analysed sectors of controlled airspace. Using correlation and regression analysis were predicted the peak values of intensity. These methods can be used for the prediction of another criteria peaks: to make it, it is necessary to collect data about these criteria. Using the following data, the expert system of the sector workload estimation can be developed.

CHAPTER 4. EXPERT SYSTEM OF THE SECTOR WORKLOAD ESTIMATION

4.1 Expert systems

An expert system is a computer system that can partially substitute a human. These systems can make the decisions similar to the expert group. The expert systems successful usage in the decision-making process was proved in 1832, when were created the “intellectual machines”, that helped to designate the most suitable medicines, being based on patient sympthomatics.

Expert systems can be used for the decision making in non-formalized tasks. They can advice the users possible ways to act, make analysis, classify the requests, look for the decision. Main expert system characteristics is ability to save, collect and renew the tasks.

The most important ES part is a database. It contains the model of expert group behavior (facts and logical conclusions from these facts). Without the database the ES will be similar to “Wizard” program- a program that contains the forms for the fulfilling with the data.

The process of an ES action can be described like: USER send the request for ES via the user interface; SOLVING PART use the previously obtained data to give the USER information he interested in; the explanation is provided with the SUBSYSTEM OF EXPLANATION. (Figure 4.1)

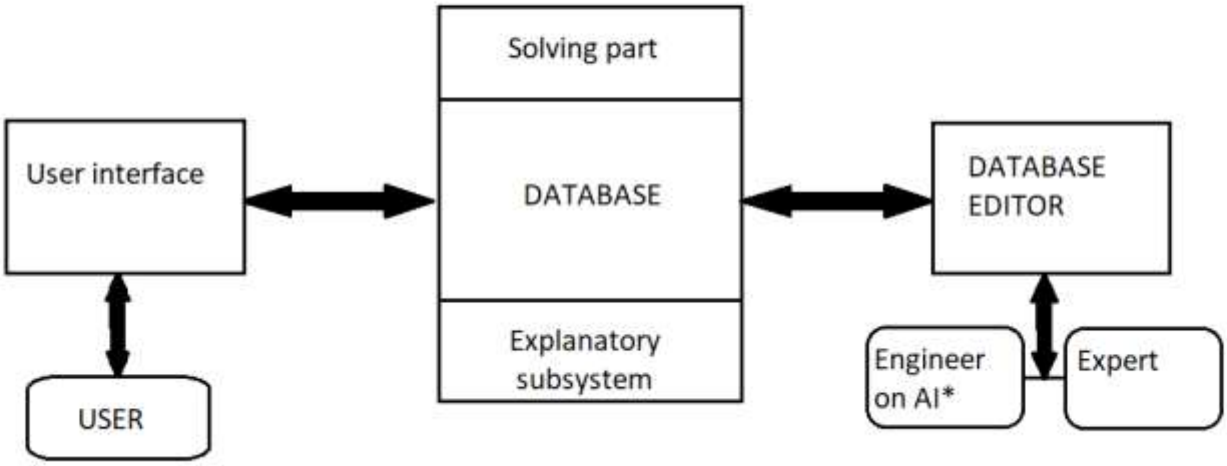


Figure 4.1 Expert system structure scheme

The ES structural blocks are:

- the Database intellectual editor that help the AI engineer (analyst) to edit the database; It contains the service tools that help the work with the DB;
- Database, that contains collected expert knowledge in a certain field; usually the statistical knowledge about the field of interest and rules (instructions) that can be applied to obtain the other facts;
- Solving part (output block), that make the decision like an expert, using the data from the DB;
- Explanatory subsystem, that help the user to see "How done it" and "Why done it". The "How done it" part contains all the steps from start to end with the references on knowledge from the DB, and the "Why done it" part is a one-step-back.
- User interface, that makes possible communication of ES and user;
- User;
- Engineer on AI.

4.1.2 Expert systems classification

The expert systems that are based on collected data, can be classify by:

-Task they can solve

-Connection with the real time

-Type of a computation system that was used for the ES development

-Compatibility with other programs (integration degree) (Figure 4.2)

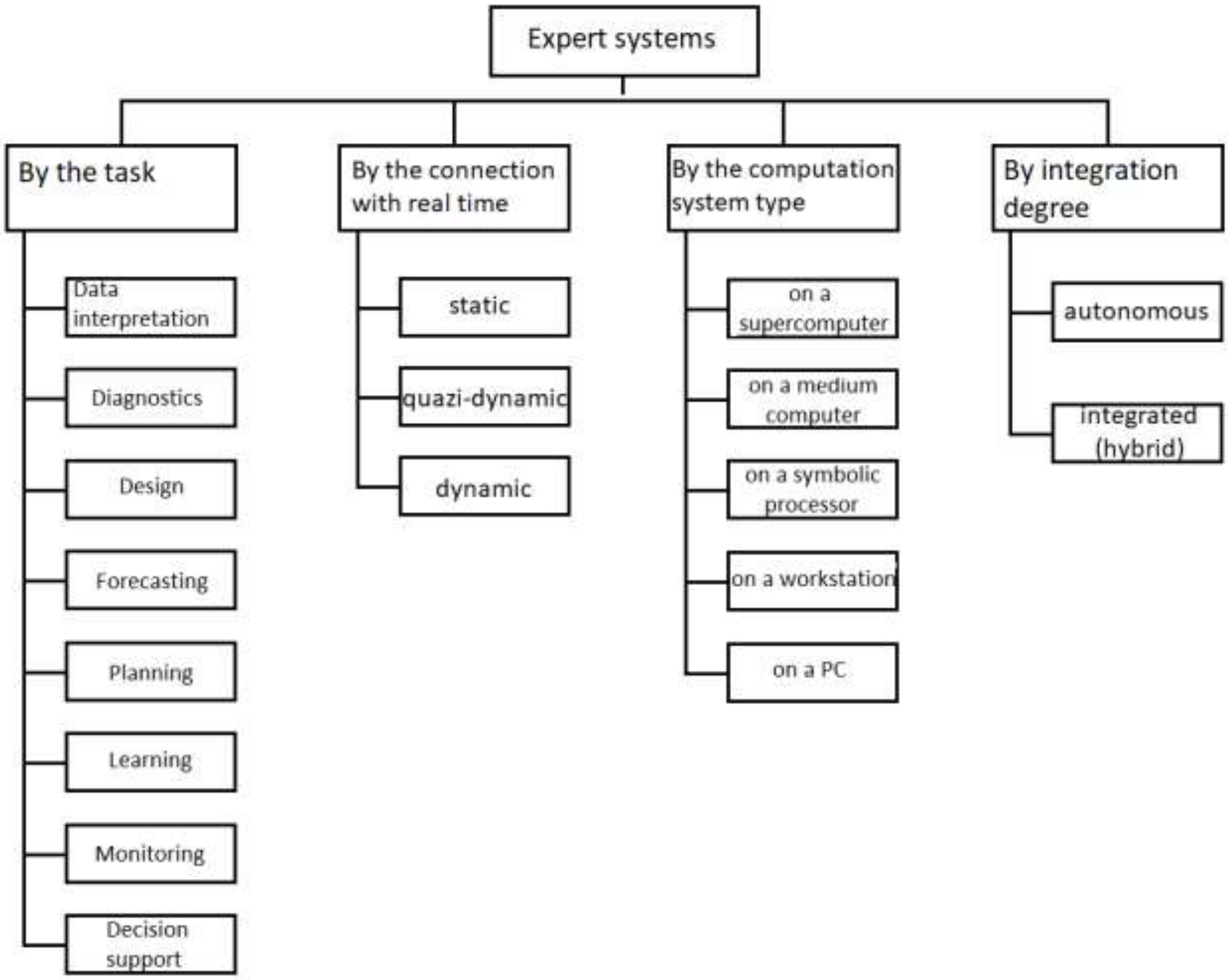


Figure 4.2 Expert systems classification

The ES can be used for solving the problems of data interpretation, diagnostics, design, planning, learning, monitoring and decision support.

Data interpretation is one from the traditional tasks of ES. It is a data meaning process, after which the results will be coordinated. Usually is implemented after the multifactor data analysis.

Diagnostics is comparison of an object of an investigation with the average characteristics and deviation detecting.

Monitoring is a permanent data interpretation in a real time mode and detecting the parameters deviation from the normal state.

Design is the object creation with the certain features. Under the design understood not only the final product of creativity, but also the way of its creation.

Forecasting allows to predict the appearance of the certain events, being based on analysis of available data.

Planning is finding of algorithm of actions of object, that can perform some function.

In learning purposes the ES can be implemented as diagnostics of the failures and recommendation of right solutions. They can accumulate data about the certain user and its usual mistakes and then are able to assist in these weaknesses removing, helping in necessary moment.

Decision support systems help to choose the right (logically) variant among the different ones.

The ES that are connected with time of event are divided onto the static, pseudo dynamic and dynamic.

The static systems are stable systems for the fields where the data doesn`t change with time.

The pseudo-dynamic systems interpret data that changes within the certain period of time.

The dynamic ES are real-time systems that usually connected with the high accuracy sensors.

On compatibility the systems can be autonomous and hybrid.

Autonomous systems are used when there is no need to implement such methods of data processing as modeling or calculations.

Hybrid systems is a complex of programs that aggregate the standard programs as mathematical statistics, linear programming or systems of databases ruling with the knowledge manipulation tools. It can be integrated environment for the decision making on basis of expert knowledge.

4.2 Prototype of the Expert System, analysing and predicting the workload on a sector

The developed expert system can be used for the data interpretation, diagnostics, forecasting, planning, learning and decision support. It is a quasi-dynamic hybrid system projected of PC. To use it, should be collected data about the expert opinions. The system will collect these data and use them to predict the future workload on a sector.

Also it should be collected data about flights amount to see the dynamics of a workload change and to make the quantitative calculations of future possible workload with the help of the correlation and regression analysis.

The collected data forms a database.

The database is divided onto two parts: Expert part (Figure 4.3) and Prediction part (Figure 4.4)

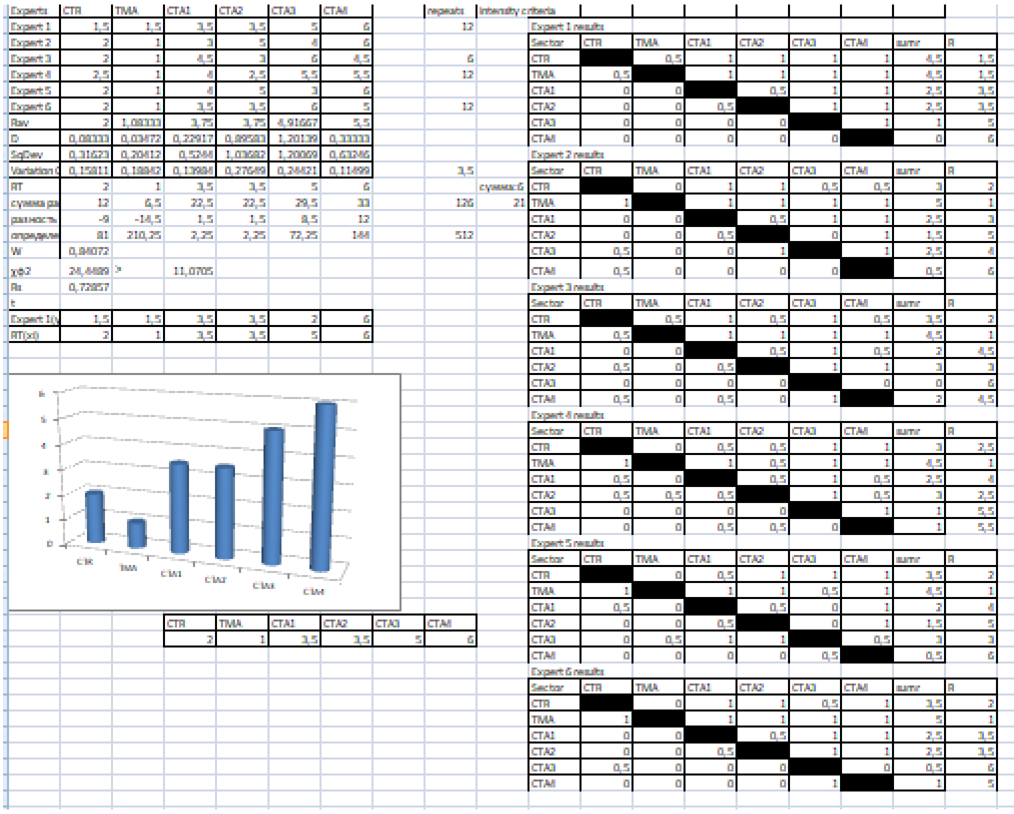


Figure 4.3 The ES part about expert opinions full view

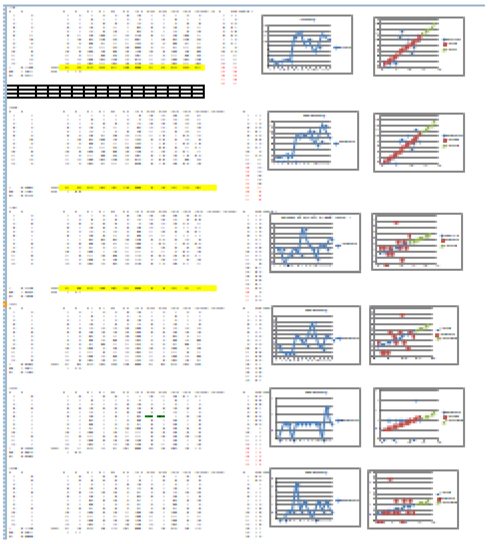


Figure 4.4 The ES part about prediction full view

Guide of usage:

1) Collection of information.

   Use the questionnaire and fulfill is with the expert marks 1, 0,5 and 0.

   Input the information about the ranks to the field, that is marked with arrow.

   Information is range the following way: the more sum in a row is (column left from the rank field), the higher a rank. Amount of experts and criteria can be widen.

   Input the information about amount of flights within the area to the field, that is marked with arrow.

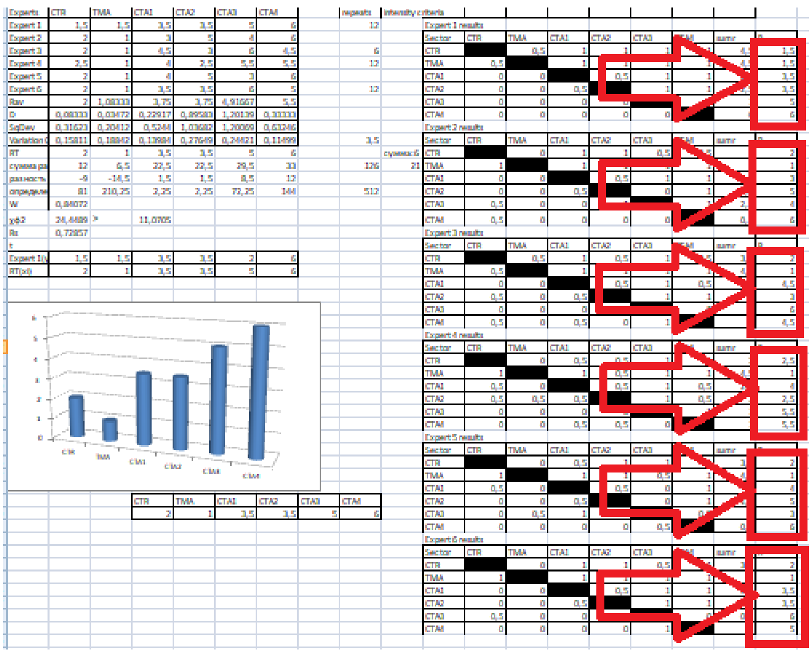


Figure 4.5 Placement of rank input

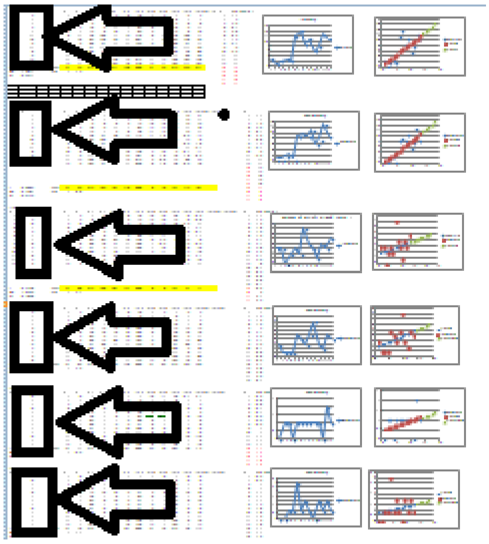


Figure 4.6 Placement of data about amount of flights input

2) Data processing

For the analysis of a sector workload, it should be made a procedure of re-ranking. Using the information from the field of average opinion of group about rank of a criteria, input the information about ranks to the field, that is marked with arrow. (Figure 4.7)

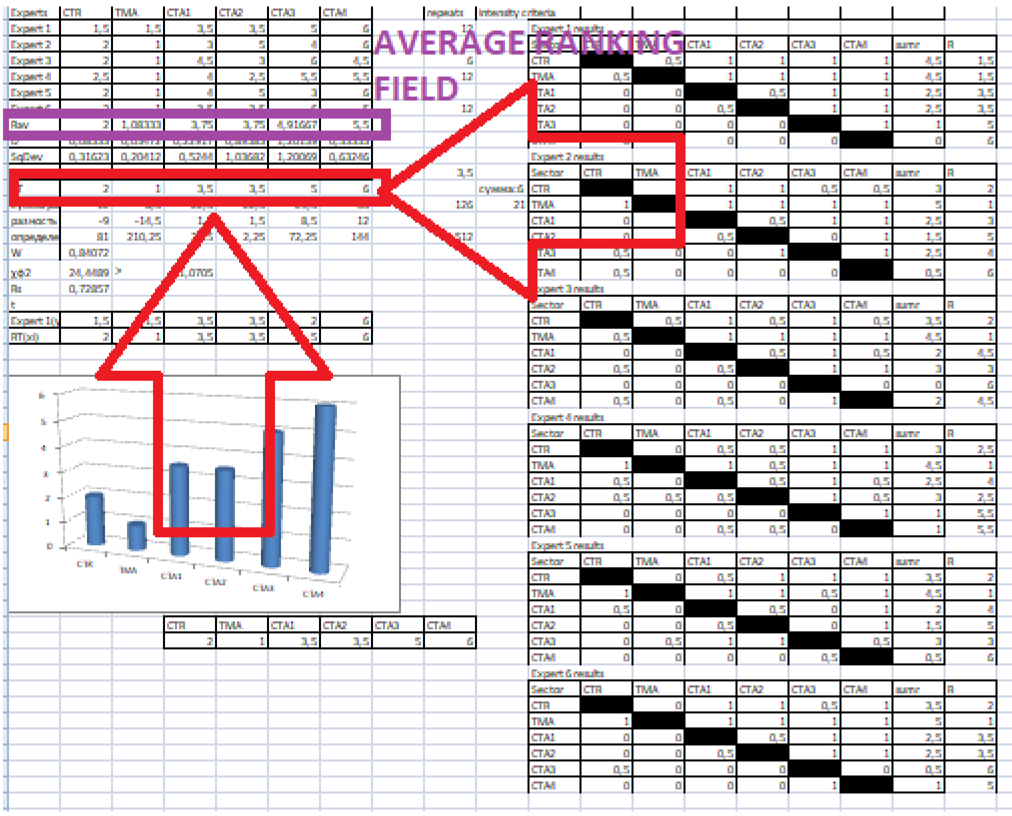
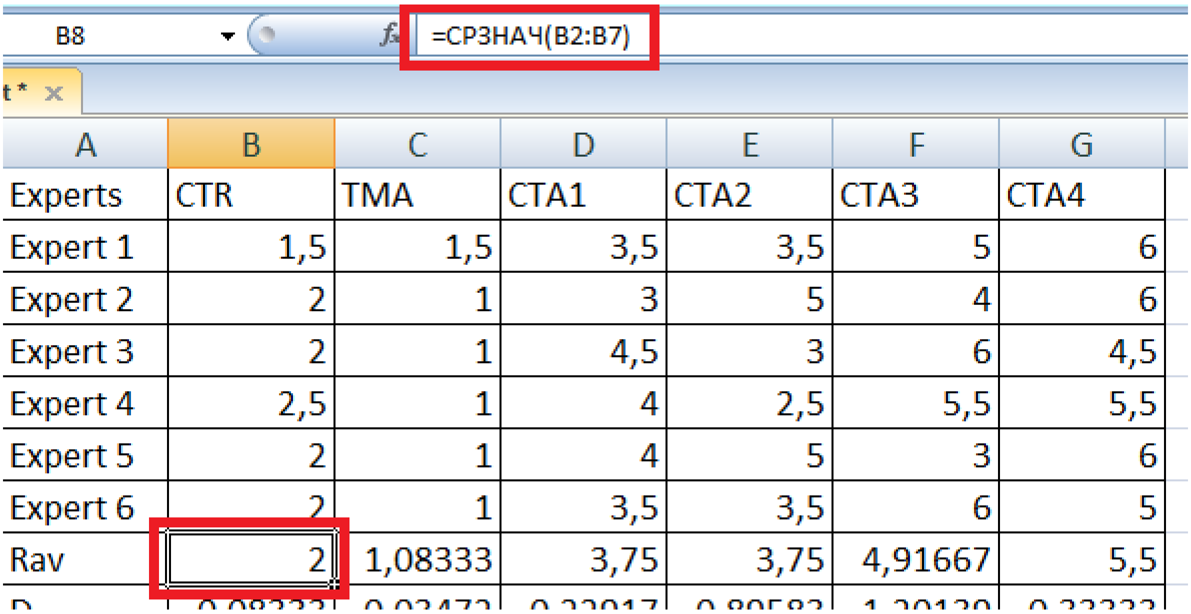


Figure 4.7 Placement of input of new ranks

Average group opinion was determined with the help of function СРЗНАЧ. (Figure 4.8)


B8 =СРЗНАЧ(B2:B7)

	A	B	C	D	E	F	G
1	Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4
2	Expert 1	1,5	1,5	3,5	3,5	5	6
3	Expert 2	2	1	3	5	4	6
4	Expert 3	2	1	4,5	3	6	4,5
5	Expert 4	2,5	1	4	2,5	5,5	5,5
6	Expert 5	2	1	4	5	3	6
7	Expert 6	2	1	3,5	3,5	6	5
8	Rav	2	1,08333	3,75	3,75	4,91667	5,5

Figure 4.8 Determination of average opinion of group about rank

3) Determination of expert group opinion coordination

To determine coordination of the expert group opinions, should be found Variation coefficient, Kendall coefficient and Spirman`s coefficient (to compare the group opinion and opinion of one expert).

To find the Variation coefficient (Figure 4.11), it is necessary to obtain first Dispersion value of group opinion (Figure 4.9) and its square deviation (Figure 4.10).

B9 =ДИСП(B2:B7)

	A	B	C	D	E	F	G
	Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4
	Expert 1	1,5	1,5	3,5	3,5	5	6
	Expert 2	2	1	3	5	4	6
	Expert 3	2	1	4,5	3	6	4,5
	Expert 4	2,5	1	4	2,5	5,5	5,5
	Expert 5	2	1	4	5	3	6
	Expert 6	2	1	3,5	3,5	6	5
	Rav	2	1,08333	3,75	3,75	4,91667	5,5
	D	0,1	0,04167	0,275	1,075	1,44167	0,4
	SqDev	0,31623	0,20412	0,5244	1,03682	1,20069	0,63246
	Variation (	0,15811	0,18842	0,13984	0,27649	0,24421	0,11499

Figure 4.9 Determination of value of group opinion dispersion

B10 =СТАНДОТКЛОН(B2:B7)

	A	B	C	D	E	F	G
	Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4
	Expert 1	1,5	1,5	3,5	3,5	5	6
	Expert 2	2	1	3	5	4	6
	Expert 3	2	1	4,5	3	6	4,5
	Expert 4	2,5	1	4	2,5	5,5	5,5
	Expert 5	2	1	4	5	3	6
	Expert 6	2	1	3,5	3,5	6	5
	Rav	2	1,08333	3,75	3,75	4,91667	5,5
	D	0,1	0,04167	0,275	1,075	1,44167	0,4
	SqDev	0,31623	0,20412	0,5244	1,03682	1,20069	0,63246
	Variation (	0,15811	0,18842	0,13984	0,27649	0,24421	0,11499

Figure 4.10 Determination of square deviation

B11 =(B10/B8)

A	B	C	D	E	F	G
Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4
Expert 1	1,5	1,5	3,5	3,5	5	6
Expert 2	2	1	3	5	4	6
Expert 3	2	1	4,5	3	6	4,5
Expert 4	2,5	1	4	2,5	5,5	5,5
Expert 5	2	1	4	5	3	6
Expert 6	2	1	3,5	3,5	6	5
Rav	2	1,08333	3,75	3,75	4,91667	5,5
D	0,1	0,04167	0,275	1,075	1,44167	0,4
SqDev	0,31623	0,20412	0,5244	1,03682	1,20069	0,63246
Variation	0,15811	0,18842	0,13984	0,27649	0,24421	0,11499

Figure 4.11 Determination of variation (if less then 0.33,opinions coordinated)

To evaluate the Kendall coefficient (Figure 4.19) and its significance (Figure 4.20) should be obtained additional data:

-taking into consideration the number of repeats. (Figure 4.12)

The number of repeats should be taken into account as each value repeat separately. For example: exists a row with the values 1,5; 1,5; 3,5; 3,5; 5; 6.1,5 repeats two times and 3,5 repeats two times. So value for input will be 2*2*2-2+2*2*2-2=12 (NOT 4*4*4-4+4*4*4-4=120) (Formulae 15 part (t^3-t)). Then system automatically will divide to 12 these data. (Figure 4.13)

-ranks sum (Figure 4.14, Figure 4.15)

-difference of ranks sum and sum divided to number of criteria (Figure 4.16)

-S (the sum of the squares of the deviations of all assessments of the ranks of each object of examination from the mean) (Figure 4.17,4.18).

Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4		repeats
Expert 1	1,5	1,5	3,5	3,5	5	6		12
Expert 2	2	1	3	5	4	6		
Expert 3	2	1	4,5	3	6	4,5		6
Expert 4	2,5	1	4	2,5	5,5	5,5		12
Expert 5	2	1	4	5	3	6		
Expert 6	2	1	3,5	3,5	6	5		12
Rav	2	1,08333	3,75	3,75	4,91667	5,5		
D	0,1	0,04167	0,275	1,075	1,44167	0,4		
SqDev	0,31623	0,20412	0,5244	1,03682	1,20069	0,63246		
Variation (	0,15811	0,18842	0,13984	0,27649	0,24421	0,11499		3,5

Figure 4.12 Placement of data about calculation with repeats

I11 =СУММ(I2:I7)/12

A	B	C	D	E	F	G	H	I
Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4		repeats
Expert 1	1,5	1,5	3,5	3,5	5	6		12
Expert 2	2	1	3	5	4	6		
Expert 3	2	1	4,5	3	6	4,5		6
Expert 4	2,5	1	4	2,5	5,5	5,5		12
Expert 5	2	1	4	5	3	6		
Expert 6	2	1	3,5	3,5	6	5		12
Rav	2	1,08333	3,75	3,75	4,91667	5,5		
D	0,1	0,04167	0,275	1,075	1,44167	0,4		
SqDev	0,31623	0,20412	0,5244	1,03682	1,20069	0,63246		
Variation (	0,15811	0,18842	0,13984	0,27649	0,24421	0,11499		3,5

Figure 4.13 Tj value for Kendall coefficient

B13 =СУММ(B2:B7)

	A	B	C	D	E	F	G
1	Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4
2	Expert 1	1,5	1,5	3,5	3,5	5	6
3	Expert 2	2	1	3	5	4	6
4	Expert 3	2	1	4,5	3	6	4,5
5	Expert 4	2,5	1	4	2,5	5,5	5,5
6	Expert 5	2	1	4	5	3	6
7	Expert 6	2	1	3,5	3,5	6	5
8	Rav	2	1,08333	3,75	3,75	4,91667	5,5
9	D	0,1	0,04167	0,275	1,075	1,44167	0,4
10	SqDev	0,31623	0,20412	0,5244	1,03682	1,20069	0,63246
11	Variation (	0,15811	0,18842	0,13984	0,27649	0,24421	0,11499
12	RT	2	1	3,5	3,5	5	6
13	Rank +	12	6,5	22,5	22,5	29,5	33

Figure 4.14 Sum of ranks determination

I13 =СУММ(B13:G13)

A	B	C	D	E	F	G	H	I	J
Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4		repeats	
Expert 1	1,5	1,5	3,5	3,5	5	6		12	
Expert 2	2	1	3	5	4	6			
Expert 3	2	1	4,5	3	6	4,5		6	
Expert 4	2,5	1	4	2,5	5,5	5,5		12	
Expert 5	2	1	4	5	3	6			
Expert 6	2	1	3,5	3,5	6	5		12	
Rav	2	1,08333	3,75	3,75	4,91667	5,5			
D	0,1	0,04167	0,275	1,075	1,44167	0,4			
SqDev	0,31623	0,20412	0,5244	1,03682	1,20069	0,63246			
Variation (	0,15811	0,18842	0,13984	0,27649	0,24421	0,11499		3,5	
RT	2	1	3,5	3,5	5	6			Sum:6
Rank +	12	6,5	22,5	22,5	29,5	33		126	21

Figure 4.15.Determination of sum of ranks sum for the next averaging

B14 fx =B13-J13

A	B	C	D	E	F	G	H	I	J
Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4		repeats	
Expert 1	1,5	1,5	3,5	3,5	5	6		12	
Expert 2	2	1	3	5	4	6			
Expert 3	2	1	4,5	3	6	4,5		6	
Expert 4	2,5	1	4	2,5	5,5	5,5		12	
Expert 5	2	1	4	5	3	6			
Expert 6	2	1	3,5	3,5	6	5		12	
Rav	2	1,08333	3,75	3,75	4,91667	5,5			
D	0,1	0,04167	0,275	1,075	1,44167	0,4			
SqDev	0,31623	0,20412	0,5244	1,03682	1,20069	0,63246			
Variation (	0,15811	0,18842	0,13984	0,27649	0,24421	0,11499		3,5	
RT	2	1	3,5	3,5	5	6			Sum:6
Rank +	12	6,5	22,5	22,5	29,5	33		126	21
Rank -	-9	-14,5	1,5	1,5	8,5	12			

Figure 4.16 Difference between the rank sum and rank sum/6

B15 fx =СТЕПЕНЬ(B14;2)

A	B	C	D	E	F	G
Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4
Expert 1	1,5	1,5	3,5	3,5	5	6
Expert 2	2	1	3	5	4	6
Expert 3	2	1	4,5	3	6	4,5
Expert 4	2,5	1	4	2,5	5,5	5,5
Expert 5	2	1	4	5	3	6
Expert 6	2	1	3,5	3,5	6	5
Rav	2	1,08333	3,75	3,75	4,91667	5,5
D	0,1	0,04167	0,275	1,075	1,44167	0,4
SqDev	0,31623	0,20412	0,5244	1,03682	1,20069	0,63246
Variation (	0,15811	0,18842	0,13984	0,27649	0,24421	0,11499
RT	2	1	3,5	3,5	5	6
Rank +	12	6,5	22,5	22,5	29,5	33
Rank -	-9	-14,5	1,5	1,5	8,5	12
S	81	210,25	2,25	2,25	72,25	144

Figure 4.17. Part of S determination

I15 f_x =СУММ(B15:G15)

A	B	C	D	E	F	G	H	I
Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4		repeats
Expert 1	1,5	1,5	3,5	3,5	5	6		12
Expert 2	2	1	3	5	4	6		
Expert 3	2	1	4,5	3	6	4,5		6
Expert 4	2,5	1	4	2,5	5,5	5,5		12
Expert 5	2	1	4	5	3	6		
Expert 6	2	1	3,5	3,5	6	5		12
Rav	2	1,08333	3,75	3,75	4,91667	5,5		
D	0,1	0,04167	0,275	1,075	1,44167	0,4		
SqDev	0,31623	0,20412	0,5244	1,03682	1,20069	0,63246		
Variation (	0,15811	0,18842	0,13984	0,27649	0,24421	0,11499		3,5
RT	2	1	3,5	3,5	5	6		
Rank +	12	6,5	22,5	22,5	29,5	33		126
Rank -	-9	-14,5	1,5	1,5	8,5	12		
S	81	210,25	2,25	2,25	72,25	144		512

Figure 4.18 S determination

B16 f_x =(I15)/(3*(6*6*6-6)-6*I11)

A	B	C	D	E	F	G	H	I
Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4		repeats
Expert 1	1,5	1,5	3,5	3,5	5	6		12
Expert 2	2	1	3	5	4	6		
Expert 3	2	1	4,5	3	6	4,5		6
Expert 4	2,5	1	4	2,5	5,5	5,5		12
Expert 5	2	1	4	5	3	6		
Expert 6	2	1	3,5	3,5	6	5		12
Rav	2	1,08333	3,75	3,75	4,91667	5,5		
D	0,1	0,04167	0,275	1,075	1,44167	0,4		
SqDev	0,31623	0,20412	0,5244	1,03682	1,20069	0,63246		
Variation (	0,15811	0,18842	0,13984	0,27649	0,24421	0,11499		3,5
RT	2	1	3,5	3,5	5	6		
Rank +	12	6,5	22,5	22,5	29,5	33		126
Rank -	-9	-14,5	1,5	1,5	8,5	12		
S	81	210,25	2,25	2,25	72,25	144		512
W	0,84072							

Figure 4.19 Kendall coefficient determination

B17 =I15/(3*7-(1/(12*5))*I11)

A	B	C	D	E	F	G
Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4
Expert 1	1,5	1,5	3,5	3,5	5	6
Expert 2	2	1	3	5	4	6
Expert 3	2	1	4,5	3	6	4,5
Expert 4	2,5	1	4	2,5	5,5	5,5
Expert 5	2	1	4	5	3	6
Expert 6	2	1	3,5	3,5	6	5
Rav	2	1,08333	3,75	3,75	4,91667	5,5
D	0,1	0,04167	0,275	1,075	1,44167	0,4
SqDev	0,31623	0,20412	0,5244	1,03682	1,20069	0,63246
Variation (	0,15811	0,18842	0,13984	0,27649	0,24421	0,11499
RT	2	1	3,5	3,5	5	6
Rank +	12	6,5	22,5	22,5	29,5	33
Rank -	-9	-14,5	1,5	1,5	8,5	12
S	81	210,25	2,25	2,25	72,25	144
W	0,84072					
χф2	24,4489	>	11,0705			

Figure 4.20.Determination of significance of Kendall coefficient (is it a random value (if less than table value 11,0705) or not and can be used for the calculations after)

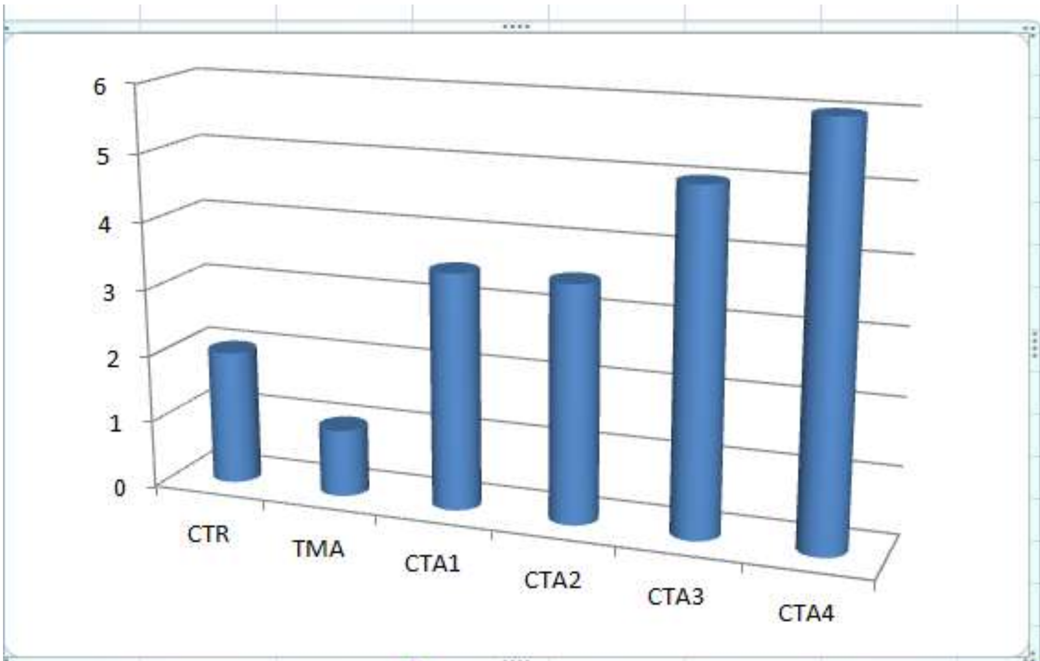
Also it was taken into account coordination of group opinion with an opinion of one expert with the help of Spirman criteria. (Figure 4.21)

B18 =1-((6*((B21-B20)^2+(C21-C20)^2+(D21-D20)^2+(E21-E20)^2+(F21-F20)^2)+(G21-G20)^2))/(6*35)

A	B	C	D	E	F	G	H	I	J	K
Experts	CTR	TMA	CTA1	CTA2	CTA3	CTA4		repeats		
Expert 1	1,5	1,5	3,5	3,5	5	6		12		
Expert 2	2	1	3	5	4	6				
Expert 3	2	1	4,5	3	6	4,5		6		
Expert 4	2,5	1	4	2,5	5,5	5,5		12		
Expert 5	2	1	4	5	3	6				
Expert 6	2	1	3,5	3,5	6	5		12		
Rav	2	1,08333	3,75	3,75	4,91667	5,5				
D	0,1	0,04167	0,275	1,075	1,44167	0,4				
SqDev	0,31623	0,20412	0,5244	1,03682	1,20069	0,63246				
Variation (	0,15811	0,18842	0,13984	0,27649	0,24421	0,11499		3,5		
RT	2	1	3,5	3,5	5	6			Sum:6	
Rank +	12	6,5	22,5	22,5	29,5	33		126	21	
Rank -	-9	-14,5	1,5	1,5	8,5	12				
S	81	210,25	2,25	2,25	72,25	144		512		
W	0,84072									
χф2	24,4489	>	11,0705							
Rs	0,72857									

Figure 4.21 Determination of expert 1 opinion and group opinion with the help of Spirman criteria

Graph after the re-ranking will show where the intensity of flights becomes higher. The lower the cylinder-the MORE intensity. (Figure 4.22)



CTR	TMA	CTA1	CTA2	CTA3	CTA4
2	1	3,5	3,5	5	6

Figure 4.22 Graphical representation of ranks of experts opinion.

4) Prediction of future workload (in numbers)

Using the collected information about the flights amount of each sector that has been input at the part 1), “ Collection of information” can be obtained the trend line and predicted the future possible peak of intensity at the next moments of time. Correlation is defined with the function КОРРЕЛ.

=КОРРЕЛ(A77:A89;B77:B89)

	A	B	C
74			
75	cta2		
76	X	Y	
77	1	3	
78	2	1	
79	3	1	
80	4	1	
81	5	5	
82	6	4	
83	7	3	
84	8	5	
85	9	8	
86	10	3	
87	11	2	
88	12	5	
89	13	4	
90	r	0,454270412	
91	b0	1,807692308	
92	b1	0,236263736	

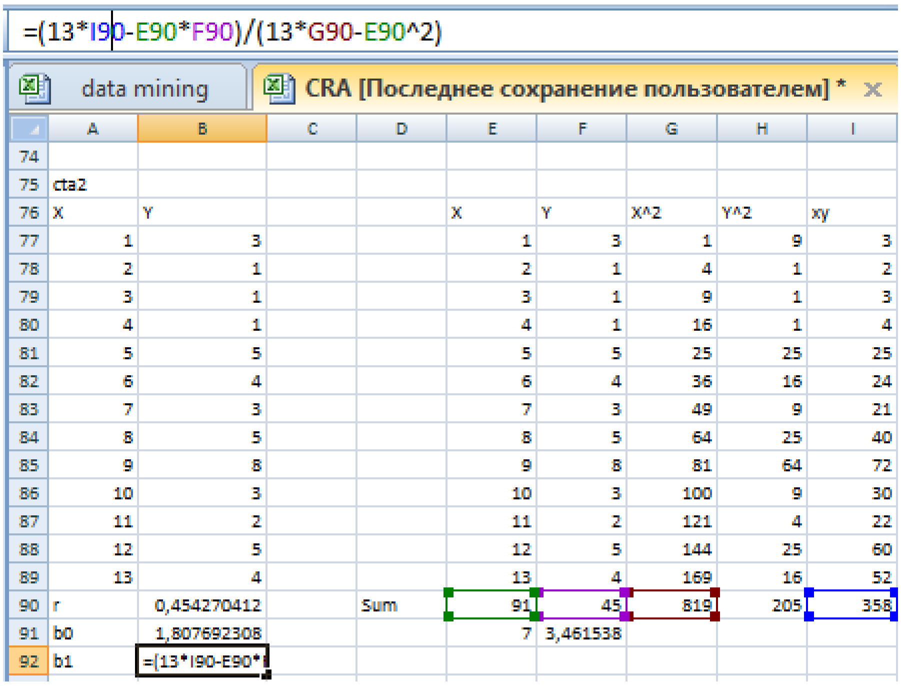
Figure 4.23 Obtaining of a correlation coefficient based on collected data

Then the trend line coefficients are obtained. (Figure 4.24, Figure 4.25).

=(F90*G90-I90*E90)/(13*G90-E90^2)

	A	B	C	D	E	F	G	H	I
74									
75	cta2								
76	X	Y			X	Y	X^2	Y^2	xy
77	1	3			1	3	1	9	3
78	2	1			2	1	4	1	2
79	3	1			3	1	9	1	3
80	4	1			4	1	16	1	4
81	5	5			5	5	25	25	25
82	6	4			6	4	36	16	24
83	7	3			7	3	49	9	21
84	8	5			8	5	64	25	40
85	9	8			9	8	81	64	72
86	10	3			10	3	100	9	30
87	11	2			11	2	121	4	22
88	12	5			12	5	144	25	60
89	13	4			13	4	169	16	52
90	r	0,454270412		Sum	91	45	819	205	358
91	b0	=(F90*G90-I90			7	3,461538			
92	b1	0,236263736							

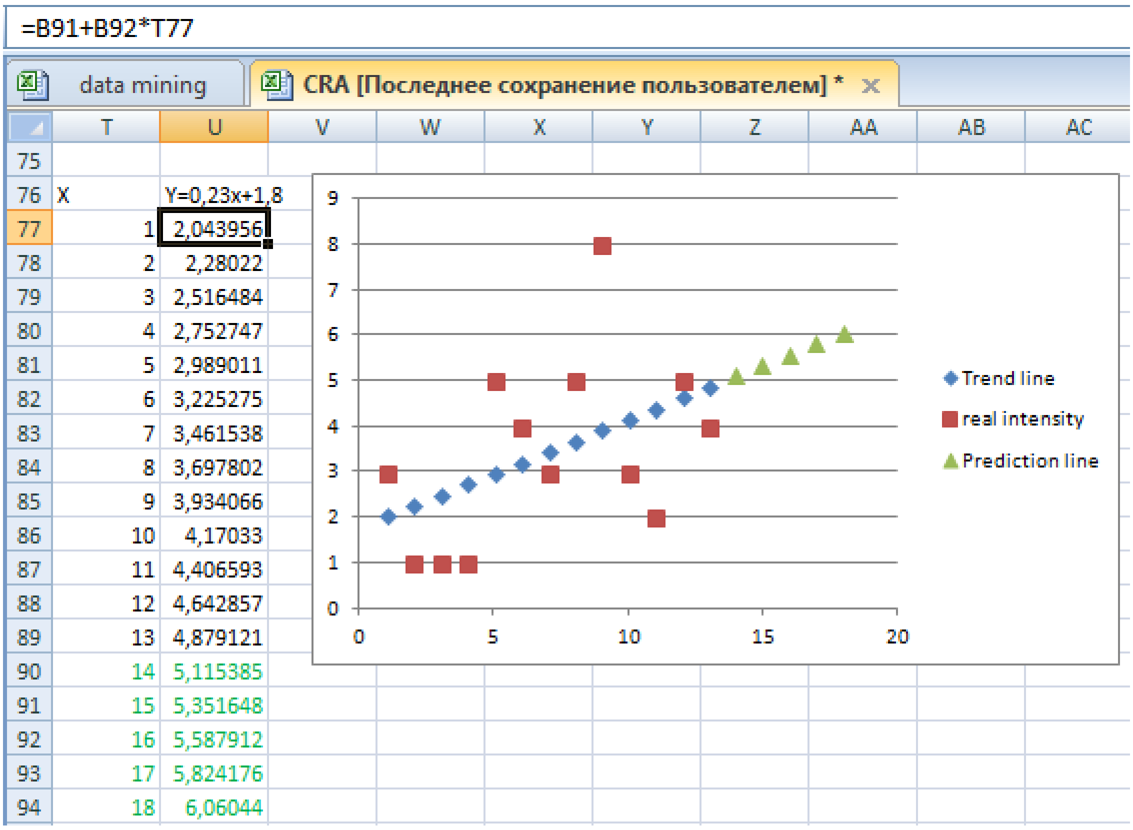
Figure 4.24 Obtaining of a trend line coefficient b0



	A	B	C	D	E	F	G	H	I
74									
75	cta2								
76	X	Y			X	Y	X^2	Y^2	xy
77	1	3			1	3	1	9	3
78	2	1			2	1	4	1	2
79	3	1			3	1	9	1	3
80	4	1			4	1	16	1	4
81	5	5			5	5	25	25	25
82	6	4			6	4	36	16	24
83	7	3			7	3	49	9	21
84	8	5			8	5	64	25	40
85	9	8			9	8	81	64	72
86	10	3			10	3	100	9	30
87	11	2			11	2	121	4	22
88	12	5			12	5	144	25	60
89	13	4			13	4	169	16	52
90	r	0,454270412		Sum	91	45	819	205	358
91	b0	1,807692308			7	3,461538			
92	b1	=(13*I90-E90*							

Figure 4.25 Obtaining of a trend line coefficient b1

After obtaining the coefficients, trend line equation was determined and data were input to build a graph of trend line with the possibility of prediction of future workload peaks. (Figure 4.26)



	T	U
75		
76	X	Y=0,23x+1,8
77	1	2,043956
78	2	2,28022
79	3	2,516484
80	4	2,752747
81	5	2,989011
82	6	3,225275
83	7	3,461538
84	8	3,697802
85	9	3,934066
86	10	4,17033
87	11	4,406593
88	12	4,642857
89	13	4,879121
90	14	5,115385
91	15	5,351648
92	16	5,587912
93	17	5,824176
94	18	6,06044

Figure 4.26 Building of a line of trend and prediction

CONCLUSION FROM THE CHAPTER 4.

The program that was developed for the Diploma Work execution can be called expert system prototype with a possibility of development. It has all the structural elements of an ES.

CONCLUSION

During the execution of a work, were analysed 6 sectors parallel with the questioning the experts. The highest workload within the TMA was estimated and successfully compared with the expert opinions.

During the investigation were used expert judgment methodology and correlation-regression analysis. EJM was used for the schematic demonstration of criteria ranking estimation on an example of such criteria as (mainly) intensity and density.CRA was used for the prediction of quantitative values of workload peaks.

Was developed the program of prediction of peaks of aircraft appearing.

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ANNEX 1.

Questionnaire for poll to built a matrix of individual preferences

1.) Matrix of individual preferences 1. Intensity analysis.

Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4
CTR						
TMA						
CTA1(LIV)						
CTA2(South)						
CTA 3(Center)						
CTA 4 (Other CTA controlled by your a/p)						

Якщо (за Вашої думки) інтенсивність польотів в секторі,що виділено жовтим, вища за інтенсивність в секторі,що не виділено, заповніть поле на перетині цих секторів одиницею. Якщо нижча, нулем. Якщо однакова або немає суттєвих відмінностей, поставте 0,5.
Если (по Вашему мнению) интенсивность полётов в секторе, который обозначен жёлтым, выше, чем в не выделенном, поставьте в поле ряда этого сектора 1. Если меньше-0. Если одинакова с не выделенным сектором-0.5
If (in Your opinion) the intensity of flights within the sector that is marked with yellow is higher than in non-marked, print 1. If less , print 0. If equal, print 0,5.

2.) Matrix of individual preferences 2. Regular flights amount analysis.

Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4
CTR						
TMA						
CTA1(LIV)						
CTA2(South)						
CTA 3(Center)						
CTA 4 (Other CTA controlled by your a/p)						

Якщо (за Вашої думки) кількість регулярних польотів в секторі,що виділено жовтим, вища за кількість регулярних польотів в секторі,що не виділено, заповніть поле на перетині цих секторів одиницею. Якщо нижча, нулем. Якщо однакова або немає суттєвих відмінностей, поставте 0,5.

Если (по Вашему мнению) количество регулярных полётов в секторе, который обозначен жёлтым, выше, поставьте 1. Если меньше-0. Если одинакова с не выделенным сектором-0.5
If,in your opinion, amount of regular flights within the sector that is marked with yellow is higher, than in non-marked, print 1. If less, print 0. If equal, print 0,5.

3.) Matrix of individual preferences 3. Not-necessary poll, possible for analysis potential safety of sector in widened ES.

Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4
CTR						
TMA						
CTA1(LIV)						
CTA2(South)						
CTA 3(Center)						
CTA 4 (Other CTA controlled by your a/p)						

Якщо (за Вашої думки) кількість польотів без надзвичайних подій в секторі,що виділено жовтим, вища за таку в секторі,що не виділено, заповніть поле на перетині цих секторів одиницею. Якщо нижча, нулем. Якщо однакова або немає суттєвих відмінностей, поставте 0,5.
Если (по Вашему мнению) количество полётов без происшествий в секторе, который обозначен жёлтым, выше, поставьте 1. Если меньше-0. Если одинаково с не выделенным сектором-0.5
If (in Your opinion) amount of flights without incidents within the sector marked with yellow is higher, print 1. If less, print 0. If equal with non-marked sector, print 0.5.

4.) Matrix of individual preferences 4. Analysis of density.

Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4
CTR						
TMA						
CTA1(LIV)						
CTA2(South)						
CTA 3(Center)						
CTA 4 (Other CTA controlled by your a/p)						

Якщо (за Вашої думки) щільність польотів в секторі,що виділено жовтим, вища за щільність в секторі,що не виділено, заповніть поле на перетині цих секторів одиницею. Якщо нижча, нулем. Якщо однакова або немає суттєвих відмінностей, поставте 0,5.

Если (по Вашему мнению) плотность движения в секторе, который обозначен жёлтым, выше, поставьте 1. Если меньше-0. Если одинакова с не выделенным сектором-0.5

If (in Your opinion) density of flights within the sector, marked with yellow, is higher, print 1. If less, print 0. If equal, print 0,5.

5.) Matrix of individual preferences 5. Capacity analysis (not-necessary, possible to use in widened ES with a big amount of respondents, taking into account individual features of personnel).

Sector	CTR	TMA	CTA1	CTA2	CTA3	CTA4
CTR						
TMA						
CTA1(LIV)						
CTA2(South)						
CTA 3(Center)						
CTA 4 (Other CTA controlled by your a/p)						

Якщо (за Вашої думки) пропускна здатність польотів в секторі,що виділено жовтим, вища за пропускну здатність в секторі,що не виділено, заповніть поле на перетині цих секторів одиницею. Якщо нижча, нулем. Якщо однакова або немає суттєвих відмінностей, поставте 0,5.

Если (по Вашему мнению) пропускная способность в секторе, который обозначен жёлтым, выше, поставьте 1. Если меньше-0. Если одинакова с не выделенным сектором-0.5

If (in Your opinion), capacity of sector, marked with yellow, is higher, print 1. If less, print 0. If equal with non-marked sector, print 0,5.