**RIGA TECHNICAL UNIVERSITY**
Faculty of Mechanical Engineering, Transport and Aeronautics
Institute of Aeronautics

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# Air Traffic Control System Establishment for Remotely Piloted Aircraft Systems Operation in Riga Flight Information Region

**Summary of the Doctoral Thesis**

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DECLARATION OF ACADEMIC INTEGRITY

I hereby declare that the Doctoral Thesis submitted for the review to Riga Technical University for the promotion to the scientific degree of Doctor of Engineering Sciences is my own and does not contain any unacknowledged material from any source. I confirm that this Thesis has not been submitted to any other university for the promotion to other scientific degree.

Monta Lacane …………………………….(Signature)

Date: ………………………

Thesis is written in Latvian, it contains introduction, 5 chapters, conclusion, list of references, 3 annexes, 44 figures, 177 pages in total. The list of references comprises 72 titles.

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# 1. TOPICALITY OF THE WORK

Air traffic in Riga Flight Information Region is organized in accordance with official documents, where the main documents are ICAO PANS-ATM Doc4444 “Air Traffic Management”, Aeronautical Publication of Latvia or AIP Latvia, as well as operational procedures for each air traffic control (ATC) sector, which is located in Riga FIR. These operational procedure manuals contain information about the procedures applicable by air traffic controllers in each control sector – East and West transit, Approach Sector, and Tower Sector. One of the main problems is that currently there are no official documents, which would describe official procedures how to organize and control remotely piloted aircraft systems (RPAS) in any of these control sectors – in Riga FIR controlled airspace. As a result, current ATC system is not ready to provide necessary service, as well as guarantee acceptable level of safety for RPAS operations with respect to other RPAS and also with respect to manned aircraft.

In the future RPAS will be fully integrated into general air traffic flow, which is defined as air traffic, which operates in accordance with the requirements and procedures from International Civil Aviation Organization (ICAO). Although there are no established procedures for RPAS, the rapid growth of this industry forces their use not only in a specially designated airspace, but also outside it. When operating outside the designated airspace, RPAS cause additional problems for other airspace users. It shall be taken into consideration that RPAS differ significantly from manned aircraft both technically and operationally. One of the main differences is that RPAS usually fly without a secondary surveillance radar (SSR) transponder on board, for this reason, such aircraft are not represented on ATC radar screens, which means that air traffic controllers are not able to provide them with the necessary service. Furthermore, ATC are not allowed to control such flights, give them clearances. But growing RPAS demand encourages their use for different purposes without informing ATC about RPAS position, intentions and other relevant information. In some parts of Riga FIR it is allowed to fly without operational transponder on board, but it must be taken into account that in such case the risk of collision with other aircraft is higher. For this reason, it is useful to analyze air traffic flow in the part of airspace, where the flight is planned.

From the current situation it is seen that it is necessary to establish official procedures for RPAS operation in Riga FIR, which would define how such aircraft shall operate in associated airspace. First of all, it would protect other airspace users’ rights, as well as would guarantee the necessary level of safety. Taking into account the specifications of RPAS operationally and technically, that they require specific assistance, it is necessary to establish ATC system how to handle such air traffic in Riga FIR.

## 2. GOAL AND TASKS OF THE PAPER

The main goal of this paper is to establish air traffic control system for RPAS operation taking into consideration current operational procedures in Riga FIR controlled airspace, requirements for technical equipment and air traffic intensity.

In the beginning the following tasks were set:

1) To conduct the RPAS operational procedures analysis on international, European and Latvian scale;
2) To formulate requirements for RPAS technical equipment in accordance with international legislation;
3) To establish adjusted NOTAM and flight plan format for RPAS use in Riga FIR;
4) To establish operational procedures for RPAS use in Riga FIR;
5) To do air traffic flow analysis in Riga FIR and to represent the results on aeronautical chart;
6) To do air traffic flow mathematical modeling;
7) To do forecast of air traffic flow intensity in Riga FIR;
8) To establish training programs for RPAS pilots and air traffic controllers about RPAS operational procedures in Riga FIR.

## 3. RESEARCH METHODS

In this work the following research methods were used:

- Mathematical modeling;
- Probability theory and mathematical statistics
- Statistics data processing by using special statistics program “R Studio”

## 4. SCIENTIFIC NOVELY

Thesis is resultant in innovative solutions:

1) Mathematical modeling of air traffic intensity has been done taking into consideration flight direction, altitude, entry and exit point into Riga FIR, as well as Minimum Sector Altitude (MSeA) sectors, which were crossed during the flight;
2) Mathematical forecast of air traffic intensity in Riga FIR has been done;
3) New operational air traffic control procedures for Riga FIR controlled airspace have been established.

**Theses to defend**

The author in this thesis defends the following:

1) Established ATC procedures for RPAS operation in RIGA FIR controlled airspace;
2) Results of mathematical modeling of air traffic intensity in Riga FIR;
3) Results of forecast of air traffic intensity in Riga FIR;
4) Established training programs for RPAS operators and ATC officers about RPAS operations in Riga FIR.

# 5. PRACTICAL VALUE

The established operational air traffic control procedures for RPAS in Riga FIR controlled airspace give opportunity to:

1) Use a definite systematic approach to organization of RPAS flights in Riga FIR by defining the system how such flights shall be committed. Such procedures make ATC work easier, as well as reduce potential risk to civil and military aviation safety, which can be reduced by injudicious behaviour or any other dangerous use of RPAS;
2) Established adjusted format of NOTAM message and a flight plan for RPAS operation gives opportunity to systemize information exchange among different airspace users, making communications faster and giving full information, so that all users involved would have better understanding about the situation.

Riga FIR sectorization depending on air traffic flow at altitudes from ground to FL100, as well as air traffic intensity forecast and such information representation on aeronautical charts gives opportunity to:

1) Analyze air traffic intensity tendencies in Riga FIR and practically use them in route planning or in solving other related questions;

2) Plan RPAS route by choosing the least congested part of Riga FIR airspace, this way increasing safety of own flight.

# 6. APPROBATION

1. **International conference “Transport Means 2014” (23 – 2 October, 2014, Kaunas, Lithuania)**

Presentation topic: *Lack of Established Procedures for UAS Operation as the Main Limiting Factor for Their Exploitation in Civil Aviation*

2. **International conference “Transport Means 2015” (22 –23 October, 2015, Kaunas, Lithuania)**

Presentation topic: *NOTAM Message Regarding UAS Operation in Riga Flight Information Region*

3. **International conference “Research and Education in Aircraft Design 2014” (15- 17 October, 2014, Vilnius, Lithuania)**

Presentation topic: *Riga FIR Division into Sectors According to the Air Traffic Flow for Safer UAS Exploitation*

4. **International conference on cooperation in civil aviation between the European Union and Russia AVIA-INVEST 2014 ( April 2014, Riga)**

Presentation topic: *Special Aspects of Operating Hybrid Aerial Vehicles in Europe» (ESTOLAS*

5. **RTU 51st International Scientific Conference (15- 16 October, 2014, Riga, Latvia)**

# 7. PUBLICATIONS

1. Lacane, M., Urbahs, A. NOTAM Message Regarding UAS Operation in Riga Flight Information Region. - In Book: Transport Means, ISSN 1822-296x, 2015, pp. 734-738.
2. Lacane, M., Urbahs, A. Lack of Established Procedures for UAS Operation as the Main Limiting Factor for Their Exploitation in Civil Aviation. - In: Transport Means, ISSN 1822-296x, 2015, pp. 249-252.
3. Lacane, M., Urbahs, A., “Riga FIR Division into Sectors According to the Air Traffic Flow for Safer UAS Exploitation”, Aviation Journal, 2015

4. Lacane, M., Urbahs, A. “Establishment of Possible Unmanned Aerial Vehicle Operational Procedures in Riga Flight Information Region” Aviation Journal, 2016.
5. Lacane, M., Urbahs, A. “Requirements for Technical Equipment of Remotely Piloted Aircraft Systems for Operation in Riga Flight Information Region” . - In: Transport Means, ISSN 1822-296x, 2016.
6. Lacane, M., Urbahs, A. “Forecasting of Air Traffic Flow in Riga Flight Information Region Using *Autoregressive Integrated Moving Average* Mathematical Model. , Aviation Journal, 2016.
7. Lacane, M., Urbahs, A. “Main Factors to be Taken into Consideration When Planning a Route for Remotely Piloted Aircraft System Flights in Riga Flight Information Region. - “Safety in Aviation and Space Technology”, 2016, Kyiv, Ukraine

**The results of this thesis have been used in a scientific project:**

1. Project of the European Regional Development Fund “Development of an experimental model of long flight distance multifunctional remotely piloted aircraft for environment monitoring” (LARIDAE)» 2014/0029/2DP/2.1.1.1/14/APIA/VIAA/088.

## 8. THESIS CONTENT AND STRUCTURE

The present thesis consists of five chapter, the first chapter contains analysis of RPAS related legislation on international, European and local scale, as well as requirements for technical equipment for RPAS flights. In the second chapter the main factors are discussed, which affect flight planning. There are also requirements formulated for flights in Riga FIR, as well as operational procedures established for RPAS flights in Riga FIR controlled airspace. This chapter also contains a solution how to adjust a NOTAM message and a flight plan format for RPAS operations. The third chapter presents the analysis of air traffic flow from ground to FL100; the results have been illustrated on aeronautical charts. The fourth chapter contains mathematical modeling of air traffic intensity in Riga FIR using statistics program “R”, the results of which have been also illustrated on aeronautical charts. Using the same tools a forecast of air traffic intensity in Riga FIR has been done and illustrated on aeronautical charts. Chapter five contains training programs for RPAS operators and air traffic controllers about RPAS operational procedures in Riga FIR.

## 8.1. Analysis of current remotely piloted aircraft systems legislation on international, European and local scale

### Development of International Civil Aviation organization legislation guidelines

International Civil Aviation Organization (ICAO) recognizes different types of aircrafts, including hot air balloons, gliders, airplanes and rotorcraft. Aircraft can be land-based, maritime and amphibian. The fact, whether the aircraft is manned or unmanned, does not affect its status. Each aircraft category possibly in the future will get an unmanned version. In order to clarify and distinguish between those pilots, who do the pilotage tasks not from a cockpit of an aircraft, but from another place, it would be more appropriate to use the term "remote pilot". It is also considered, whether it is better to use "pilotless" or "manned without a pilot". [18; Ch4]

Safety is a state, when the possibility to endanger people or damage a property is reduced to an acceptable level and is maintained at this level or higher, by continuously monitoring danger identification and risk management process. Aircrafts which operate without a pilot on board, in many ways cause danger to civil aviation system safety. Such possible danger causes shall be identified and reduced by using airspace planning, new equipment and new procedure establishment tools.

The term "safety management" includes two conceptions. The first one is State Safety Program SSP, which is a group of integrated rules and activities, the main purpose of which is to increase safety. The second conception is Safety Management System SMS, which is a systematic approach to safety management, including all necessary organizational structures, responsibilities, policy and procedures.

Each country itself shall establish its own SSP, which would include its policy, rules, development and vision connected with safety. The establishment of such rules shall be based on wide range information of State aviation system analysis, including risk identification and management. At the beginning of RPAS use, the State shall support such safety related analysis for navigation equipment, RPAS in general and other affecting factors.

Operators and service providers are responsible for SMS establishment and implementation. States are responsible for the monitoring of such system, ensuring of RPAS integration in whole civil aviation system. The whole system shall be established taking into consideration Annex 6 to the Chicago Convention "Operation of Aircraft", Annex 11 "Air

Traffic Services" and Annex 14 "Aerodromes" first part "Aerodrome Design and Procedures" standards. It is expected that it will be necessary to supplement Annex 6 to include also information connected with RPAS. Consequently, such information would be also related to RPAS.

Currently ICAO main guidelines concerning RPAS are contained in its document Doc10019 AN/507 "Manual on Remotely Piloted Aircraft Systems" which was first issued in May, 2015. This document considers both technical and operational guidelines for RPAS use and integration in civil aviation. It shall be taken into account that levels of safety and use of RPAS shall be discussed in details by each Contracting State itself. But application of Standards and Recommended Practices (SARPs) help states in reaching the desirable result. More likely RPAS will be required to show the same performance as manned aircraft, but some issues might be changed. In such cases appropriate authorities shall offer alternate ways how to keep the same or even better level of safety. [23; 3.1-3.6]

**Guidelines of Remotely Piloted Aircraft Systems Legislation on European Scale**

Currently the majority of RPAS flights in the European airspace are committed in segregated zones to protect other airspace users, or such aircraft operate at high altitudes, which extend above flight levels used by civil aviation or above sea areas, using special permissions. In the areas, where operation of RPAS is allowed outside segregated areas, it would be useful to introduce several restrictions for safety purposes. For this reason, Eurocontrol has established and published some documents, which help in harmonization of ATC procedures, using RPAS outside special zones.

Some specifications have been submitted by Eurocontrol in 2007, and they are still under development. There are guidelines, which give voluntary approach to them, which means that the Contracting States themselves can decide, whether to follow them or not, whether to include the guidelines in local legislation or not. In specification the main focus is on RPAS, which operate as OAT (Operation Air Traffic), including flight in controlled and uncontrolled airspace. [12.]

On March 6, 2015, in Riga, Latvia Riga Declaration was approved, which was the outcome of the meeting, where representatives from the European Commission, European Union and other important members took part. European Aviation Community agreed that it is necessary to establish European legislation on RPAS use, which would encourage the development of new industry, as well as would ensure safe and viable integration of innovative technologies. In Riga Declaration, aviation community highlighted the following principles, which shall be taken into consideration when working on European RPAS policy and legislation:

1) RPAS shall be considered a new type of aircraft, for the operation of which it is necessary to adjust current rules and laws, depending on a potential risk it can cause to environment, people or other aircrafts. It was emphasized that new rules shall be easily understandable to give opportunity for new companies or individuals, which use relatively small risk RPAS, to join and operate in this industry. Higher risk flights shall have more strict requirements and operational restrictions.
2) Already now it is necessary to establish legislation for RPAS use in the European Union airspace. Rules connected with flight safety shall be considered on the European scale and shall be established by the European Aviation Safety Agency (EASA). But more important requirements shall be harmonized, coordinated on international level in cooperation with such organizations as JARUS (Joint Authorities for Rulemaking on Unmanned Systems) and ICAO.
3) Technological and general standard development shall guarantee full integration of RPAS in the European airspace. During the meeting industry representatives and public institutions stressed that in this question in order to get successful results there was a necessity for adequate investment in technologies, which are connected with RPAS integration process – SESAR program.
4) Support and acceptance from the public sector. Here it is necessary to take into account each individual's basic rights, privacy and private data protection. Responsible authorities shall establish necessary guidelines and monitoring system, which would guarantee compliance with the current rights.
5) RPAS operator is responsible for its use. If RPAS is operated in a prohibited area, in unsafe manner or for illegal purposes, responsible authorities shall have rights to call to account. Such details shall be specified in the national legislation. In order to be able to prosecute a guilty person, RPAS shall have its owner's identification information attached to it.

In Riga Declaration it is mentioned that in terms of RPAS also insurance and monitoring shall be considered. RPAS monitoring could be done, for instance, by using different web applications or other tools. To gradually improve RPAS operation safety and reduce possible risk and damage to other people, it would be necessary to establish safety management and incident reporting system. Such statistics data would be of a great importance for insurance companies. [49.]

EASA is responsible for the use of the European airspace and safety in it. On December 18, 2015 EASA published a document Technical Opinion, which considers the use of RPAS. This document also contains guidelines for RPAS legislation establishment, as well as safety promotion to guarantee that these types of aircraft would be used in a safe manner, as well as would have the smallest effect possible on other aviation systems. In EASA Technical Opinion document there are 27 proposals for small risk RPAS operation. These proposals mostly are connected with questions regarding not RPAS technical equipment and technical specifications, but more regarding its use and flight commitment.

**Legislation Regarding Remotely Piloted Aircraft Systems in Latvia**

Regulation No 656 of the Cabinet of Ministers of the Republic of Latvia "Order, how RPAS and similar types of aircraft, which are not classified, and aircraft whose flights shall be committed, which are established in accordance with Aviation Law's article 47, state the main rules, which shall be taken into account in the use of RPAS and other similar aircraft, which are not classified as aircraft. These rules determine how RPAS shall operate in the Latvian airspace and other airspace, which is delegated to Latvia, all together – Riga Flight Information Region.

It is allowed for RPAS to operate in controlled airspace of the Republic of Latvia (it is an airspace of defined dimensions, where flights are committed in accordance with visual or instrument flight rules) or in part of airspace, which is less than 10 kilometers away from any airfield, taking into account the following requirements:

a) If there is no segregated airspace for RPAS operation, they shall commit flight, not exceeding 120 meters of altitude;
b) If RPAS operator is not at least 18 years old.

During the flight RPAS shall not cause any danger to person's life, health or property, flight safety or environment. The aircraft shall be designed and equipped so that it could land, when it is necessary or to self-destroy, if its operator has lost control over it.

When RPAS operates in the uncontrolled airspace, its operator shall have continuous two-way radio communications with other airspace users on one frequency to be able to inform others about aircraft's position and intended route. During the flight RPAS can use only those frequencies or frequency range, which has officially been delegated for intended activities. The flight shall be committed in parts of airspace, which the operator has chosen and which is at least 500 meters wide and 200 meters long. Operator of a radio controlled aircraft has to make sure that the chosen part of airspace and the buffer zone or safety area of 50 meters around it is clear of people, animals, other vehicles, as well as flammable and explosive objects.

Before the flight the operator has to make sure that:

a) The frequency, which is used for the control station, is not used by anyone else;
b) Control station is fully operative before and after the aircraft engine start.

If there are people closer than 200 meters from the startup position of the RPA, then during the take-off initial stage the aircraft shall be taken to the middle of the designated airspace. If during the flight there is a communication loss between the operator and its RPA, the flight shall be terminated as soon as possible, and the RPA shall be landed. If before the flight a pre-flight check has not been done, then the first flight shall be at least 20 meters away from people.

It is prohibited to operate a radio controlled aircraft model if:

a) It flies closer than 200 meters from buildings, bridges, highways, road overpasses, road splits, high and low voltage loops, cemeteries, national parks and military objects, which are used by National Armed Forces;
b) There is possibility that a radio-controlled model can get out of direct visibility, direct line-of-sight;
c) It commits a flight or the portion of a flight over car parks or other places with people. [40.]

Nowadays RPAS have found use in many fields, for instance, agriculture, forestry, science, security and many other. Mostly such aircraft are used for monitoring of territories, which are not easily accessible, or in places, where the use of RPAS is economically and technically advantageous. Although at the beginning RPAS were used for military purposes, nowadays even more and more often they are used for civil needs. Developing this branch and establishing appropriate legislation, which would work as a tool for safe RPAS flights, it would be possible to use them even more and more effectively.

Unlike manned aircraft, RPAS do not have special standards for technical equipment. ICAO document Doc 10019 Manual on Remotely Piloted Aircraft provides guidelines, but more detailed rules ICAO remain in the scope of authority of each Contracting State.

When establishing a list of minimum technical equipment, the following issues shall be taken into account:

a) RPAS manufacturing state's requirements;
b) RPAS manufacturer's own requirements and specifications;
c) RPAS country's of registration specifications and requirements;
d) RPAS pilot's or operator's requirements and practice;
e) General international and other criteria.

When designing a new RPAS type, it would be necessary to get its Type Certificate TC, which would show that the particular RPAS and its associated components comply with criteria stated. Usually TC is given by a country, in which it is produced. TC includes also other components, which define specific criteria for technical equipment in more details – Instructions for Continuing Airworthiness ICA and a Flight Manual FM. ICAO defines FM requirements for manned aircraft, as well as guidelines, which shall be taken into consideration in terms of RPAS:

a) RPAS handling procedures from one RPA control station to another, if more than one control station is used;
b) Command and control link or C2 specifications and procedures how to react to C2 link loss;
c) Flight termination procedures, if possible and required;
d) Procedures connected with flight safety, which are related to RPAS only (RPAS control station's security and C2 link security).

If an aircraft complies with airworthiness requirements, then it is given a Certificate of Airworthiness CoA. In terms of RPAS ICAO Doc10019 suggests to equip RPA with such systems, which would be able to give the following features:

a) There are no definite standards for RPAS equipment, but there shall be a system, which would identify and inform the user about system errors, failures or other shortcomings, which could affect the airworthiness of the aircraft, as well as its ability to continue the flight;

b) Identification of critical equipment and component configuration of RPA and RPAS;
c) RPAS incident and accident registration and reporting system.

The equipment of manned and unmanned aircraft mostly depends on the type of airspace, in which the flight is committed, as well as flight rules used – visual or instrument. RPAS navigation equipment shall be able to give information to its operator or pilot about its course, altitude and position at any time. Communication equipment must be sufficient to maintain two-way communications using C2 data link between RPA and control station, as well as voice communications with the appropriate ATC unit. If according to class of airspace a transponder is mandatory (controlled airspace), then RPAS shall be equipped with secondary surveillance radar transponder in Mode A/C/S. In order to guarantee safe separation between other airspace users, obstructions and to avoid collisions, RPAS shall have Sense and Avoid or Detect and Avoid System, if appropriate ATS authority requires so.

## 8.2. Establishment of Procedures for Remotely Piloted Aircraft Operation in Riga Flight Information Region Controlled Airspace

Information Publications of the Republic of Latvia (AIP) contain requirements, which have been established for flights in Riga FIR. In accordance with this document all aircraft, which operate in this airspace, shall comply with ICAO Annex 6 rules and additional ICAO regional requirements, which have been stated in ICAO Doc 7030/4-EUR.

According to visual flight rules (VFR), which are described in ICAO Annex II (Rules of the Air), VFR flight in non-segregated areas and non-populated areas must maintain at least 500 ft vertical separation from the surface, except over open water. 1000 ft vertical separation must be maintained above the highest obstacle within horizontal radius of 2000 ft, when an aircraft flies over congested area of a city, town, or settlement or over any open air assembly of people. Taking into account 500 ft rule, in order not to cause any risk to manned VFR flights, RPAS should not be flown above 500ft, if no flight plan has been submitted and if an aircraft does not carry a secondary surveillance radar transponder on board. For the purpose of safety, in cases, when VFR manned aircraft fly exactly at 500 ft, there should be a safety area established for the purpose of keeping manned and unmanned unidentified aircraft clear of each other.

Consequently, the upper limit for UAS without having a flight plan, without any notification to ATC, should not exceed 400 ft above the ground. Lowest altitude for such flights depends on RPAS used and operator's decision, but must be clear of obstacles, without causing any risk to buildings, people etc., away from segregated areas. In uncontrolled airspace (class G airspace in Riga FIR) up to altitude 400ft, a maximum speed limit is required for RPAs, which fly without a valid flight plan, NOTAM or transponder on board – 50kts.

In order to describe the need for another restriction in defining maximum operational vertical distance and related rules, two parameters have been used – Minimum Sector Altitude (MSeA) and Minimum Safe Altitude (MSA). ICAO defines MSeA as the lowest altitude that may be used under emergency conditions that provides a minimum clearance of 300 meters (1000 feet) above all obstacles within a sector of a circle of 46 kilometers (25 NM) centered on a navigational aid. MSA is defined as an altitude depicted on an instrument approach chart and identified as the minimum safe altitude which provides 1000 feet of obstacle clearance within a 25 NM radius from the navigational facility upon which the MSA is predicated. If the radius limit is other than 25 nm, it must be stated. This altitude is for emergency use only and does not necessarily guarantee navigation aid reception. When the MSA is divided into sectors and each sector is assigned a different altitude, the altitudes in these sectors are referred to as "minimum sector altitudes".

Minimum Sector Altitude (MSeA) should be established as the upper reference point for UAS flights with a valid flight plan and notification to ATC. Taking into account the fact that in Riga FIR it is prohibited to fly in accordance with instrument flight rules (IFR) below 4500 feet, only VFR flights might operate at lower altitudes. But in a state of emergency manned aircraft might descend to MSeA. For this reason, a buffer zone should be established to provide minimum separation for manned aircraft, which have priority. According to ICAO PANS-ATM Doc4444 a "500ft separation minima might be applicable as a contingency measure". The highest operational altitude for such aircraft shall be MSeA-500ft. Consequently,

**Highest Altitude for such RPAS= MSeA-500ft**

When flying above 400ft, but below MSeA, a notification to ATC and other airspace users is mandatory. This shall be done as a special NOTAM. This way all air traffic, operating in uncontrolled airspace of Riga FIR without flight plan, would know, approximately in which area RPAS might operate, at what altitudes and maximum speeds. The difference for this flight area is that maximum take-off weight (MTOW) of the RPAS shall also be taken into consideration. If aircraft's MTOW is 2.5kg or below, it shall not be operated at speeds above IAS 50kts. If such aircraft intends to operate at higher speeds, then it shall comply with all requirements for RPAS with MTOW above 2.5kg.

If MTOW of UAS is above 5kg, then, in addition to NOTAM, SSR transponder is also required. SSR Mode A shall give identification of an aircraft (four-digit identification code or squawk), Mode C shall provide altitude indication and according to requirements stated by Eurocontrol, Mode S transponder shall also be used. If UAS is equipped with SSR transponder, then it is also visible on ATC displays and ATC is able to provide the necessary service. Moreover, SSR Mode A code gives opportunity using Radar Data Processing and Display System (RDPDS) to associate the SSR response shown on the radar screen with the flight plan of that particular flight. Basic guidelines of possible RPAS procedures in Riga FIR are summarized in Table 2.

Apart from valid flight plan and transponder on board, it is needed to file a NOTAM, as it was said above.

NOTAM is a short message, which contains vital information, which should be passed to all airspace users in order to inform them about any special activities, conditions of navigation or communication aids, or any other relevant notes. ICAO Annex 11 defines NOTAM as a notice containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.

For any RPAS, which operates above 400ft in class G airspace, a special NOTAM is required. Notification about the part of airspace, within which the flight is performed, is needed in case of RPAS emergency or any other unforeseen circumstances. The way of RPAS perform after any communication failure between RPAS and the operator or RPAS and ATC strongly depends on the type of control system (or autopilot), which is used for the particular RPAS. Consequently, it is not known how each RPAS will act in case of any emergency, and, if communication is lost, then such flight technically cannot comply with any requirements. To reduce risk which might arise to other airspace users, NOTAM (notice to airmen) is a requirement. Procedures for RPAS operation and summarized in Table 1.

Table 1

Established operational procedures for RPAS in Riga FIR controlled airspace

| Altitude | MTOW of RPA | |
|---|---|---|
| | Below or equal to 2.5kg | Above 2.5kg |
| ground - 400ft | - lowest altitude depends on RPAS operator's decision and aircraft must be clear of obstacles during the whole flight and cannot cause any danger to person's life, property, vehicles or nature;<br>- IAS (indicated airspeed) max 50kts | |
| 400ft - (MSeA-500ft) | - IAS max 50kts;<br>- NOTAM required with area, altitudes, MTOW and max IAS of the RPA involved | - NOTAM required with area, altitudes, MTOW and max IAS of the RPAS involved;<br>- Secondary surveillance radar (SSR) Mode A/C/S transponder required;<br>- flight plan required |
| above (MSeA-500ft) | - NOTAM required with area, altitudes, MTOW and max IAS of the RPAS involved;<br>- Secondary surveillance radar (SSR) Mode A/C/S transponder required;<br>- flight plan required | |

All flights, which are planned above MSeA-500 feet, shall be done in accordance with the rules, which are applicable to RPAS with MTOW above 2.5 kilograms above 400 feet.

**Establishment of NOTAM Message Format for Remotely Piloted Aircraft in Riga Flight Information Region**

To enable air traffic controllers to provide the necessary service, aircraft pilot or other person involved must submit a flight plan at definite times and using definite format, which is regulated by ICAO. In some cases, when it is needed to inform other airspace users about current or planned activities, a NOTAM message shall be submitted, the format of which is also regulated by ICAO. It is a specially coded message. This paper contains an established adjusted NOTAM message, its content, to provide more effective and clear information exchange about RPAS operation to other airspace users.

If it is necessary to pass information to other airspace users about the UAS flight in RIGA FIR, which will take place on a specific date, then it shall be written as:

**QAFLW**

AF – flight information region (second and third letters as a subject)

LW – will take place (fourth and fifth letter as a condition)

The third section is devoted to the type of traffic. In case of IFR letter “I” is inserted, letter “V” for VFR, “K”, if the NOTAM is a checklist, “IV”, if flight rules are combined. As UAS does not operate in accordance with any of these conditions, then it is suggested to use a specific letter for such flight.

**U- Unmanned aerial system in operation**

As for UAS operations and the fourth section dealing with purpose of the flight, a code for a NOTAM concerning flight operations shall be used.

**O- NOTAM concerning flight operations**

Scope of the flight

**A- aerodromes**

**E- en-route**

The sixth and seventh sections shall specify the upper and lower limit of the altitude, at which the UAV will operate. Each altitude shall be expressed using three digit code.

**000/999 – form ground to unlimited**

**000/003 – from ground to 300 feet AGL**

Coordinates or radius of the area, in which the UAS will operate. In brackets a name of the place or building should be given, which is located in the area of UAS operation for better understanding and perception of the information.

**565928N0240430E (EVRS, Spilve Airport)**

After consideration of a typical NOTAM format and introduction of possible changes related to UAS operations, there is an example provided, which might be used to inform other airspace users about UAS activities in Riga FIR.

**NOTAM example for UAS operation in Riga FIR**

A) This is an indication of the affected FIR

**EVRR - Riga FIR**

B) time and date, when the activities will start in the following order: year, month, date, time in UTC (yymmddtttt)

**1404031230**

C) time and date, when the activities will end in the following order: year, month, date, time in UTC (yymmddtttt)

**1404041400**

D) If the activities are going to take place for several days, then in this section time, when the planned actions will be in operation daily, shall be given:

**DAILY 1230-1400**

In addition there shall be information written in plain English, which would describe the intentions of UAS in more detail. This part of the NOTAM shall consist of six parts:

E) a message, which is written in plain language;

UAS TYPE shall be specified, including maximum operational speed, which shall be expressed as indicated airspeed nautical miles and designator IAS shall be added as well.

**UAS TYPE: XXXXX MAX IAS: 190KTS**

LATERAL LIMITS of the area, within which the UAS is going to operate. It shall be given in geographical coordinates or if the area is a circle, then as a radius from a specific geographical point. Information shall be given in nautical miles and coordinates following WGS-84 format (XXXXN0XXXXE).

**LATERAL LIMITS: 0.25NM RADIUS OF 565928N0240430E**

VERTICAL LIMITS shall specify the minimum and maximum altitude of the intended flight. Information shall be given in feet.

**VERTICAL LIMITS: FROM GROUND TO 300FT AGL**

TIME OF ACTIVITY shall specify the time in hours and minutes, when the event will take place. It shall be given as UTC. If not, then it shall be noted. (UTC – Universal Time coordinated; LCL – local time). Words “FROM” and “UNTIL” shall not be omitted.

**TIME OF ACTIVITY: FROM 12:30 UTC UNTIL 14:00 UTC.**

OPERATOR LOCATION shall be added as well, because UAS operates as a system – the UAV (unmanned aerial vehicle) and the operator. In case of emergency or any other extraordinary situation this information might be useful. It shall be expressed following the WGS-84 format for geographical coordinates.

OPERATOR LOCATION:

**OPERATOR LOCATION: 565928N0240430E (EVRS, Spilve Airport)**

CONTACT DETAILS of a person involved. UAS NOTAM shall include also a phone number of the UAS operator.

**TEL. + 371 2745 45 45**

F) once again, the lower altitude, at which the flight will operate, shall be given. In this case:

**GND – ground**

E) once again, the upper limit, at which the flight will operate, shall be given. In this case:

**300ft - 300 feet**

Consequently, the whole NOTAM message shall look like this:

**EVRR - RIGA FIR**

**B0001/14 NOTAM**

**Q) EVRR/QAFLW/U/OE/000/003/565928N0240430E**

**A) EVRR B) 1404031230 C) 1404041400**

**D) DAILY**

**E) UNMANNED AERIAL SYSTEM OPERATION TYPE: XXXX/ MAX IAS 190KTS. LATERAL LIMITS: 0.25NM RADIUS OF 565928N0240430E. VERTICAL LIMITS: FROM GROUND TO 300FT AGL. TIME OF ACTIVITY: FROM 12:30 UTC UNTIL 14:00 UTC OPERATOR LOCATION: 565928N0240430E (EVRS, Spilve Airport) TEL. + 371 2745 45 45.**

**F) GND G) 300FT**

### 8.3. Riga Flight Information Region Sectorization Depending on Air Traffic Intensity from Ground to FL100

Riga Flight Information Region (FIR) is a part of North Europe airspace, which consists of airspace extending upwards from the territory of Latvia, and a part of the Baltic Sea, which according to Chicago Convention is delegated to Latvia (Figure1). Also in this airspace the number of RPAS flights is growing. In order to find out how safe it is to operate in the airspace mentioned above, air traffic flow analysis has been done.

Air traffic intensity analysis has been done in the time period from January 1, 2010 until December 31, 2015. The flight data have been divided into MSeA sectors depending on each flight route. In total there are 23 MSeA sectors as shown in Figure 1. Each flight had been analyzed taking into consideration its aerodrome of departure, airport or navigation point of its destination. Consequently, the total number of flights, which crossed each MSeA sector in a definite time period was found.

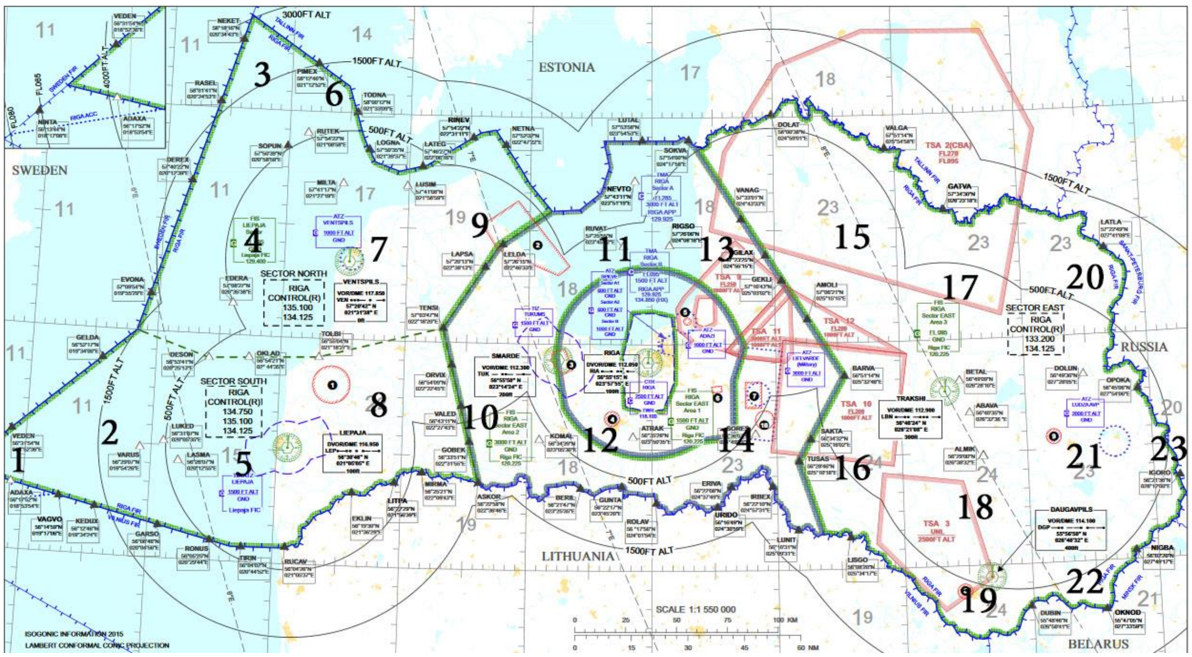


Figure 1. MSeA diagram for Riga FIR [38.].

The example of air traffic flow analysis is shown using data from year 2012. These data had been divided into three parts according to time of flights – from January until April, from May until August, from September until December. Each route was analyzed depending on its actual point of entrance and exit into Riga FIR. If it was a transit flight, when country's border was crossed, then entry and exit point of Riga FIR was taken. If the flight's departure and destination aerodrome was the same, then point of that aerodrome was taken twice. All points and aerodromes have been designated using official ICAO designators with four letters, if it is an aerodrome or airport, such as EVRA form Riga International airport, or five-letter designator, if it is a navigation point, such as NINTA, which is on the border between Riga and Sweden FIR. A part of data as an example is shown in Table 2.

To protect Latvian Air Navigation Service Provider's policy and rights, air traffic intensity is shown in percent from the total number of flights, not in absolute values.

Table 2

Riga FIR Flight Intensity Division Depending on Flight Route from Ground to FL100

| ROUTE | Air Traffic Intensity, % from total | ROUTE | Air Traffic Intensity, % from total |
|---|---|---|---|
| ERIVA- EVRA | 3.11 | LUTAL- BERIL | 0.62 |
| EVAD- SOKVA | 0.62 | LUTAL- EVRA | 3.11 |
| EVRA- EVRA | 1.86 | NINTA- IGORO | 0.62 |
| EVRA- LATEG | 1.24 | PARKS- VISTA | 0.62 |
| EVRA- NEKET | 52.17 | RASEL- EVRA | 0.62 |
| EVRA- SOKVA | 2.48 | SOKVA- GUNTA | 0.62 |
| EVRS- EVRA | 1.24 | SOKVA- NINTA | 0.62 |

Each MseA sector was considered separately, and each flight was considered according to its route. For example, if a flight was committed from Riga International Airport EVRA to Sweden, crossing the border over point NEKET, then the flight crossed MSeA sectors 3, 6, 7, 9, 11 and 12.

Furthermore, air traffic density in each MSeA sector was found and was related to flight safety – the more congested the sector is, the greater is risk to meet another aircraft. There were 5 intensity classes introduced, which later were used in the analysis. These classes are: very low, low, low to medium, medium, high. This classification is shown in Table 3.

Table 3

Air Traffic Intensity Division into Intensity Groups

| | Air Traffic Intensity | Group | Meaning | Associated Colour |
|---|---|---|---|---|
| 1 | 1 ... 50 | VL | Very Low | |
| 2 | 51 ... 100 | L | Low | |
| 3 | 101 ... 150 | L/M | Low to Medium | |
| 4 | 151 ... 200 | M | Medium | |
| 5 | 201 un vairāk | H | High | |

Consequently, all 23 MSeA sectors were classified in accordance with Table 3 criteria. As the considered time period was divided into three parts, the results of each part separately were displayed on aeronautical chart. This way it was possible to get information, which would also show seasonal effect on air traffic intensity.

Such information display – on aeronautical charts – gives a better understanding and better interpretation of the information concerned. As an example there is such aeronautical chart with colour-coded information for air traffic intensity in Riga FIR from May to August, 2012.

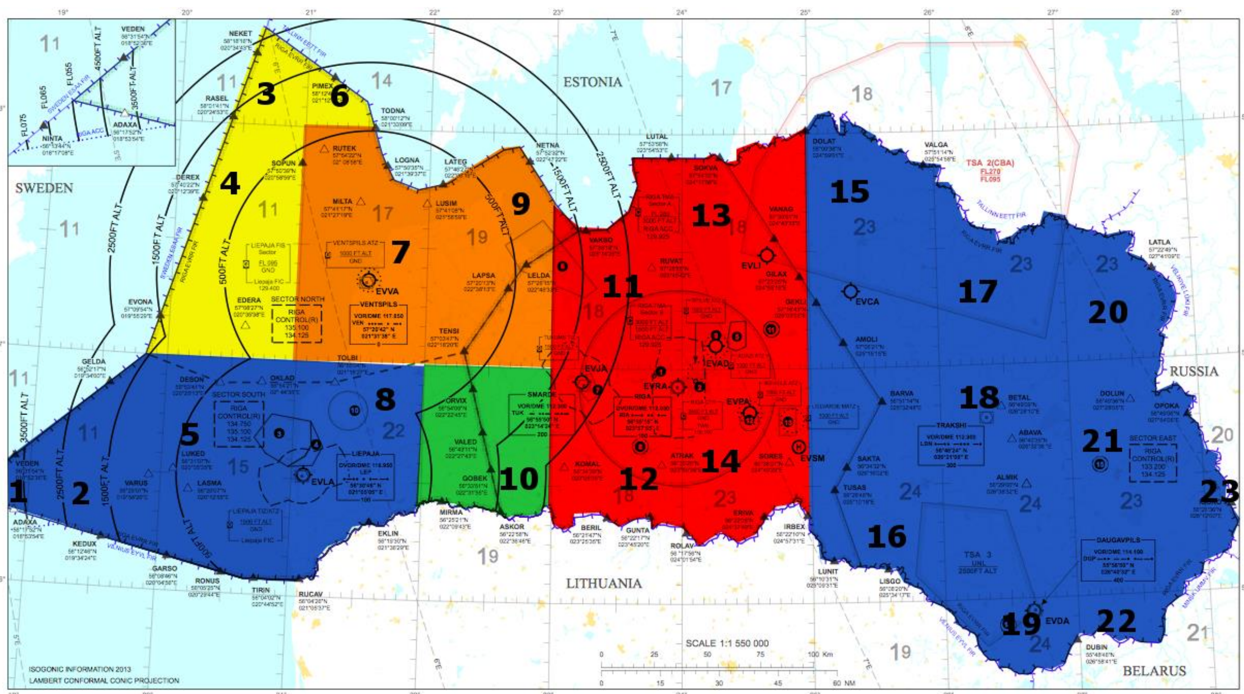


Figure 2. MSeA Sector Colour Coding Depending on Air Traffic Intensity from May until August, 2012.

It can be seen from the diagram that a part of Riga FIR with MSeA sectors 15 to 23, the Eastern part of Latvia, is the least congested airspace. This means that air transport operations, including RPAS, would be the safest in cases, when the aircraft commits a flight without receiving any service from appropriate ATS authority – flight information or air traffic control service. Very low traffic intensity has been recorded also in sectors 1, 2 and 5. The flight intensity in sectors 4, 6 and 7 changes noticeably depending on the time of the year, especially in summer time (from May to August). The most congested part of Riga FIR is the central part, first of all because International Airport Riga is located there, as well as aerodrome Spilve, which is frequently used for practical pilot training purposes.

Air traffic intensity, which was recorded in year 2012 from January until April was displayed on a 3D chart as shown in Figure 3. Here it is seen that the most intense traffic was observed in the central part of Latvia, and the most intense route was from the radio navigation point RIA until navigation point NEKET. The least congested airspace is in the Eastern part of Latvia, which, consequently, is considered to be the safest for flights without a valid flight plan and instructions from ATC.

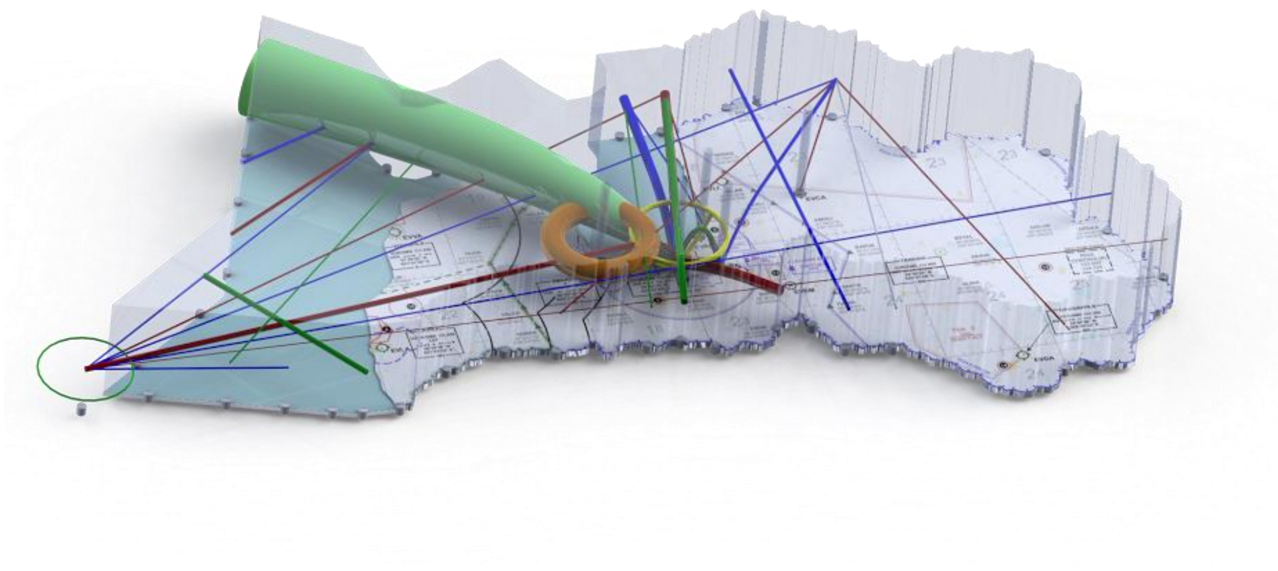

Figure 3. Air traffic intensity depending on route in Riga FIR from January until April, 2012 in 3D projection.

### 8.4. Mathematical Modeling of Air Traffic Intensity Analysis in Riga Flight Information Region

Mathematical modeling is used to analyze different processes, which consider changes of that process in time. One of such mathematical models is Autoregressive Integrated Moving Average ARIMA, which is used to forecast time series future tendency by using integration of discrete time series values. The result of such integration is a sequence of “static” values. The value of time series is considered to be static, if its properties do not change in time. Stationary series do not have a trend, its variation around mean value has constant amplitude, and the changes of the amplitude show periodic properties. ARIMA mathematical model comprises two parts:

a) Autoregressive model, which is designated as (AR);
b) Moving Average model, which is designated as (MA).

Autoregressive model is a mathematical model, in which one variable value is compared with variable values from previous periods. AR(p) is autoregressive model, which consists of p-number periods:

$$y_t = \mu + \sum_{i=1}^{p} \gamma_i \gamma_{t-i} + \epsilon_t, \tag{1}$$

where:

$y_t$ – dependent value in time period t

μ – constant

p – number of period in time series

$\gamma_i$ – autoregression coefficient

$\gamma_{t-I}$ – value of the previous period

$\varepsilon_t$ – “white noise”

Simple AR model can be written by using AR(1). In this case the value of time series in the considered period can be expressed like this:

$$y_t = \mu + \gamma y_{t-1} + \epsilon_t = \mu + \gamma(Ly_t) + \epsilon_t \text{ or} \tag{2}$$

$$(1 - \gamma L)y_t = \mu + \epsilon_t \tag{3}$$

If $y_t$ designated the value of the variable in time t, then $y_{t-1}$ designates the value of time series in previous time period t-1. This element can also be written as $Ly_t$, as it is shown in the equations.

Moving average (MA) model defines relation between the variable and the values of time series from the previous periods. MA(q) is the moving average mathematical model with q number of periods:

$$y_t = \mu + \epsilon_t + \theta_i \epsilon_{t-1}, \text{ kur} \tag{4}$$

$\Theta_q$ – coefficient for the lagged error term in time t-q.

MA(1) coefficient shows how previous period affects the current situation;

MA(2) coefficient shows how period, which was two periods before, affects the current situation;

MA(3) coefficient shows how period, which was three periods before, affects the current situation.[1]

ARIMA model usually is written as ARIMA (p, d, q), where

P – autoregressive polynomic order;

D – integration order;

Q – moving average order.

If ARIMA model comprises also seasonal components, then such model is written by using three more parameters:

**ARIMA (p, d, q)(P, D, Q)$_s$,**

where

p – autoregressive polynomic order;

d – integration order;

q – moving average polynomic order;

P – seasonal autoregressive polynomic order;

D – seasonal average integration order;

Q – seasonal average polynomic order;

S – seasonality component. [2.]

For air traffic analysis in Riga FIR for flights from ground to FL100 the previously described mathematical model ARIMA was used. Data analysis and forecast were done using statistics program "R Studio 3.2.4." for the purpose of forecasting possible air traffic intensity in each MSeA sector of Riga FIR. There are 23 MSeA sectors as shown in Figure 1.

As it was previously mentioned, ARIMA model consists of two parts – (p, q, d), which considers time-series changes, and (P, Q, D), which considers seasonality effect on time-series. Figure 4 shows a simplified ARIMA model. There are three or 3 knobs used, and each of them is related to one of the previously mentioned ARIMA components or functions – p, q, d, P, Q, D. The main goal of the model it to adjust the knobs in a way to filter out the "white noise" of time-series.

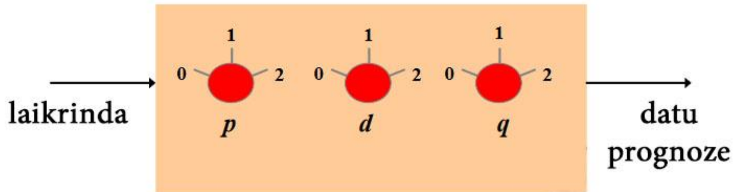


Figure 4. Basic principles of ARIMA mathematical model [2.].

Using ARIMA in “R Studio” in the beginning it is necessary to check, whether the data in each MSeA sector are a stationary or non-stationary process, as this mathematical model is applicable only to stationary time series (Each MSeA sector was analyzed separately). Stationary process is a stochastic process, whose joint probability distribution does not change when shifted in time. This was done by using Unit Root Test, the outcome of which is p-value. Unit Root Test can be done by using Dickey-Fuller Test, the resultant coefficient of which will give the answer to null test. If p value is less than 0.05 ($p < 0.05$), then the sequence is not a stationary process. The next step in ARIMA modelling is the correlation check, which uses autocorrelation function ACF and partial autocorrelation function PACF. These two coefficients will be used to find out the order of autoregression and moving average. ACF is a diagram with correlation bars, which shows correlation between time series and orders. PACF isolates a few parameters, for this reason, ACF function shows the resultant value slower. If PACF integrated bars show rapid changes and/or lag-1 autocorrelation is positive, then AR value in the model shall be increased. The order, in which PACF value closes, is the resultant one. And the other way round, if the integrated time series show rapid decrease and/or lag-1 autocorrelation is negative, then it is necessary to increase the MA order in the model. The integrated order, in which ACF rapidly decreases, shows the resultant MA value. [29.]

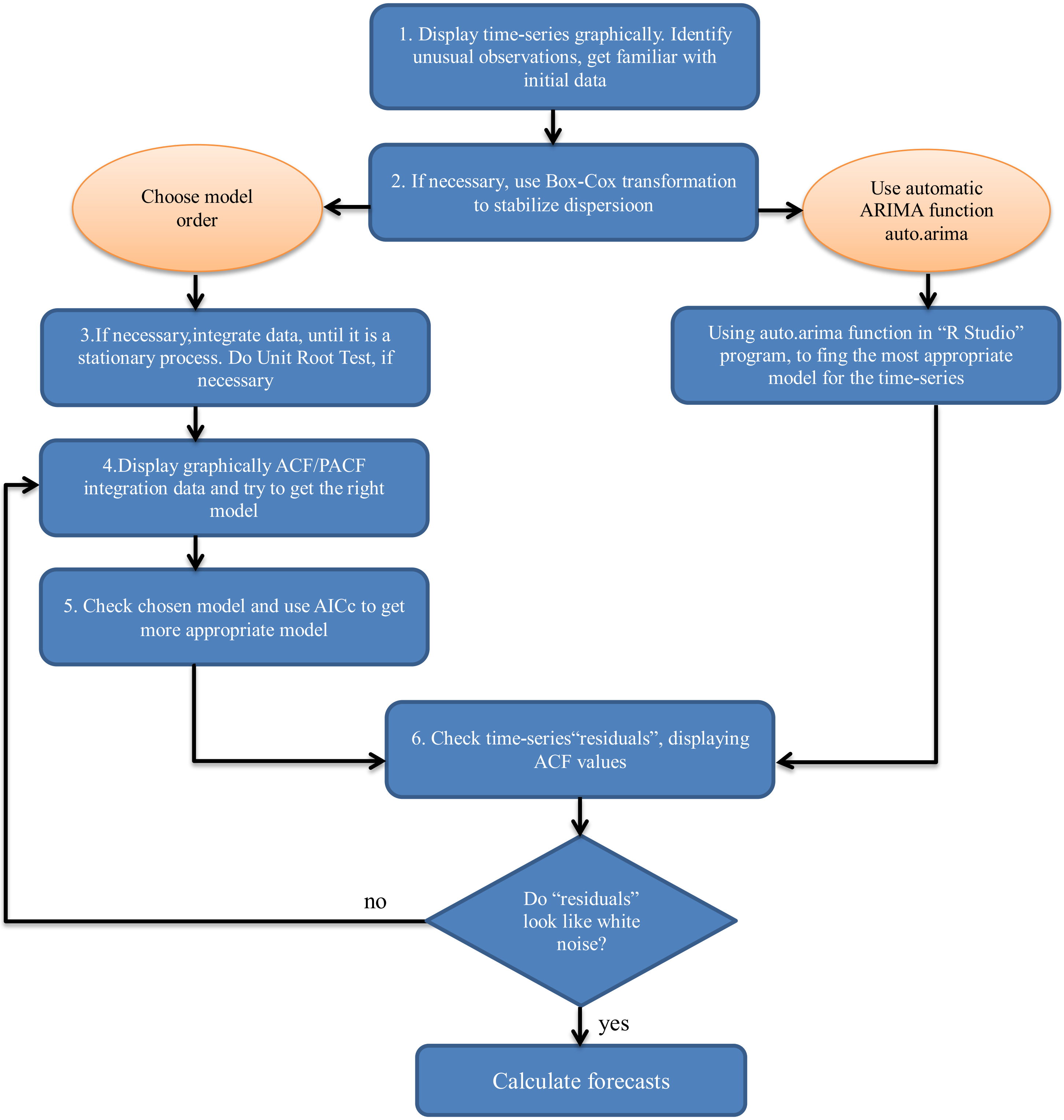


Figure 5. ARIMA Mathematical Model Algorithm.

In order to do the analysis of air traffic intensity in Riga FIR from ground to FL100, ARIMA mathematical model was used. Later using the same model air traffic intensity forecast was done to see possible values of air traffic intensity in the next two years.

For mathematical modeling and forecast program "R Studio 3.2.4." was used. This program gives opportunity to do the analysis either manually or automatically. The greatest attention was paid to each MSeA sector's median or the middle value of time-series data – half of the values are greater than median and half- smaller. Median describes the situation more precisely than arithmetical mean, if there are some very large or small values. Furthermore, median values are shown in Figure 5. [5.]

The highest air traffic intensity was observed in sectors from 12 to 14, which are in the middle part of Riga FIR, which is connected with the presence of International Airport Riga. But the lowest flight intensity was observed in Eastern part of Latvia, where MSeA sectors from 16 to 23 are located. Air traffic intensity can directly be connected with flight safety – the greater the traffic flow is, the greater is probability to meet another aircraft on the way. Later statistics data are represented on aeronautical chart, which is shown in Figure 6.

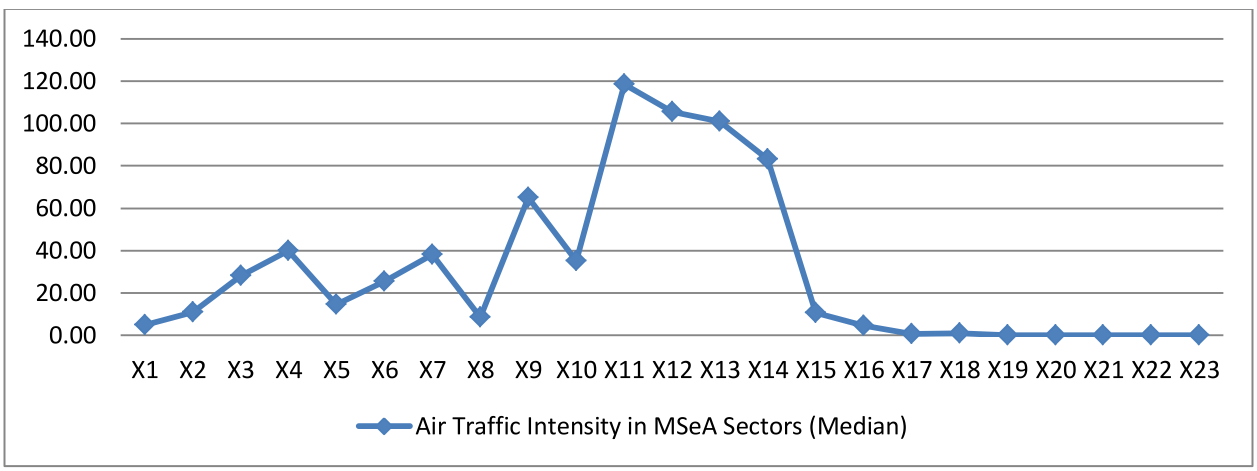


Figure 6. MSeE sectors median value for air traffic intensity in Riga FIR from 2010 until 2015 from ground to FL100, aircraft.

**Analysis of Median Value for each MSeA Sector**

Using the data from "R Studio" summary, it is possible to obtain an aeronautical chart for Riga FIR, which will show five-level air traffic intensity from ground to FL100. These five levels are based on median value. As these values are in the range from 0 to 120, then the following division has been used:

a) Air traffic intensity from 0 to 25, excluding those, to which blue colour is assigned;

b) Air traffic intensity from 25 to 50, excluding those, to which green colour is assigned;

c) Air traffic intensity from 50 to 75, excluding those, to which blue, yellow is assigned;

d) Air traffic intensity from 75 to 100, excluding those, to which orange colour is assigned;

e) Air traffic intensity from 100 and more, to which red colour is assigned;

Air traffic intensity from ground to FL100 from year 2010 until 2015 median values and their division are shown in Table 4 and Figure 7.

Table 4

MSeA sector median value for air traffic intensity in Riga FIR from year 2010 until 2015 for altitudes from ground to FL100

| Air traffic intensity interval (SII) | Corresponding MSeA sector | Corresponding colour in Riga FIR | |
|---|---|---|---|
| $0 < SII > 25$ | 1, 2, 5, 8, 15, 16, 17, 18, 19, 20, 21, 22, 23 | Blue | |
| $25 \leq SII_1 < 50$ | 3, 4, 6, 7, 10 | Green | |
| $50 \leq SII_2 < 75$ | 9 | Yellow | |
| $75 \leq SII_3 < 100$ | 14 | Orange | |
| $100 \leq SII_4$ | 11, 12, 13 | Red | |

Further there is a description how to get the most appropriate ARIMA model (p, q, d)(P, Q, D) orders, which later on will be used in ARIMA forecast. It is possible to get ARIMA autoregressive coefficients AR, seasonality SAR and Intercept values as well. There is also a standard deviation given for each coefficient and is designated as s.e.

In the beginning model (1,0,0)(1,0,0) was chosen, but after that other models were used for manual model selection to check, whether it is the most appropriate. In “R Studio” the code is written in the following way:

```
> arimax14_1 <- Arima(Book1X14,order=c(1,0,0), seasonal=c(1,0,0))
> print(arimax14_1)
Series: Book1X14
ARIMA(1,0,0)(1,0,0)[3] with non-zero mean


Coefficients:
         ar1     sar1  intercept
      0.3616   0.6649   103.2208
s.e.  0.2089   0.1715    37.8521
```

```
sigma^2 estimated as 2436:  log likelihood=-95.06
AIC=198.12   AICc=201.2   BIC=201.68
```

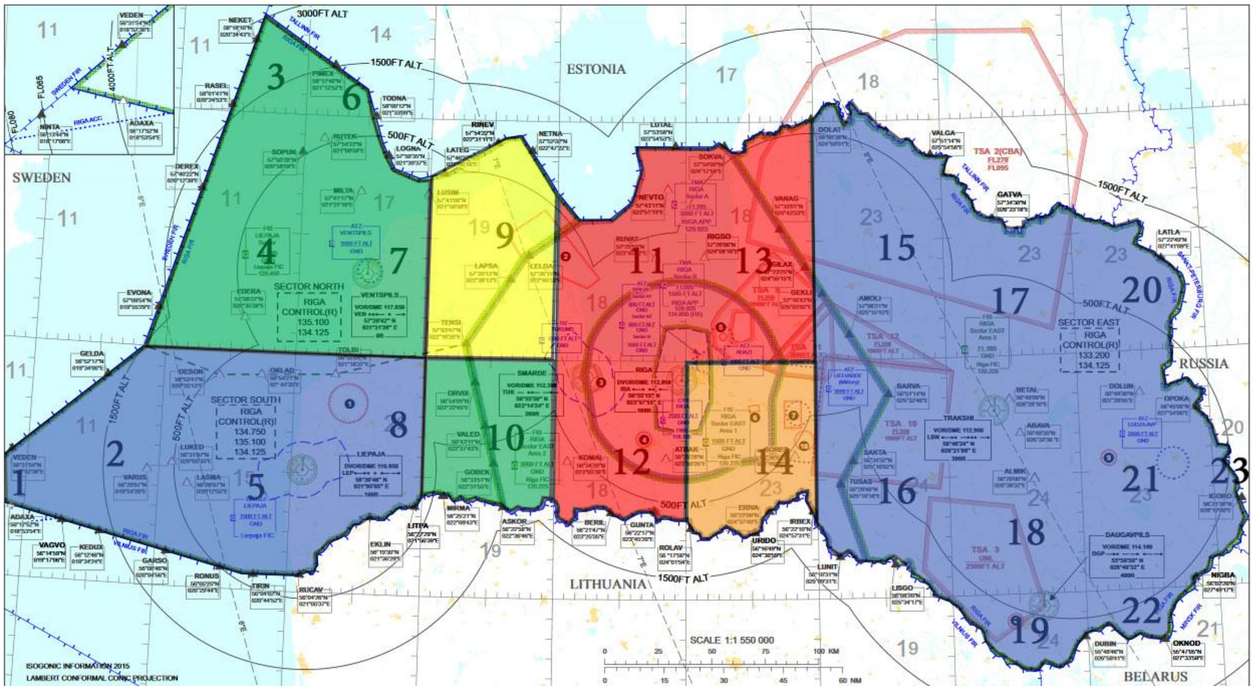


Figure 7. MSeA sector median values for air traffic intensity in Riga FIR from ground to FL100, aircraft.

ARIMA model shall be chosen in way to have the smallest AR SAR and I coefficient values. To check the results, whether it is the smallest value of the coefficient, the same actions shall be done using other models. An example for manual ARIMA model selection is shown in Table 5, where as an example MSeA sector 14 have been used.

The coefficients given by “R Studio” AIC, AICc and BIC are used to check the chosen ARIMA model’s accuracy. Also these coefficients shall be the smallest possible. In Table 5 the smallest values are coloured green. From here it is seen that manually and automatically selected model (1,0,0)(1,1,0) is the most appropriate for MSeA sector 14.

Table 5

Example for manual ARIMA model selection

| | **p,q,d** | **P,Q,D** | **AR** | **AR_s.e** | **AR** | **AR_s.e** | **MA** | **MA_s.e** | **SAR** | **SAR_s.e** | **Intercept** | **Intercept_s.e** | **AIC** | **AICc** | **BIC** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1,0,0 | 1,0,0 | 0.3616 | 0.2089 | | | | | 0.6649 | 0.1715 | 103.221 | 37.8521 | 198.12 | 201.2 | 201.68 |
| 2 | 0,0,0 | 1,1,0 | | | | | | | -0.2842 | 0.2396 | | | 165.3 | 166.3 | 166.72 |
| 3 | 1,0,0 | 1,1,0 | 0.7967 | 0.1465 | | | | | -0.7743 | 0.1481 | | | 156.7 | 158.88 | 158.82 |
| 4 | 2,0,0 | 1,1,0 | 1.0552 | 0.3287 | -0.2608 | 0.3037 | | | -0.8352 | 0.1297 | | | 158.01 | 162.01 | 160.84 |
| 5 | 1,0,1 | 1,1,0 | 0.7676 | 0.1723 | | | 0.1607 | 0.2743 | -0.8094 | 0.1436 | | | 158.36 | 162.36 | 161.2 |
| 6 | 0,0,0 | 1,1,0 | | | | | | | -0.2842 | 0.2396 | | | 165.3 | 166.3 | 166.72 |
| auto | 1,0,0 | 1,1,0 | 0.7967 | 0.1465 | | | | | -0.7743 | 0.1481 | | | 156.7 | 158.88 | 158.82 |

From here it is seen that the smallest SAR values are -0.7743 and SAR_s.e. 0.1481. P-value is checked by finding the division of these values. As previously mentioned, this is called Dickey-Fuller test. Correspondingly:

$$\text{p-value}_{\text{MSeA14}} = \frac{-0.7743}{0.1481} = 5.2282 > 1.96 \qquad (5)$$

As the result of division is greater than 1.96, which corresponds to 95% accuracy range, then the time-series is considered a stationary process.

Table 6

ARIMA modeling automatic autoregressive, integration and seasonality coefficients and the most appropriate ARIMA model for each MSeA Sector in Riga FIR, coefficients

| Sector | ARIMA order | Sesonal order | Note | AR1_1 | AR1_s.e. | MA_1 | MA_s.e. | Intercept | Intercept_2 | SAR1_1 | SAR1_s.e. | SMA_1 | SMA_s.e. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0,0,1 | 1,1,0 | | | | | | | | -0.6788 | -0.6788 | | |
| 2 | 0,0,0 | 1,1,0 | | | | | | | | -0.5684 | 0.2015 | | |
| 3 | 0,1,0 | | | | | | | | | 758.9 | -80.49 | | |
| 4 | 0,1,0 | 1,0,0 | | | | | | | | 0.4768 | 0.1997 | | |
| 5 | 0,0,0 | 1,1,0 | | | | | | | | -0.6531 | 0.1797 | | |
| 6 | 0,1,0 | | | | | | | | | 589.8 | -78.35 | | |
| 7 | 0,1,0 | 1,0,0 | | | | | | | | 0.5281 | 0.1854 | | |
| 8 | 0,0,0 | 2,0,0 | with non-zero mean | | | | | | 12.0614 | 0.2262 | 0.5982 | | |
| | | | | | | | | | 3.9821 | 0.1923 | 0.218 | | |
| 9 | 0,1,0 | 1,0,0 | 3 | | | | | 1196 | | 0.687 | 0.1417 | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 0,0,0 | 1,0,0 | 3 | | | | | 33.2982 | 8.4502 | 0.5664 | 0.1745 | | |
| 11 | 1,0,0 | 0,1,0 | 3 | 0.5764 | 0.217 | | | | | | | | |
| 12 | 1,0,0 | 0,1,0 | 3 | 0.5328 | 0.2172 | | | | | | | | |
| 13 | 0,1,0 | 1,0,0 | 3 | 0.8098 | 0.104 | | | | | | | | |
| 14 | 1,0,0 | 1,1,0 | 3 | 0.7967 | 0.1465 | | | | | -0.7743 | 0.1481 | | |
| 15 | 0,0,0 | 0,1,0 | 3 | 95.93 | | | | | | | | | |
| 16 | 1,0,0 | 1,1,1 | with drift-0.3429/0.0611 | -0.9589 | 0.0582 | | | | | -0.0798 | 1.4114 | 10.1634 | 1.4025 |
| 17 | 1,1,0 | | | -0.7366 | 0.1978 | | | | | | | | |

**Air Traffic Intensity Forecast in Riga Flight Information Region Using ARIMA Model**

ARIMA mathematical modeling and statistics program “R Studio” can be used not only for analysis of the current data, but also to forecast the intensity in the future to see the tendency.

Previously obtained ARIMA models (p, q, d)(P, Q, D) will be used for forecasting of flight intensity in each MSeA sector in Riga FIR for years 2016 and 2017. The forecast results for MSeA sector 14 are shown in Figure 8.

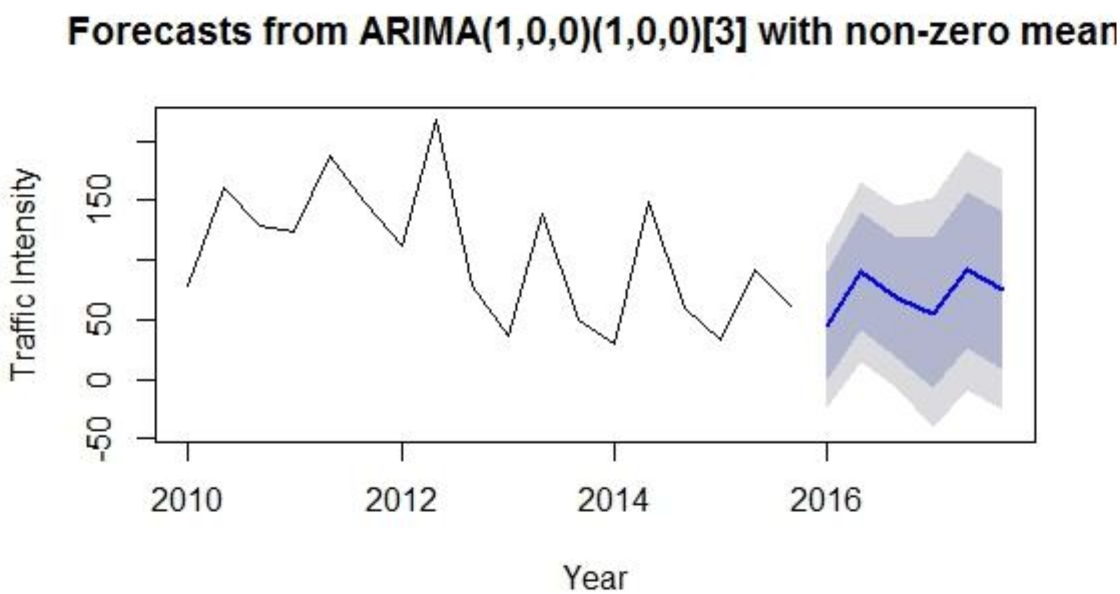


Figure 8. ARIMA air traffic intensity forecast for Riga FIR MSeA sector 14, aircraft.

The obtained ARIMA forecast data show the forecasted values in the chosen time period, as well as with two probability classes – 80% and 95%. Such values for MSeA sector 14 are shown in Table 7.

Table 7

ARIMA air traffic intensity forecast for MSeA sector 14 in Riga FIR, aircraft

| | Time period | Forecast | Lo 80 | Hi 80 | Lo 95 | Hi 95 |
|---|---|---|---|---|---|---|
| Sector 14 | | | | | | |
| | 2016_1 | 60.43 | 14.79 | 106.08 | -9.37 | 130.24 |
| | 2016_2 | 157.50 | 99.14 | 215.86 | 68.25 | 246.75 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 2016_3 | 82.08 | 16.92 | 147.23 | -17.57 | 181.72 |
| | 2017_1 | 48.98 | -24.23 | 122.18 | -62.98 | 160.93 |
| | 2017_2 | 109.14 | 31.26 | 187.03 | -9.97 | 228.26 |
| | 2017_3 | 85.26 | 4.55 | 165.98 | -38.18 | 208.71 |

From Table 7 it is seen that the highest air traffic intensity is expected in the second quarter of year 2016, but the lowest intensity – in the first quarter of 2017. The results for other MSeA sectors are shown in Annex 3.

In Figure 8 there are ARIMA forecast values for the second quarter of year 2016.

Table 8

ARIMA air traffic intensity forecast for Riga FIR MSeA sectors in the second quarter of year 2016, aircraft

| **MSeA sector** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|
| Air traffic intensity forecast, aircraft | 11.82 | 31.29 | 6.00 | 25.83 | 40.65 | 4.00 | 20.92 | 22.71 |
| **MSeA sector** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |
| Air traffic intensity forecast, aircraft | 35.61 | 38.23 | 113.99 | 101.56 | 90.63 | 157.50 | 27.00 | - |
| **MSeA sector** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | |
| Air traffic intensity forecast, aircraft | 0.78 | 1.44 | 0.00 | 0.00 | 1.02 | 0.00 | 0.33 | |

From the forecast results in Table 8 it is seen that the highest intensity is expected in MSeA sector 13, reaching the value of 113.99 aircrafts. The lowest intensity is expected in the Eastern part of Riga FIR from sector 17 to 23, where only 0 to 1.2 aircraft are expected. Air traffic intensity forecast results for each MSeA sector are shown in Figures 9 and 10.

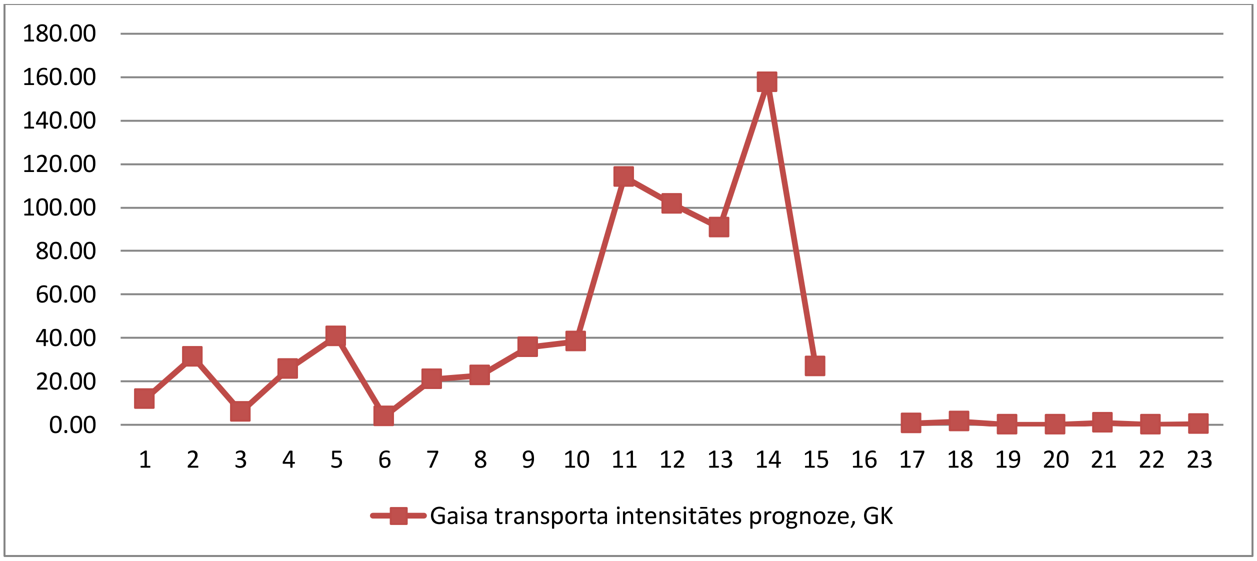


Figure 9. ARIMA air traffic intensity forecast for Riga FIR MSeA sectors in the second quarter of year 2016, aircraft.

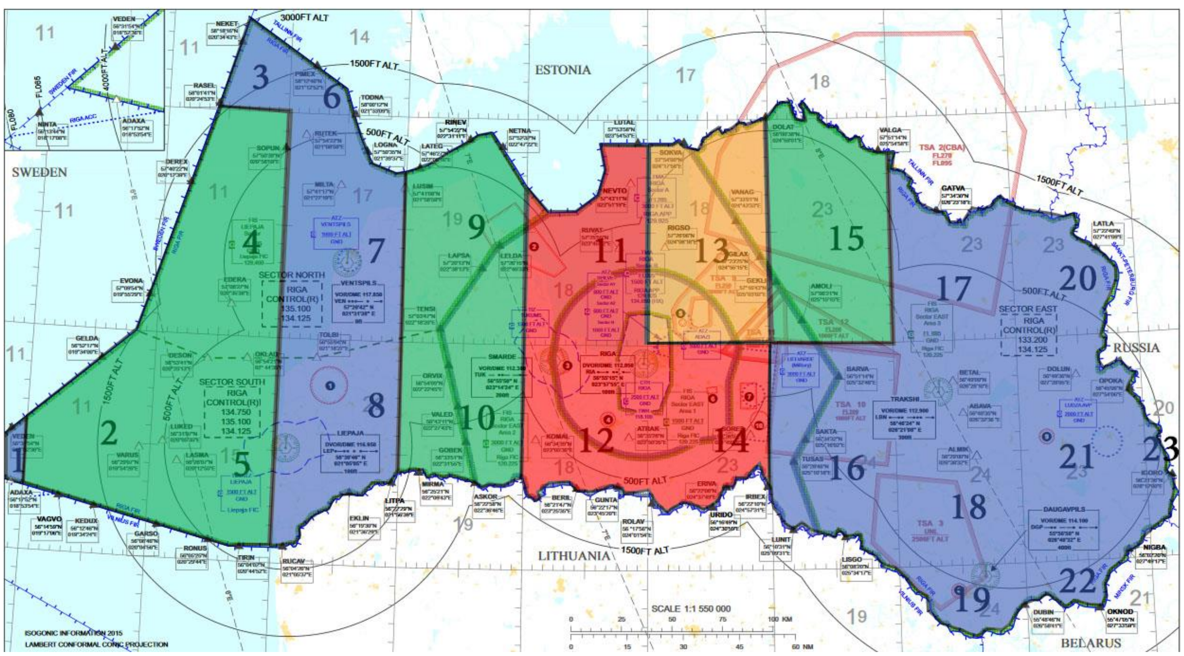


Figure 10. ARIMA air traffic intensity forecast for Riga FIR MSeA sectors in the second quarter of year 2016, aircraft.

### 8.5. Training programs

The fifth chapter of this work is devoted to establishment of training programs for RPAS operators and air traffic control officers. Training programs are established in accordance with the first part of article 72 of the State Administration Structure Law, internal rules of the Ministry of Education and Science, which determine order how education programs are established and organized. Correspondingly, RPAS training programs are referred to professional development education programs.

Each training program consists of two parts – theory and practical training, as well as tests of knowledge and internship. In accordance with requirements there are entry requirements established for each part of the training program – for RPAS operators and also for ATC. Candidates, who have successfully passed the tests, at the end of the course will get a certificate, which correspondingly will give opportunity to operate RPAS in Riga FIR.

# 9. CONCLUSIONS

1. As a result of international, European and Latvian RPAS legislation analysis, it was found that there are no definite rules or laws, which regulate RPAS operations in different parts of airspace. Current situation encourages to concentrate on local legislation establishment to eliminate possible danger caused by RPAS to flight safety, privacy and conflicts of interest.
2. Technical equipment of RPAS shall be sufficient to be able to do the same functions as manned aircraft depending on the class of airspace. Communication equipment shall guarantee two-way communications between RPA and its control station by using command and control link C2. If the class of airspace requires so, it is necessary to establish two-way radio communications between RPAS and associated ATC unit, as well as other airspace users. Navigation equipment shall give opportunity to determine RPA position, track and altitude at any times, but surveillance equipment shall contain secondary surveillance radar transponder in Mode A/C/S. Additionally, Detect and Avoid or Sense and Avoid systems shall be used.
3. New adjusted formats for a NOTAM message and a fight plan for RPAS operation were established to make information exchange between different airspace users more effective. NOTAM message shall contain information about RPAS type, including its maximum indicated airspeed, operation zone lateral and vertical limits, planned activities time, and operator's position and phone number.
4. RPAS operational procedures for operation in Riga FIR controlled airspace were established. In accordance with Annex 2 to Chicago Convention "Rules of the Air", aircraft flying in accordance with visual flight rules shall maintain at least 500 feet separation from the highest

obstacle or from the ground. When establishing operational procedures, it was taken into account, moreover, additional 100 feet buffer zone was added, as a result getting maximum height 400 feet, where there is no risk of collision between manned and unmanned aircraft. As in case of emergency an aircraft can descend to MSeA altitude, then adding 500 feet buffer zone can get MSeA-500 feet vertical distance limit, where RPAS will avoid collisions with IFR or commercial aircraft. RPAS operational procedures outside segregated airspace shall be controlled depending on its maximum take-off weight, operational height and technical equipment.

5. The analysis of air traffic flow in Riga Flight Information Region in time period from 2010 until 2015 showed that the most intense traffic was on route from Riga International Airport, which internationally is designated as EVRA, until navigation point NINTA, which is located on the border between Riga and Sweden FIR. Data showed that 52.17% of the whole traffic went in this direction. When dividing Riga FIR into MSeA sectors, the analysis of air traffic flow in the same time period showed that in the first quarter of year 2015, from January until April respectively, the most intense traffic was in the central part of Riga FIR – 140 up to 143 flights. The least intensity was observed in the Eastern part of Latvia, 0 to 4 flights. In the summer time, from May until September, the most intense was the central part of Riga FIR, 257 until 264 flights, but the lowest intensity in the Eastern part, 0 to 8 flights. In the third quarter of year 2015, from September until December, the most intense traffic flow was also in the central part of Riga FIR, in the range from 118 to 119 flights. Furthermore, the lowest intensity was in the Eastern part of Riga FIR, from 0 to 2 flights. It shall be admitted that the lower the traffic intensity is, the safer it is to fly in that particular area. The obtained results were illustrated on aeronautical charts.
6. The analysis of air traffic intensity in Riga FIR using ARIMA (Autoregressive Integrated Moving Average) showed that the central part of Riga FIR is the most intense, where corresponding MSeA sectors median values were 118.5 and 105.5 aircrafts. Using ARIMA modeling it was obtained that air traffic intensity in the Eastern part of Riga FIR is very low, because median values are close to 0. This leads to high level of flight safety in terms of air traffic flow. The obtained analysis results were shown on aeronautical charts.
7. The air traffic intensity forecast showed that the highest air traffic intensity in the second quarter of year 2016, from May until September, is forecasted to be in the central part of

Riga FIR, ranging from 63.68 until 82.08 flights. The lowest air traffic intensity is forecasted to be also in the Eastern part of Riga FIR, ranging from 0 to 2 flights. The forecast for the first quarter of year 2017 shows that the most intense traffic will still be observed in the central part of Riga FIR, ranging from 48.98 until 61.52 flights. There is a significant fall in air traffic intensity, comparing to summer period, which shows seasonality effect on air traffic in Riga FIR. The obtained statistics data were shown on aeronautical charts.

8. There were training programs established for RPAS operators and air traffic control officers about RPAS operational procedures in Riga FIR. Training programs consist of theoretical and practical modules, which are further subdivided into flight in normal and abnormal situations. The training programs cover the following topics: introduction to RPAS, history and use of RPAS, legislation concerned, RPAS technical specifications and flight planning, flight plans and NOTAM messages, RPAS operational procedures in Riga FIR and standard phraseology for ATC and other airspace users.

# LIST OF REFERENCES


1. Academy of Econometrics: ARIMA Time series analysis/ Internet.- https://sites.google.com/site/econometricsacademy/econometrics-models/time-series-arima-models
2. ARIMA Modeling: non-seasonal models/ Internet.- http://people.duke.edu/~rnau/Notes_on_nonseasonal_ARIMA_models--Robert_Nau.pdf
3. ARIMA Modeling in R: t-series analysis/ Internet.- http://127.0.0.1:14790/library/tseries/html/adf.test.html
4. Avionics Today: Europe's Answer: UAVs in Controlled Airspace/ Internet. - http://www.aviationtoday.com/av/issue/featre/Europes-Answer-UAVs-in-Controlled-Airspace_1022.html#.Uklzp7Hj9oJ
5. AIXM Class. NOTAM Data Model (Presentation). AIXM 5.0 RC2. Washington D.C. - October 10–11, 2007.
6. Blom J. D. Unmanned Aerial Systems: A Historical Perspective. - Kansas, USA: Combat Studies Institute Press, US Army Combined Arms Center Fort Leavenworth, 141 pages.
7. Carr E. B. Unmanned aerial Vehicles. Examining the Safety, Security, Privacy and Regulatory Issues of Integration into U.S. Airspace. – USA, 2012.
8. Chesebro J. Unmanned Airsraft Systems (UAS) US Description. - USA, 2012. - 12 p.
9. EASA “Technical Opinion” Introduction to a Regulatory Framework for the Opeation of Unmanned Aircraft”, Related A-NPA: 2015-10- RMT.0230-December 18, 2015 – 50 pages
10. Eurocontrol. Eurocontrol Specifications for the Use of Military Remotely Piloted Aircraft as Operational Air Traffic Outside Segregated Airspace. Eurocontrol- SPEC-0102 – February 2012.
11. EUROCONTROL (1997) doc. "Radar Sensor Performance Analysis" SUR.ET1.ST03.1000-STD-01-0
12. Eurocontrol: Unmanned Aerial Systems/ Internet.- http://www.eurocontrol.int/articles/unmanned-aerial-systems
13. Gaszczak, A., Breckon, T.P., Han, J. Real-time People and Vehicle Detection from UAV Imagery// Proc. SPIE Conference Intelligent Robots and Computer Vision XXVIII: Algorithms and Techniques 7878 (78780B). doi: 10.1117/12.876663 - November 5, 2013
14. Gelman, A., Hill, J. (2006) Data Analysis Using Regression and Multilevel/Hierarchical Models. Cambridge University Press.
15. Guntis Arnicāns. LU FizMat. Lekciju materiāli, 2006., Rīga
16. Hayashi, Fumio. (2000) Econometrics, Princeton University Press.
17. Grady M. FAA Issues UAV Policy// Avweb – February 14, 2007.
18. ICAO. Doc 4444 ATM/501. Procedures for Air Navigation Services. Air Traffic Management. Edition. ICAO.
19. ICAO. Annex 2 to the Chicago Convention of International Civil Aviation. Rules of the Air. Tenth Edition. -ICAO. July 2005.
20. ICAO. Annex 11 to the Chicago Convention of International Civil Aviation. Air Traffic Services. ICAO.
21. ICAO. Chicago Convention on International Civil Aviation, Doc 7300/9, Ninth Edition. ICAO.
22. ICAO. Annex 15 to the Chicago Convention of International Civil Aviation. Aeronautical Information Services. Fourteenth Edition. ICAO. July 2013

23. ICAO. Cir 328 AN/190, Unmanned aircraft Systems (UAS). - Quebec, Canada, 2011.
24. ICAO Doc9869 AN/462 First Edition Manual on Required Communication Performance (RCP) 3–1 2006
25. ICAO Aeronautical Information services-aeronautical information management study group (AIS-AIMSG). Fifth meeting. Montreal, 7 November, 2011. Agenda Item 3: AIM information and data assembly, exchange and promulgation. NOTAM Guidance.
26. ICAO Guidance Material on Comparison of Surveillance Technologies. First Edittion. September 2007. Page 9.
27. ICAO Flight Planning Amendment 1-2012. Training Module. ICAO Flight Plan Form Changes. (Presentation). -2012.
28. ICAO Manual on Remotely Piloted Aircraft Systems. ICAO. May 2015.
29. Investopedia: Introduction of stationary and non-stationary processes/ Internet.- http://www.investopedia.com/articles/trading/07/stationary.asp
30. John H. Cochrane, "Time Series for Macroeconomics and Finance", Graduate School of Business, University of Chicago, spring 1997.
31. J.W. Galbraith, V. Zinde-Walsh, "Autoregression based estimators for ARFIMA models", CIRANO Working Papers, No: 2011s-11 Feb, 2001
32. J. Scott Armstrong, "Findings from evidence-based forecasting: Methods for reducing forecast error", International Journal of Forecasting 22 (2006), pages: 583–598.
33. J. Scott Armstrong, "Combining Forecasts", Principles of Forecasting: A Handbook for Researchers and Practitioners; J. Scott Armstrong (ed.): Norwell, MA: Kluwer Academic Publishers, 2001.
34. J.D. Hamilton. Time Series Analysis. Priceton, 1984
35. Kenneth P. Werrell. The Evolution of the Cruise Missile. Maxwell Air Force Base, Alabama: Air University Press, 1985.
36. Kenneth P. Werrell. For a thorough discussion of both the German and American programs.
37. Laurence R. Newcome, Unmanned Aviation: A Brief History of Unmanned Aerial Vehicles. - Barnsley, South Yorkshire: Sword and Pen, 2007.
38. Latvian Civil Aviation Agency. Aeronautical Information Publications of Republic of Latvia - Riga, 2013.
39. Latvijas Universitātes e-studiju materiāli: Dispersijas analīze/ Internet.- http://estudijas.lu.lv/pluginfile.php/91586/mod_resource/content/0/Jaunais_saturs/2/Dispersiju_analize.pdf
40. Ministru kabineta noteikumi Nr.656. "Kārtība, kādā veicami bezpilota gaisa kuģu un tādu cita veida lidaparātu lidojumi, kuri nav kvalificējami kā gaisa kuģi" saskaņā ar likumu "Par aviāciju". - Rīga – 2006.gada 15.augusts. 37l pp.
41. Montgomery, D.C. (2013) Introduction to Linear Regression Analysis, Fifth Edition Set. Wiley
42. M. Nathan, Cooper J., Zakrzewski E. Integrating Unmanned Aircraft Into NextGen Automation Systems, The MITRE Corporation. 31st Digital Avionics Systems Conference. – October 16–20, 2012.
43. P. van Merlin. Ikhana. Unmanned Aircraft System Western States Fire Mission. -NASA. Washington D.C. 2009. 123 pages.
44. R. Austin. Unmanned Aircraft Systems. UAVS Design, Development and Deployment. A John Wiley and Sons, Ltd, Publications. -USA -365 pages

45. R. Yanushevsky. Guidance of Unmanned Aerial Vehicles. CRC Press. Taylor & Francis Group. Florida, USA, 2011. 371 pages
46. R. Adhikari, R. K. Agrawl ”An Introductory Study on Time Series Modeling and Forecasting”. – USA. 2006. 63 pages.
47. R. J. Hyndman. Forecasting: Principles and Practise. University of Western Australia. 2014. –138 pages.
48. R. Nau. Lecture Notes on Forecasting. Duke University. Fuqua School of Business. 2014.
49. Riga Declaration on Remotely Piloted Aircraft (drones) “Framing the Future of Aviation”. Riga, 6 March 2015.
50. Santamaria E., Royo P., Barrado C. Mission Aware Flight Planning for Unmanned Aerial Systems. American Institute of Aeronautics and Astronautics. AIA Guidance, Navigation and Control Conference and Exhibit, Honolulu, Havaii, August 18–21, 2008.
51. Schwarz, C. J. Sampling, Regression, Experimental Design and Analysis for EnvironmentalScientists, Biologists, and Resource Managers, In course notes for beginning and Itermediate Statistics, Department of Statistics and Actuarial Science, Simon Fraser University. September 23, 2011, 183 pages
52. Sokalski, J., Breckon, T.P., Cowling, I. Automatic Salient Object Detection in UAV Imagery// Proc. 25th International Conference on Unmanned Air Vehicle Systems. - November 5, 2013.
53. Texts online. Opean-access Textbooks. Seasonal ARIMA models. https://www.otexts.org/fpp/8/9
54. Tirans I. Bezpilota lidaparāti Latvijā. Militārais Apskats. 2009. Nr.2.
55. The American Heritage® Dictionary of the English Language, Fourth Edition copyright ©2000 by Houghton Mifflin Company. Updated in 2009. Published by Houghton Mifflin Company:, July 1, 2001, 960 pages
56. The Swedish Transport Agency's regulations on unmanned aircraft systems (UAS), The Swedish Transport Agency’s Statute Book, Swedish Transport Agency, 2009, 44 pages
57. UK Ministry of Defense. Joint Doctrine Note 2/11, The UK Approach to Unmanned Aircraft Systems. - United Kingdom:, March 30, 2011.
58. UK Ministry of Defense. Joint Doctrine Note 3/10 Unmanned Aircraft Systems: Terminology, Definitions and Classification. - United Kingdom, Shrivenham. - 2010. - 21 p.
59. UNAV, LLC UNAV 3500 Autopilot. User's Manual rev. 1.31. – Marysville, WA, USA. – September 2009.
60. U.S. Airforce. Fact Sheets / Internet. - http://www.af.mil/AboutUs/FactSheets.aspx
61. UVS International. Civil Remotely Piloted Aircraft System Operations, RPAS CivOpsCat-120812. – France, Paris: Blyenburgh & Co, 2012.
62. А. Самарский, А. Михайлов. Математическое моделирование: Идеи. Методы. Примеры. Физико- математическая литература. Москва, 2001. 319 стр.
63. Егоренков и др. Основы математического моделирования. Анализ и построение моделей с примерами на языке MATLAB. 190 стр.
64. Кузнецов. Численное моделирование стохастических дифференциальных уравнений и стохастических интегралов. Книга посвящена проблеме численного решения стохастических дифференциальных уравнений Ито. 460 стр.
65. Колемаев. Экономико-математическое моделирование. Моделирование макроэкономических процессов и систем. 2005 год. 295 стр

66. Самарский, Михайлов. Математическое моделирование: идеи, методы, примеры. 2001 год. 320 стр.
67. Шикин, Чхартишвили. Математические методы и модели в управлении. МГУ. 2004 год. 440 стр.
68. Н. Я. Василин. Беспилотные летательные аппараты. Боевые. Разведывательные. – Попурри, 2003 г. – 272. стр.
69. Т. МакЛэйн, Р. Биард. Малые беспилотные летательные аппараты: теория и практика. – 312 стр.
70. М. Павлушенко, Г. Евстафьев, И. Макаренко. Беспилотные летательные аппараты: история, применение, угроза распространения и перспективы развития. Издательство «Права человека» Москва 2005. –612 стр
71. М.И.Павлушенко, Г.М.Евстафьев, И.К.Макаренко. Беспилотные летательные аппараты: история, применение, угроза распространения и перспективы развития.
72. В. Фетисов, Л. Неугодникова, В. Адамовский, Р. Красноперов. Беспилотная авиация: терминология, классификация, современное состояние. Уфа: ФОТОН, 2014. – 217 стр.