МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
Факультет аеронавігації, електроніки та телекомунікацій
Кафедра аеронавігаційних систем

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри АНС
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«____» ____________ 2023р.

ДИПЛОМНА РОБОТА
(ПОЯСНЮВАЛЬНА ЗАПИСКА)
ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ «МАГІСТР»
за освітньо-професійною програмою
«ОБСЛУГОВУВАННЯ ПОВІТРЯНОГО РУХУ»

Тема:

Залежність пропускної спроможності аеродрому від різних чинників

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Київ-2023

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF AIR NAVIGATION, ELECTRONICS AND TELECOMMUNICATIONS
AIR NAVIGATION SYSTEMS DEPARTMENT

PERMISSION FOR DEFENCE

Head of the Department
Doctor of Sciences (Engineering)

prof. _________V.Yu. Larin

"_____" ______________ 2023

MASTER'S THESIS

ON THE EDUCATIONAL PROFESSIONAL PROGRAM

" AIR TRAFFIC SERVICES"

(EXPLANOTARY NOTE)

Theme: " Dependence of an airport capacity on various factors"

Performed by: _______________ O.O. Semenenko

Supervisor: Senior Teacher _____________ M.M. Bogunenko

Standard inspector Senior Teacher _______________ G.F. Arhunov

KYIV 2023

Факультет аеронавігації, електроніки та телекомунікацій

Кафедра аеронавігаційних систем

Навчальний ступінь «Магістр»

Спеціальність 272 «Авіаційний транспорт»

Освітньо-професійна програма «Обслуговування повітряного руху»

ЗАТВЕРДЖУЮ

Завідувач кафедри

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« ___ »________2023 р.

ЗАВДАННЯ

на виконання дипломної роботи Семененком Олексієм Олексійовичем

1. Тема дипломної роботи: «Залежність пропускної спроможності аеродрому від різних чинників »

2. Термін виконання дипломної роботи:

3. Вихідні дані до проекту: теоретичні дані керівних документів Міжнародної організації цивільної авіації та національних документів України у сфері обслуговування та виконання польотів цивільних повітряних суден.

4. Зміст пояснювальної записки : Вступ; фактори, що впливають на пропускну здатність; методи збільшення пропускної спроможності; оптимізація пропускної спроможності для авіації; Збільшення пропускної здатності аеропорту Жуляни; висновки; список використаних джерел

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: рисунки, таблиці, формули.

6. Календарний план-графік :

№ пор.	Завдання	Термін виконання	Відмітка про виконання
1.	Підготовка та написання 1 розділу «Фактори, що впливають на пропускну здатність аеропорту»	23.10.23 – 30.10.23	Виконано
2.	Підготовка та написання 2 розділу «Методи збільшення пропускної спроможності аеропорту»	01.11.23 - 08.11.23	Виконано
3.	Підготовка та написання 3 розділу «Збільшення пропускної здатності аеропорту Жуляни»	09.11.23 – 16.11.23	Виконано
4.	Підготовка та написання 4 розділу «Охорона навколишнього середовища»	17.11.23 – 24.11.23	Виконано
5.	Підготовка та написання 5 розділу «Охорона праці»	25.11.23 – 31.11.23	Виконано
6	Оформлення та друк пояснювальної записки	01.12.23 – 05.12.23	Виконано
7.	Підготовка презентації та доповіді	06.12.23 – 11.12.23	Виконано
8.	Попередній захист дипломної роботи	12.12.23 - 15.12.23	Виконано

1. Дата видачі завдання: «29» вересня 2023 р.

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MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
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AIR NAVIGATION SYSTEMS DEPARTMENT

APPROVED BY
Head of the Department
_______________V. Larin
“____”_____________2023

Master’s Thesis Assignment

Student`s name: Semenenko Oleksii

1. The thesis theme: “Dependence of an airport capacity on various factors
2. The thesis should be performed from 23.10.2023 to 31.12.2023.
3. Initial data: theoretical data of the guiding documents of the International Civil Aviation Organization and national documents of Ukraine in the field of maintenance and execution of civil aircraft flights.
4. The content of the explanatory note (the list of problems to be considered): Introduction; factors affecting capacity methods of increasing capacity; optimization of throughput for aviation; Increasing the capacity of the Zhulyany airport; conclusions; references.
5. List of mandatory graphic (illustrative) material: figures, tables, formulas.
6. Calendar Schedule of Performing the Master’s thesis.

Tasks	Period of works execution	Execution note
Preparation and writing of Chapter 1 "Factors Affecting Airport Capacity"	23.10.23 – 30.10.23	done
Preparation and writing of Chapter 2 "Methods of increasing airport capacity"	01.11.23 - 08.11.23	done
Preparation and writing of the 3rd section "Increasing the carrying capacity of the Zhulyany airport"	09.11.23 – 16.11.23	done
Preparation and writing of Chapter 4 "Environmental Protection and Labor safety""	17.11.23 – 31.11.23	done
Preparation of presentation and report	01.12.23 – 05.12.23	done
Preliminary thesis defense	06.12.23 – 11.12.23	done
Writing an explanatory note	12.12.23 - 15.12.23	done

Date of issue: «29» September 2023.

Supervisor of master's thesis ________________ Mykola BOGUNENKO

Excepted the task ________________ Oleksii SEMENENKO

ABSTRACT

Explanatory note to the thesis "Dependence of an airport capacity on various factors"**:** 99 pages, 11 figures, 31 used sources, 2 appendices.

The purpose of the thesis- Study of airfield capacity under different conditions, in particular with an increase in the number of boards, a decrease in intervals, as well as an analysis of the work of dispatchers and the impact on their work capacity. Determining the possibility of increasing the throughput capacity of Zhulyany airport.

Object of study - aeroport capacity.

Subject of study — efficiency of service operations at Zhulyany airport.

Study Methodes theoretical methods, analytical calculations, mathematical and computer modeling.

Relevance - the relevance of the study is a very real solution for the future improvement and improvement of the airport and the industry as a whole.

The result of the thesis is recommended to be used for the aviation industry.

CAPACITY, AIRPORT, RISK, SECURITY, MULTI-AGENT SYSTEMS, AVIATION, PASSENGER SERVICE

REMARKS SHEET

CONTENT

List of conventional abbreviations

ICAO - International Civil Aviation Organization

A-CDM - Airport Collaborative Decision Making

ATC – Air Traffic Control

ATCO – Air Traffic Control Operator

ATCS – Air Traffic Control System

ATFM – Air Traffic Flow Management

ATM – Air Traffic Management

GDP - Ground Delay Programs

A-CDM - Airport Collaborative Decision Making

AI -Artificial Intelligence

MAS -Multiagent Systems

EUROCONTROL – European Organization for the Safety of Air Navigation

FIR – Flight Information Region

FIS – Flight Information Service

ICDMS – Intelligent Collaborative Decision-Making System

IDSS – Intelligent Decision-Making System

IFR – Instrument Flight Rules

LIST OF DEFFINITIONS

Capacity of the airport is the number of passengers and luggage that can be served in the airport in one hour.

Airport capacity is the number of passengers, baggage and cargo, as well as aircraft by type that can be served at the airport during a set period of time, which includes the capacity of runways, terminals and aprons.

Runway capacity is the number of aircraft movements that do not pose a danger to flights, the performance of which according to the conclusion of Ukraviatrans.

INTRODUCTION

Aviation transport is one of the main elements of the transport and logistics system of the country and the world. It is also the most expensive mode of transport, which significantly affects the price of transportation. Transportation costs are a large part, and reducing them is the main goal of the transportation process.

The growing volume of air transport, the ambitious development strategies of airlines and the growing expectations of passengers to leave in front of airports not only ensure safety and speed of service, but also optimize the operation of air traffic control as much as possible. Ensuring the high endurance of dispatchers becomes strategically important, since they are the ones who use aircraft trajectories, resolve conflict situations and ensure the smooth circulation of a large number of aircraft in a limited space.

Due to its good location, Kyi,v as a capital of Ukraine, is a potential leader among European countries in the number of air transportation. Unfortunately, due to the war, the sky in Ukraine is closed, but after the victory, we will receive a large number of air transports, so it is necessary to approach the issue of safety and comfort as reliably as possible.

In this context, there is an understanding and implementation of new technologies that contribute not only to increasing the capacity of airports, but also to increasing the stamina of dispatchers. Optimizing the work of air traffic control and using advanced automation systems can greatly facilitate their tasks and help in solving the challenges associated with the growth of air traffic. In this context, the development of automated air traffic control technologies becomes an integral part of the strategy to improve the efficiency and duration of airport controllers.

In order to achieve success, it is necessary to optimize the distribution of material and technical resources during the ground handling of aircraft at the airport. This means that all airport services must be ready to serve the aircraft, regardless of flight delays or deviations from the daily flight plan.

In turn, we can offer an option that will allow for more efficient use of airport resources and increase the number of aircraft that will be serviced on the ground at the airport.

To achieve the goal of the diploma work, the following tasks must be solved:

1. Analysis of factors affecting airport capacity.

2. Methods of increasing airport capacity.

3. Increasing the capacity of Zhulyany airport.

CHAPTER 1.

ANALYSIS OF FACTORS AFFECTING AIRPORT CAPACITY

1.1 Analysis of documents

According to Article 48 of the "Air Code of Ukraine", airports are classified by purpose into domestic and international. The international airport must perform the functions of customs, border, sanitary control and other types of control established by law. Any airport, including one that is a joint venture or owned by a foreign investor, must undergo certification and registration in accordance with current Ukrainian legislation.

State executive authorities are responsible for the construction, reconstruction and maintenance of access roads to airports, ensure the movement of passenger transport on these roads and telephone communication between settlements and airports.

According to the order dated 16.07.2004 n 645 of the Ministry of Transport of Ukraine "On approval of the Rules for allocating time slots for arrival and departure flights at international airports of Ukraine", it was determined that the purpose of developing rules for allocating time slots for arrival and departure flights at international airports of Ukraine is to provide a regulatory framework , which regulates the activity of civil aviation of Ukraine, in accordance with the standards of the European Union and international standards and recommendations of the International Civil Aviation Organization (ICAO).

An uncoordinated airport is an airport where the actual capacity corresponds to user requests. Slot allocation is the responsibility of the airport, airline and ground handling agent.

An airport with flexible scheduling is an airport where busy periods of the day, week or season are possible. Allocation of slots is likely to be by airport, airline and ground handling agent.

A capacity-constrained airport (coordinated airport) is an airport where the actual capacity does not match user demand.

A block is a period of time when a non-stop flight is allowed between two airports, at least one of which is open less than 24 hours a day.

An airport slot (time slot) is a specified day and time of an aircraft's arrival at the airport or its departure from the airport, usually in an interval of 15 or 30 minutes.

An air traffic control authority slot is the time of take-off or landing of an aircraft, designated by the relevant air traffic control authority for the optimal use of capacity on the route or at the airport for the purpose of effective regulation of air traffic flows.

The IATA Schedule Coordination Conference is a voluntary association of airlines to reach consensus on amendments to flight schedules in accordance with airport capacity constraints.

A slot retention requirement is a set level of usage of an allocated slot over a specified period of time required to retain it, usually expressed as a percentage, for example 80% of the maximum possible number of flights.

3. Procedures for forming a seasonal flight schedule

Airports, depending on the capacity, are divided into the following categories:

- the airport is uncoordinated;
- an airport with flexible scheduling;
- airports with limited capacity (coordinated airport).

Ukraviatrans assigns the airport to a certain category after analyzing the performance of flights for the previous IATA season.

The rules and technologies for coordinating slots for regular and charter flights at airports with limited capacity should be based on the principles of equality and impartiality in the distribution, taking into account the priority of regular flights.

The allocation of an airline slot takes into account the airport's capacity, determined by criteria such as:

- runway capacity;
- capacity of platforms by types of aircraft;
- capacity of passenger terminals.

Allocating an airline priority right to land at an airport does not mean automatic slot acquisition, and conversely, slot allocation does not give the airline priority to land.

In the case of regular flights by airlines of other countries to an airport with limited capacity, overnight parking of the aircraft may be provided in the presence of relevant agreements between the aviation authorities of Ukraine and a foreign country.

The draft seasonal schedule for a specific airport must be formed 27 days before the second Saturday of June and 27 days before the second Saturday of November.

Airlines operating regular or charter flights are required to send a telegram of a specified format - SSIM - to the airport.

In the absence of comments, the slot is given to the airline and included in the draft seasonal schedule.

If there are objections, the airport must offer the airline a new slot within three days. The slot confirmed by the airline is included in the draft seasonal schedule; otherwise, the proposed slot is canceled within three days.

No later than 30 days before the start of the new IATA season, the formed seasonal schedule of airlines is reviewed and, in the absence of objections, agreed by Ukraviatrans.

For one-time charter flights at an airport with limited capacity, the slot is agreed on the day before the flight with the relevant airport and Ukraviatrans. Arrival or departure of a flight without prior approval of the slot is prohibited.

1.2 Airport capacity is the main factor influencing the efficiency of the aviation system

In the context of airspace capacity, the goal is to efficiently manage the flow of air traffic within a given airspace while ensuring safety and avoiding congestion.

Dynamic airspace sectorization is an interesting solution for improving throughput. There is an option to divide airspace into sectors dynamically based on real-time traffic demand and airspace constraints. Algorithms can be used that constantly analyze current and forecasted air traffic, weather conditions and other important factors. Airspace sector boundaries need to be adjusted in real-time to evenly distribute traffic and account for fluctuations in demand.

There should be an analysis of current and projected air traffic demand to understand the distribution and density of flights in different airspace regions.

Algorithms need to be developed that estimate the demand for airspace services, taking into account factors such as the number of flights, types of aircraft and their expected trajectories. These algorithms can use machine learning techniques to predict traffic patterns based on historical and real-time data.

In order to reduce the load, it is possible to balance the load on the dispatcher, and here are some recommendations:

Load balancing in air traffic management involves distributing air traffic evenly between different sectors to prevent congestion and ensure optimal use of resources. This is critical to maintaining safety, efficiency and effective communication in the air traffic control system.

Algorithmic considerations:

Load balancing algorithms for air traffic management must be adaptive and responsive to the dynamic nature of air traffic. Here are some considerations for developing such algorithms:

1. Traffic monitoring:

Continuous monitoring of air traffic to determine the current load in each sector. This may include factors such as the number of aircraft, their altitudes, speeds and flight path complexity.

2. Assessment of workload:

Develop algorithms to estimate the workload of air traffic controllers in each sector. This may depend on the number of aircraft they service, the complexity of the instructions required and other relevant parameters.

3. Adjustment of the dynamic sector:

Implement algorithms that dynamically adjust sector boundaries based on current load. Sectors with high traffic or increased complexity can be split, and sectors with lower traffic can be combined to balance the workload.

4. Controller workload balancing:

Consider the workload of air traffic controllers in the process of load balancing. Algorithms should be aimed at evenly distributing the workload between controllers, preventing situations where some controllers are significantly busier than others.

5. Communication frequencies:

Take into account communication frequencies and the load on communication channels. Workload balancing should also involve optimizing the use of communication resources to avoid congestion on certain frequencies.

6. Predictive modeling:

Use predictive modeling to predict changes in air traffic patterns. This can help the system adjust sector boundaries early before congestion occurs.

Algorithmic answer:

- The load balancing algorithm detects the imbalance and adjusts the sector boundaries, creating a new intermediate sector.

- The algorithm redistributes aircraft between the three sectors to achieve a more balanced workload.

- Communication frequencies are optimized to ensure effective information exchange between controllers.

This adaptive approach ensures that air traffic is evenly distributed between sectors, preventing congestion, reducing discrepancies in controller workloads and maintaining a smooth communication flow.

A method such as dynamic adjustment of sector boundaries can also be used in conjunction with load balancing. This method perfectly redistributes flows and thereby reduces the load on the dispatcher.

Dynamic adjustment of sector boundaries is a strategy used by air traffic controllers to adaptively manage air traffic during peak hours. The goal is to prevent congestion and balance the load between different sectors by dynamically changing their boundaries. This approach allows more flexible and efficient use of airspace resources based on real-time air traffic needs.

Example:

Let's consider a scenario where dynamic sector boundary adjustment is applied during a peak traffic period:

- In sector A, there is a surge in air traffic due to an increase in the number of flights during the morning rush hour.

- Sectors B and C, adjacent to sector A, have relatively lower loads.

Algorithmic answer:

- Load balancing algorithm detects increased workload in sector A and lower workloads in sectors B and C.

- Dynamic adjustment of sector boundaries is initiated to redistribute excess traffic from sector A to sectors B and C.

- The algorithm takes into account factors such as the number of aircraft, their trajectories and the historical characteristics of each sector.

- Adjusted boundaries allow for a more even distribution of the workload, preventing congestion in the A sector.

Result:

- Air traffic controllers in sector A experience a more manageable load as excess traffic is shared with neighboring sectors.

- Sectors B and C effectively absorb additional traffic without compromising safety and causing congestion.

Key considerations:

1. Monitoring in real time:

- Continuous monitoring of air traffic in each sector is crucial to identify workload imbalances.

2. Adaptive algorithms - must be adaptive and respond to changes in air traffic patterns, ensuring timely adjustments during peak hours.

3. Safety and efficacy

The main goal is to balance the load while maintaining safety and efficiency. Algorithms should prioritize these factors in adjusting sector boundaries.

4. Communication coordination:

Adjustments should take into account communication frequencies and coordination between controllers in different sectors to ensure a seamless exchange of information.

5. Historical data:

Historical data on air traffic patterns can be used to predict peak hours and adjust sector boundaries in advance.

By dynamically adjusting sector boundaries, air traffic control systems can effectively handle different workloads, increase controller efficiency, and maintain overall airspace safety and efficiency.

1.3 The influence of the physical characteristics of the runway on the carrying capacity of the airport

The physical capacity of the runway is determined by a number of criteria that often interact with other aspects of airport capacity, including airspace (Fig. 1.1, 1.2). These criteria include:

- The number and location of runways, their use in different weather conditions, the construction of exits and taxiways.
- The distance between aircraft when approaching the runway.
- Lateral separation between aircraft, especially in bad weather, on parallel runways.
- Sequence and separation of departure and landing of aircraft on intersecting runways.
- Sequence of departure and arrival of aircraft on a single runway.
- Sequence of aircraft approaches to airports in close proximity where one aircraft must cross the path of another aircraft landing nearby.
- The presence of obstacles limiting the use of the runway according to the characteristics of the aircraft.
- Mix of aircraft operating at the airport, including aircraft categories, distance between them, busy time, scheduling norms.
- Weather conditions such as visibility, ceiling, wind direction, speed, precipitation, low temperatures, etc.
- Runway condition due to weather and impact on aircraft performance.
- Equipment such as type of navigation systems, ATC (Landing and Traffic Control) equipment, etc.
- Staffing level of ATC (Aviation Transport Center) and other factors.

These aspects affect airport capacity and throughput, and their optimization is key to the efficient operation of airport infrastructure.

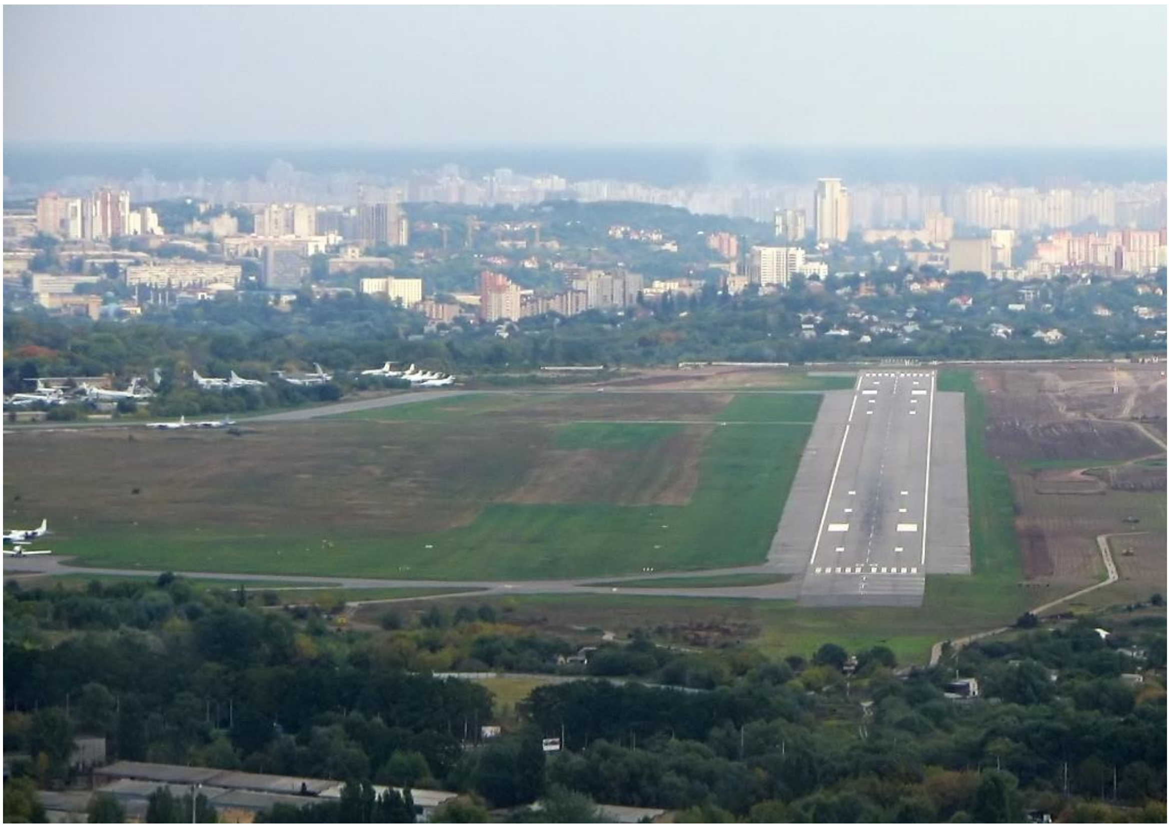

Figure 1.1 - View of the runway of the Zhulyany airfield

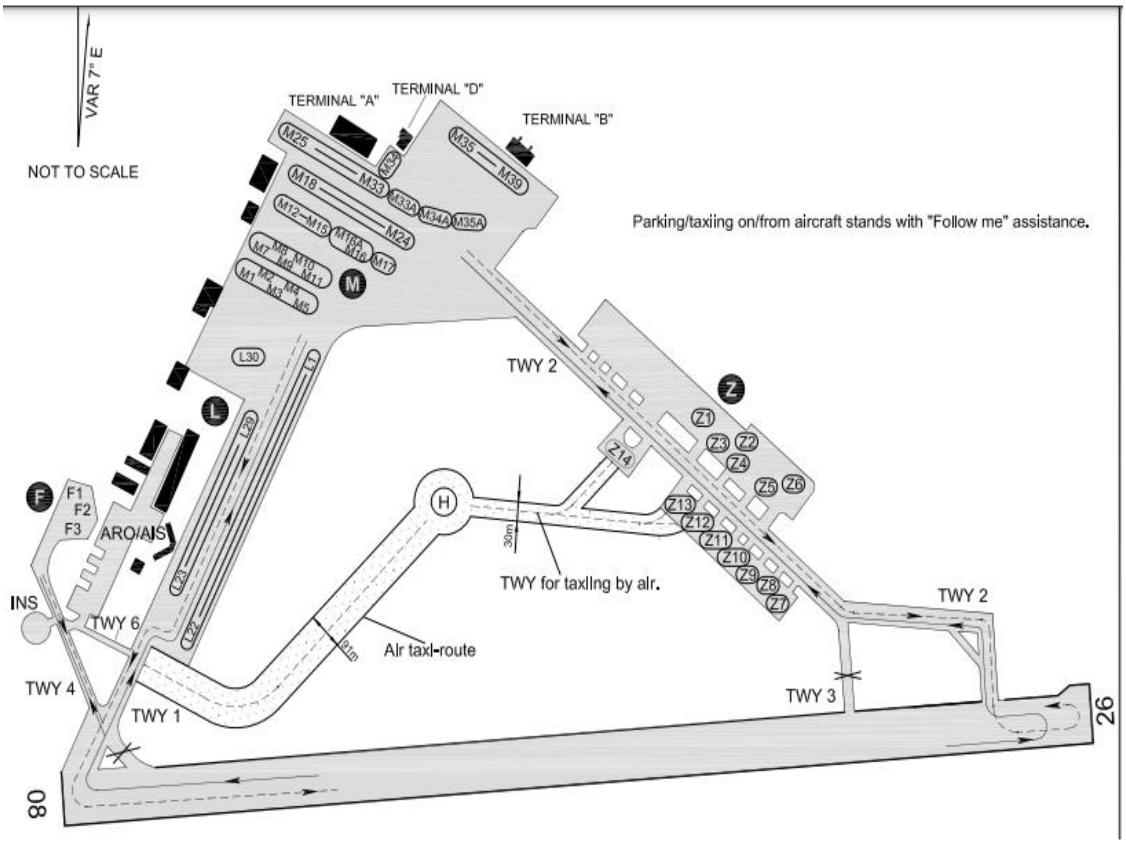

Figure 1.2 - Scheme of the runway of the Zhulyany airfield

1.4 The influence of platform dimensions on capacity

The size of the airport apron and the number of stands required determine the apron/stand capacity required to serve different numbers of aircraft over a period of time. Annual throughput and peak capacity remain the key factors, but apron/stand capacity also affects elements such as service times and the distribution of different types of aircraft at the airport. The optimal situation is when the available stands meet the capacity needs of the various aircraft operating at the airport.

Ramp/seat capacity can be a limiting factor, especially when aircraft operators are upgrading their fleets or rapidly changing aircraft types. However, building or modifying aircraft stands can be a lengthy process that requires time and planning.

1.5. Influence of terminal characteristics

The size of the airport terminal depends not only on the annual capacity, but also on the annual passenger flow and expected peak hourly flows. This can become a limiting factor for the airport's capacity. To ensure the efficient movement of passengers at the touch points in the terminal, the capacity of these touch points is crucial. These points include checkpoints, border control, boarding gates, baggage sorting or check-in desks.

Figure 1.3 – Image of Zhulyany airport terminal.

The design of the terminal, its configuration, as well as signage and orientation, affect the throughput of the available space, as well as ensure a smooth flow of passengers through the terminal. Limiting any of these touchpoints can seriously impact the airport's overall throughput. External accessibility, such as parking, driveways and public transport, can also affect terminal efficiency.

1.6. The main problem of airlines

Demand for air transport in Europe is expected to grow by at least 53% by 2040 compared to 2017, according to EUROCONTROL's Growth Challenges 2018 report. Forecasts also indicate a planned 16% increase in capacity between Europe's 111 airports by 2040, with demand potentially exceeding capacity by 1.5 million passengers, equal to 8% of demand and 160 million passengers.

Expanding the physical capacity of airports is one obvious way to increase overall capacity. However, this often requires approval from the government and the public, which complicates the process. Lack of open space, environmental concerns and impacts on neighboring communities complicate expansion decisions.

In addition, investments in capacity expansion often require significant funds. This could lead to a short-term increase in airport charges or upfront funding, which then declines after new capacity is introduced. This may cause opposition from airlines, which are short-term focused on spending for the next season, while airports have a long-term plan to serve passengers.

Opposition to investment is particularly strong if airlines see competitors using new capacity, as this could affect competition on the route.

The ability of airports to maximize their capacity on the ground affects the efficiency of runways and is important to overcome the problems of capacity shortages, which lead to significant delays. This is especially relevant in the context of crunch in the air and the need to implement the Single European Sky.

The introduction of new technologies and procedures in the field of runways can help improve capacity, but this requires investment and an integrated approach that takes into account the airspace and physical capacity of the airport.

It is also important to optimize bandwidth through slot allocation. However, the existing slot allocation process in Europe, regulated by Regulation 95/93, needs to be reformed. This will help make better use of available capacity and avoid unwanted behaviors such as babysitting, and ensure a more efficient allocation of resources for airlines.

Also the importance of managing airport capacity in unforeseen circumstances such as adverse weather, network failures, and delays. It is noted that airports should be prepared for temporary capacity reductions in such situations and effectively return to normal operation after their elimination.

An important element is the number of stands, which should take into account the contingencies that the airport can count on. It is noted that schedules must be resilient enough to adapt to such events.

The text also notes that adverse weather conditions and reduced runway capacity can lead to increased processing times, affecting other airports in the event of a diversion.

A key element of the strategy is minimizing the gap between "normal" capacity to act and capacity to act under unforeseen circumstances, as well as closing this gap after normalization of the situation. Integrated operations management, collaboration and coordination between airport stakeholders play an important role in ensuring clear lines of communication and coordinating disaster recovery.

It also notes that an integrated view of the actual and projected situation at the airport, provided by the APOC (Aviation Operations Centre), is key to providing clarity on the capacity situation, expected deviations and ensuring a coordinated response.

1.7 Daily flight schedule

The entire list of flights that depart and arrive at the airport during the day is examined in the context of the reasons for violations of flight performance. It is noted that the factors that determine the level of regularity of flights can be classified into four groups: technical, technological, resource and organizational.

Technical factors include the airport's radio navigation system capabilities and the technical resources of the manufacturing base for aircraft training. Technological factors reflect the level of development of technologies for ground training of aircraft in order to ensure safety and regularity of flights. Resource factors characterize the resource capabilities of the airport to ensure the required level of regularity of flights. Organizational factors refer to the appropriateness of the organizational structure of the airport, its divisions and services interacting in the ground handling of air transport, the production management system and the efficiency of the use of resources.

In the context of the formation of PPPs, airlines are trying to reduce the time during which aircraft are on the ground in order to increase the efficiency of their use. Aircraft ground handling service (GST) is defined as one of the most expensive for airlines, but it affects the level of air fares and, accordingly, the cost of transported goods. Reducing costs and increasing the competitiveness of the airline industry depends on the creation of the NOPS system, which combines the work of services according to the principles of "just-in-time" and "door-to-door" logistics in accordance with the requirements of the schedule. Improving the efficiency of operational processes of the NOPS will contribute to reducing the time for inter-flight preparation of aircraft, which affects the productivity of the airline and the throughput capacity of the airport.

Considering the various external factors that create serious difficulties in the operation of airports during the NOPS, the text emphasizes the need for integrated management and coordination to effectively overcome the challenges.

The regularity of flights is calculated according to the formula:

$$R_i = \frac{P_{\text{per}_i}}{P_i} \cdot 100\ \%\ ,$$

P_{per_i} — кількість відправлених регулярних рейсів;
P_i — загальна кількість відправлених рейсів передбачених ДПП

When analyzing the incoming flow of aircraft (aircraft), it is important to determine the deviation of the actual time of arrival of the service request in the system from the planned time. If the arrival or departure of the aircraft according to the schedule is not taken into account, the planning problem can be solved in a deterministic setting. In this case, the actual arrival time of the ith flight from the planned one will look like this: $\Delta t\_ipr = 0$.

The deterministic task will greatly simplify the model of ground handling of air transportation, but it does not fully reflect the real state of affairs. An analysis of the statistical data of Boryspil International Airport shows that deviations from the DPP occur in most cases. These deviations negatively affect the regularity, safety of flights, throughput and economic efficiency of ground handling of air transportation. Therefore, the deterministic model cannot provide accurate results (since it is necessary to take into account the number of aviation ground equipment and the distribution of their functions over time).

In the context of these problems, the stochastic nature of the analysis can be taken into account in order to more accurately reflect the real conditions and improve the forecasting and planning of aircraft ground handling.

The prediction of small deviations, which constitute a large part of the DPP, is of key importance for the organization of aircraft maintenance. The analysis of the incoming flow of Boryspil airport confirmed that aircraft often arrive before the scheduled time. In this regard, it is necessary to take these points into account during operational planning in order to avoid disruptions in the work of ground air transport services (GST). Forecasting small deviations, not exceeding 60 minutes, is of great importance for effective operational planning of NOPS.

Constant deviation from the daily flight schedule leads to flight delays, which can be caused by a number of factors, such as an increase in the number of serving airlines, an increase in the number of flights per day, an increase in passenger traffic, technological defects, underoptimized use of resources, and others. Therefore, the effective organization of the work of services that deal with the ground handling of aircraft requires clear guidance and constant monitoring to improve the productivity of the airport.

Optimizing the distribution of material and technical resources in situations of uncertainty in the management of ground handling can be determined by the chief dispatcher of the production and dispatching service of the airport (VDSA). The decision made by the dispatcher affects the costs of both the airport and the airline. Thus, the issue of optimizing airport resources under uncertainty is important for further research.

The efficiency of the airport directly depends on how fast and high-quality the ground service is. Therefore, the airport should contribute to the improvement of ground handling technologies, which will contribute to maintaining the regularity of flights, ensure flight safety and increase the technical and economic efficiency of technological processes of ground handling.

There is a method that calculates the capacity of airports for the future. The capacity of the airport is understood as its ability to carry out a certain volume of passenger Wп and cargo Wв transportations per year.

$$W_n = q \cdot \lambda_ч^{\max} \cdot \frac{T_\partial \cdot 365}{k_\partial \cdot k_ч}$$

where q is the average planned number of passengers per plane; max □h – airfield capacity (aircraft takeoffs and landings per hour).

Td - the number of hours of operation of the airport per day

kd – coefficient of daily unevenness of aircraft movement, i.e. the ratio of the maximum daily number of take-off and landing operations to the average daily number for the year;

kch - the coefficient of temporal irregularity of aircraft movement, i.e. the ratio of the maximum time number of take-off and landing operations to the hourly average for the maximum day.

1.8 Occurrence of problems due to overloading of dispatchers

Human-induced operational errors can occur for a variety of reasons, and understanding these factors is critical to improving the safety and efficiency of any complex system, including air traffic control.

Aviation safety (ASF) is largely determined by the human factor and includes the influence of the actions and decisions of pilots, crews and other personnel at all stages of aviation operations. The people who operate and maintain aircraft play a critical role in ensuring the safety and efficiency of air traffic.

Pilots, as key players in aviation, make decisions in conditions of high risk and unpredictability. They must interact effectively with aviation systems, taking into account weather conditions, air traffic and the technical condition of the aircraft. Training, professional training and communication skills greatly determine their ability to respond effectively to unforeseen situations and avoid potential hazards.

In addition, communication between crew members and communication with air traffic control, dispatch services and other participants in the airspace is an important element. Communication is a key factor in preventing conflicts, clarifying instructions and resolving any safety issues.

The human factor also includes the training and performance of personnel who provide aircraft maintenance, airport security, and other functions. Effective cooperation between all participants in the aviation process is a key factor for ensuring a high level of flight safety and avoiding incidents.

The problems associated with the overloading of controllers are a significant problem in the aviation sector, especially in the conditions of the growth of air traffic and the complexity of air traffic management. Controllers play a key role in ensuring the safety and efficiency of aircraft movements, but rapid workloads can affect their ability to effectively manage and coordinate air traffic.

One of the reasons for the transportation may be the increase in the volume of air traffic resulting from the increase in passenger and cargo transportation. The increase in the number of aircraft traversing the airspace puts additional pressure on air traffic control services, particularly those with high volumes of air traffic, such as airports or key air corridors.

Technological challenges can also make their appearance in the system, especially if air traffic controls cannot effectively interact or optimize processes. Some territories may face a lack of modern technology, which makes interaction and management difficult.

Overloading dispatchers can affect their concentration, speed of reaction and interaction with other services. This can lead to delays, errors in decision-making and threats to air traffic safety.

The solution to this problem can be the improvement of the infrastructure, the introduction of modern technologies and automated systems, as well as the improvement of the skills of dispatching personnel. Continuous improvement and adaptation to increasing volumes of air traffic is a challenge to ensure the efficiency and safety of the aviation system.

Here are some common causes of errors when working with examples:

1. Fatigue:

Example: A controller who works long hours without adequate rest may experience a decline in mental function, leading to errors in giving clear instructions or monitoring the aircraft's position.

2. Lack of awareness of the situation:

Example: If a controller is overwhelmed by the volume of air traffic or loses focus, he may not notice a conflict between aircraft, increasing the risk of errors.

3. Disruption of communication:

Example: A misunderstanding during radio communication between a controller and a pilot due to unclear instructions or language problems can lead to incorrect actions and a potential safety hazard.

4. Excessive dependence on automation:

Example: A controller may become complacent and rely entirely on automated systems, neglecting to cross-check information or intervene when necessary, leading to errors in air traffic control.

5. Stress and heavy workload:

Example: During peak traffic or emergency situations, dispatchers may experience increased levels of stress and increased workload. Under such conditions, they may make hasty decisions or miss important information.

6. Gaps in education:

Example: Inadequate training in new procedures or technologies may result in dispatchers lacking the skills necessary to

solving specific situations that will lead to errors in the control of the aircraft or equipment.

7. Poor human-computer interaction:

Example: Difficulty navigating or understanding the user interface of ATC systems can lead to errors such as entering incorrect data or misinterpreting information displayed on radar screens.

8. Problems with team coordination:

Example: Ineffective communication and coordination among team members can lead to conflicting instructions, missed transmissions, or other errors that compromise overall air traffic control.

9. Satisfaction:

Example: Long periods without challenging situations can lead to complacency where controllers become less alert and attentive. This can lead to oversights or delays in responding to new issues.

10. Cognitive biases:

Example: Confirmation bias, when a controller interprets information in a way that confirms his biases, can lead to missing conflicting data and making decisions based on incomplete or biased information.

11. Individual differences:

Example: Differences in experience levels, decision-making styles, or personal factors among controllers can lead to inconsistencies in how situations are handled, contributing to errors in the system.

12. Environmental distractions:

Example: External distractions, such as loud noises or interruptions, can divert a controller's attention from critical tasks, increasing the likelihood of errors in air traffic control.

Addressing these factors involves implementing strategies such as robust training programs, effective communication protocols, fatigue management policies, and continuous monitoring of system performance. By understanding and mitigating the human factor, organizations can reduce the potential for error and improve the overall safety and efficiency of complex systems like air traffic control.

Of course, addressing the human factor in air traffic control requires a multifaceted approach. Here are examples of solutions and strategies for mitigating common causes of human error at work:

1. Fatigue management:

Solution: Implementation of fatigue risk management systems and optimization of shift schedules to ensure adequate rest for dispatchers between shifts.

Example: introduce shorter shifts during peak traffic hours, provide opportunities for breaks and offer tools for self-assessment of fatigue levels.

2. Improving situational awareness:

Solution: Develop and implement training programs aimed at improving situational awareness skills and providing tools for effective information management.

Example: Use realistic simulation exercises to expose controllers to different scenarios, improving their ability to process and prioritize information.

3. Improving communication:

Solution: Establish clear communication protocols, improve language training, and implement effective communication tools.

Example: Conduct regular communication drills where dispatchers practice sending and receiving clear instructions in a simulated environment.

4. Automation training and supervision:

Solution: Provide comprehensive training to automated systems and emphasize the importance of proactive monitoring and intervention when necessary.

Example: Include regular simulator sessions where dispatchers practice using automated tools and responding to system failures or unexpected situations.

5. Stress and workload management:

Solution: Develop workload management strategies, including the use of automation and shared decision-making.

Example: Implement workload monitoring tools that provide real-time feedback to controllers, helping them more efficiently distribute tasks during periods of high workload.

6. Continuous training and development of skills:

Solution: Create a culture of continuous learning by offering regular learning updates and professional development opportunities.

Example: Provide controllers with access to online courses, workshops and seminars to keep them abreast of the latest technologies and procedures.

7. Improved human-computer interaction:

Solution: Invest in user-friendly interfaces, conduct usability testing, and collect feedback from controllers to improve the design of ATC systems.

Example: Collaborating with human factors experts to design interfaces that reduce cognitive load and facilitate efficient information processing.

8. Team coordination and communication protocols

Solution: Develop standardized communication procedures, encourage open communication within teams, and implement cross-checking mechanisms.

Example: Use debriefing sessions after critical events or exercises to discuss communication issues, identify areas for improvement, and share lessons learned with team members.

9. Learning to make decisions under stress:

Solution: Integrate stress management and decision-making training into the regular curriculum, including scenario-based exercises that simulate high-stress situations.

Example: Create immersive training scenarios that recreate the complexities of managing air traffic during emergencies, allowing air traffic controllers to practice effective decision-making under stress.

10. Cultural shift towards security:

Solution: Foster a safety culture that encourages reporting errors, accidental errors, and lessons learned without fear of retribution.

Example: Establish a confidential reporting system where controllers can voluntarily report incidents and use this information to identify system problems and implement preventive measures.

By implementing these solutions, air traffic control organizations can significantly reduce the impact of human factors on operational errors, increase overall system safety, and improve air traffic control controller productivity. It is important to constantly evaluate and adapt these strategies to the evolving challenges of the aviation industry.

Increasing bandwidth definitely affects these factors, so there should always be an algorithm to solve these problems.

I want to give an example of how an event occurred due to a dispatcher's error, which can show how serious the human factor is, and what needs to be done to prevent such situations from occurring. First of all, there are already certain discussions about how, for example, artificial intelligence can warn in advance about potentially conflict situations. This plane crash happened because poor visibility was a factor in the crash, and it should not be overlooked that overfatigue and exhaustion could also have contributed to this collision.

Two passenger planes, Boeing 747 of KLM (flight 4805) and Pan American (flight 1736), collided on the runway of the airport. As a result of this terrible event, 583 people died, which makes this aviation disaster one of the most tragic in the history of aviation.

The cause of the accident includes not only the error of the dispatcher's command, but also the misunderstanding of the communication between the crews and the dispatchers. Dense fog at the airport made visibility difficult. What was important was the misinterpretation of the team and their incorrect execution of the crews. The crew of the KLM plane made the decision to take off, despite the fact that the Pan Am plane was still on the runway. This resulted in the KLM plane hitting the tail of the Pan Am plane, causing both planes to burn.

Improving air traffic control (ATC) controller vigilance is a critical aspect of ensuring the safety and efficiency of air traffic. Attention is a key attribute to effectively deal with situations and manage large volumes of air traffic.

Improving mindfulness can include training and simulations that allow dispatchers to realistically recreate various scenarios and situations that may arise during the work. This helps to increase their reactivity and to ensure the preservation of concentration even in stressful conditions.

In addition, the implementation of technological solutions, such as automated monitoring and decision support systems, can help improve dispatcher attentiveness. These systems can provide additional information resources and alerts, helping dispatchers effectively analyze situations and make informed decisions.

It is also important to ensure adequate rest and work conditions for dispatchers, as fatigue can negatively affect their attention and productivity. Establishing clear procedures for recording work and rest time can contribute to maintaining the psycho-emotional state of the staff.

Overall, improving ATC dispatcher alertness requires a comprehensive approach that includes training, use of technology, maintenance of work conditions, and establishment of safety and performance standards.

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CONCLUSION TO CHAPTER 1

Aviation transport is defined as a key element of the transport and logistics system of the country and the world. However, its high costs significantly affect the cost of transportation. Reducing transport costs becomes an important goal of the transport process. Optimizing the allocation of logistical resources for aircraft ground handling is a key aspect of this task, especially given the expected growth in demand for air transportation.

The proposal to increase the carrying capacity of the airport in Kyiv takes into account its potential as a leader among European countries in the field of air transportation. Overcoming the limitations associated with increasing throughput can contribute to more efficient use of the airport's resources and increase its competitiveness.

The importance of an airport's capacity is found in the ability to effectively deal with various factors, such as weather conditions and route restrictions. Considering the problems and risks associated with increasing bandwidth is an important step for developing effective strategies in this direction.

The conclusion from the text is that the optimization of airport capacity is important for increasing the efficiency of the transport process, reducing costs and solving various challenges that arise in the modern aviation industry.

CHAPTER 2.

METHODS OF INCREASING AIRPORT CAPACITY

2.1 Load balancing strategies in air traffic control

Load balancing strategies in air traffic management involve redistributing air traffic to ensure optimal use of airspace, reduce congestion and minimize delays. These strategies are especially important during peak hours, when demand for air travel is highest. Here are detailed descriptions and examples of load balancing strategies:

1. Adjustment of the dynamic boundary of the sector:

During peak hours, controllers can dynamically adjust sector boundaries to redistribute air traffic and balance workloads.

Adjusting the dynamic boundary of the sector is an important aspect of air traffic management aimed at optimizing the distribution and control of air traffic. This process allows controllers to dynamically adapt air sector boundaries to changes in traffic volume, weather conditions, or other factors.

The key purpose of dynamic sector boundary adjustment is to avoid congestion and ensure efficient use of available airspace. Controllers can adapt sector boundaries in response to arrivals or departures of aircraft, changes in air traffic, or other circumstances that may affect traffic planning.

This process requires accurate monitoring of traffic volumes, use of technological solutions and automation systems for operational data analysis. When dynamically adjusting sector boundaries, it is important to ensure safety and efficiency of traffic, avoid conflicts and ensure optimal use of airspace in real time.

Given the constant changes in air traffic and other circumstances, the adjustment of the dynamic boundary of the sector is a necessary element of modern air traffic management, contributing to the improvement of productivity and ensuring the optimal organization of airspace.

2. Ground Delay Programs (GDP): These are air traffic management measures designed to regulate the flow of aircraft departures during periods of high demand or

adverse conditions. These programs are implemented by air traffic controllers to prevent congestion in airspace and airports. GDP involves the temporary delay of departures on the ground, thereby distributing the flow of traffic and ensuring that the air traffic control system can cope with the demand without causing delays or blockages.

The Ground Delay Program (GDP) is a strategic approach and action aimed at effectively managing and optimizing the operations of airports and air ports, especially in the context of minimizing aircraft ground delays. The main goals of GDP are to ensure flight safety, increase airport capacity and optimize the use of resources to reduce the time that aircraft spend on the ground between phases of the flight cycle.

These applications include the use of automation technologies, control and interaction systems, ranging from the coordination of ground services such as fueling, boarding and disembarking, to the control of aircraft traffic on taxiways and runway access, which can significantly facilitate and accelerate these processes.

With one key element of GDP is the interaction between airports, air navigation services and airlines to determine optimal departure and landing times and to prevent and manage potential delays. This will help coordinate the work of various elements of the air transport chain, ensure effective coordination and avoid overload.

In a world of increasing air travel and the ever-evolving aviation industry, programmed ground delays remain an increasingly important tool for achieving optimal performance and safety in airport environments.

3. Allocation of slots and their management:

Airports may allocate specific time slots for arrivals and departures to regulate traffic.

Example: During peak hours, airlines can be assigned specific arrival and departure slots, which helps controllers manage the sequence of flights and prevents simultaneous increases in congestion.

The allocation and management of time slots in the aviation industry is an aspect of ensuring the efficient use of airspace and airports. A time slot is a certain time slot assigned by an airline for departure or landing at a certain airport. This scheduling system ensures the order and timing of each aircraft's arrival or departure to avoid congestion, conflicts and delays.

Timetable management is issued by coordinating bodies such as the Airport Authority and the National Aviation Administration. These authorities set aircraft schedules taking into account many factors such as infrastructure constraints, airport capacity, airspace availability and air traffic.

The allocation of time slots is very important to maintain uninterrupted air traffic, prevent congestion and ensure safety. This will be especially important at large airports and air traffic hubs where large numbers of aircraft compete for limited resources.

The use of technology and an automated waiting time management system can reduce delays, improve airport resource efficiency and reduce new environmental impacts. At the same time, the individual needs of the Airline are taken into account, which contributes to the optimal organization of air traffic and ensures a high level of passenger service.

4. Collaborative Decision Making (CDM) involves cooperation between airlines, airports and air traffic control authorities to make joint decisions that optimize the flow of air traffic.

Example: Airlines may adjust their flight schedules or agree to certain departure or arrival procedures during peak hours based on joint decisions with air traffic management to balance overall demand.

Collaborative Decision Making (CDM) is a strategic approach in aviation aimed at improving efficiency and safety in air traffic management. This concept arose in an effort to solve various challenges associated with the growth of air traffic volumes, the complexity of coordination between different parties of the industry, as well as increasing requirements for accuracy and speed of decision-making.

CDM is based on the integration and exchange of data between various participants in the aviation process, such as airlines, airports, air navigation services and government regulators. This contributes to the creation of a single information space in which all parties can receive up-to-date and uniform information regarding flights, airport operations and airspace.

The main goal of CDM is to improve accuracy and predictability in air traffic management, reduce delays, optimize the use of airport resources and reduce the impact on the environment. Interaction between the participants of the aviation process within the framework of CDM allows timely response to unforeseen circumstances, taking into account the individual needs of airlines and maximally using available technologies to automate decision-making processes.

CDM becomes a key component of the "Single European Sky" concept, contributing to the integration and harmonization of aviation processes in Europe and on a global scale. The application of this approach allows creating more transparent, predictive and dynamic air traffic control systems for the further development of the aviation industry.

5. Air retention schemes:

Aircraft can be assigned airspace waiting patterns before reaching their destination to create spacing and manage the flow of arrivals.

Example: During peak arrival times, aircraft can enter a holding pattern, allowing controllers to gauge traffic flow and prevent congestion on the approach to the airport.

Air-holding patterns are strategies and techniques used to keep aircraft airborne for extended periods of time without landing. These patterns are becoming an important element of flight planning, particularly for pilots using gliders, unmanned aerial vehicles, and some military and research missions.

One typical hovering scheme is circular flight, where the aircraft uses thermal currents or winds to hover. This is especially true for gliders, which can use updrafts to extend their flight.

Staying in the air is essential for unmanned aerial vehicles, which can be used for a variety of purposes, including surveillance, communications, aerial photography and other tasks. Such devices can use the technique of pseudo-satellite flight, staying in certain regions or performing routes in the mode of "holding in the air".

Some aircraft can also use the technique of staying in the air with the help of turbulent flow from other aircraft. This may include holding in the air behind another aircraft in the outgoing air stream.

Considering the different purposes and types of aircraft, air holding schemes demonstrate the flexibility and adaptability of air transport for optimal use of energy and performance in a variety of situations.

6. Tactical flow management:

Tactical flow management involves making real-time adjustments to air traffic flow based on current conditions and requirements.

Example: Controllers can dynamically reroute an aircraft to avoid congested areas or adjust routing standards for higher volumes of traffic during peak hours.

Tactical aviation system flow management is a strategy and techniques aimed at optimizing the movement of aircraft in real time to ensure the efficiency, safety and smoothness of air traffic. It is an aspect of aviation management that focuses on the dynamic interactions between aircraft and airport infrastructure as they move through the air and on the ground.

Tactical flow management includes a large number of aspects such as aircraft routing, altitude control, slot allocation, responding to unexpected changes in weather conditions or other circumstances that may affect aircraft movement. The primary goal of tactical flow management is to avoid conflicts, delays, and congestion while ensuring the optimal movement of each aircraft in the system.

Modern technologies and automation systems help improve tactical flow management, providing more accurate and operational solutions. The integration of adaptive algorithms, a forecasting and big data processing system allows you to quickly respond to changes and make the most of available air and airport resources. Tactical flow management is becoming an integral part of the modern aviation system, contributing to the optimization of air traffic in the conditions of a constant increase in air traffic volumes and requiring its safety and efficiency.

7. Preferred routes and dynamic route adjustments:

Setting preferred routes and dynamically adjusting routes based on current conditions helps optimize the use of airspace.

Example: During peak hours, dispatchers may encourage or require the use of certain preferred routes that help distribute traffic more evenly, reducing congestion in certain sectors.

Priority routes and dynamic route coordination are the main aspects of air traffic management aimed at optimizing the efficiency, safety and use of resources in air transport.

Priority routes are the main airlines designated by national or international aviation authorities to serve aircraft between destinations. This route is the optimal route to achieve maximum efficiency and reduce fuel consumption.

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11. Gradual release

Gradual release is a strategic approach to air traffic management, where aircraft are systematically released into the airspace at designated time intervals. This controlled and phased release mechanism is designed to avoid a sudden influx of departures that could potentially lead to airspace congestion and subsequent delays. By assigning specific time slots for departures, air traffic controllers can regulate the flow of aircraft entering the airspace, ensuring a smooth and orderly promotion. This proactive control strategy helps distribute the workload evenly and prevents airspace saturation at any time.

The phased release system is particularly useful during peak hours or in heavy traffic conditions when a sudden burst of departures can overwhelm the air traffic control infrastructure. By implementing controlled releases, aviation authorities can optimize the use of airspace, reduce the likelihood of mid-air conflicts and minimize the risk of delays, ultimately contributing to a more efficient and predictable flow of air traffic.

2.2 The importance collaborative decision making

Collaborative Decision Making (CDM) in aviation refers to the process in which key stakeholders such as airlines, airports, air traffic controllers and other relevant parties work together to optimize operational efficiency, improve safety and improve overall decision-making processes. The goal is to share information and coordinate actions in real time to solve problems and make informed decisions that benefit the entire aviation system. Here are the main aspects and examples of joint decision-making in aviation:

1. Exchange of information:

Example: Airlines and airports share real-time information about their operations, including flight schedules, delays and resource availability. This shared data allows all stakeholders to have a complete picture of the current situation.

2. Coordination before departure:

Example: Prior to departure, airlines work with air traffic controllers and airports to optimize departure slots, reducing congestion on the ground and in the airspace. This ensures smoother shipments and minimizes delays.

3. Exchange of weather information:

Example: Meteorological data is shared between airlines, airports and air traffic control authorities to predict and mitigate the effects of adverse weather conditions. This helps reroute flights, adjust schedules, and make timely decisions to ensure safety.

4. Joint management of slots:

Example: Airports and airlines work together to efficiently manage airport slots. If delays or disruptions occur, stakeholders work together to adjust slot allocation and optimize the use of available resources.

5. Dynamic airspace management:

Example: Air Traffic Control works with airlines to dynamically adjust airspace routes based on real-time conditions. This can include rerouting aircraft to avoid congestion, optimize fuel efficiency and reduce delays.

6. Joint decision-making during failures:

Example: In the event of unforeseen disruptions, such as natural disasters or security incidents, airlines, airports and authorities work together to quickly assess the situation, share information and make joint decisions to minimize the impact on operations.

7. Collaborative Airport Decision Making (A-CDM):

Example: A-CDM programs involve close cooperation between airports and airlines to optimize ground handling processes, gate assignments and resource utilization. This helps to reduce the time of work and increase the overall efficiency.

8. Integration of technologies:

Example: Shared decision-making tools and technologies, such as digital platforms and communication systems, allow stakeholders to share information in real time. For example, the use of common platforms for data exchange facilitates better coordination between different organizations.

9. Flow control:

Example. Shared decision-making processes are used to manage air traffic flows during peak hours or special events. This involves coordination to ensure a smooth flow of air traffic without overloading the capacity of airspace or airports.

Collaborative decision-making in aviation is essential to improving the overall efficiency of the air transport system, improving safety and providing a more convenient experience for both passengers and industry stakeholders. It relies on effective communication, data sharing and collaborative decision-making to address the dynamic and complex nature of the aviation environment.

2.3. Airport Collaborative Decision Making (A-CDM)

A-CDM is a concept that aims to improve airport performance through enhanced collaboration and information sharing between various stakeholders, including airlines, airport authorities, ground operators and air traffic controllers. The main goal is to optimize processes, reduce delays and improve overall productivity. Here is a more detailed description with examples:

1. Cooperation and exchange of information:

A-CDM promotes collaboration by facilitating real-time information sharing between the airport's various stakeholders. This includes data on flight schedules, passenger flows, aircraft turnover times and other relevant operational details.

Example: Airlines communicate estimated departure and arrival times, refueling requirements, and other operational information to airport and ground handling services. This allows all parties to have a synchronous view of the current situation and plan accordingly.

2. Optimization of ground handling processes:

A-CDM aims to optimize ground handling processes by ensuring efficient use of resources such as gates, stands and baggage handling facilities. This helps to reduce the time of flights arriving and departing.

Example: Ground operators receive real-time updates on the status of arriving flights, allowing them to efficiently allocate ground resources. This can result in a faster turnaround of the aircraft, which is critical to maintaining the smooth flow of operations.

3. Assignment of gates and use of resources:

A-CDM involves joint decision-making regarding the assignment of exits and the use of other airport resources. Effective gate management is essential to minimize congestion and delays.

Example: An airport, airlines and ground operators jointly assign departures based on real-time flight status. By optimizing the use of gates, airports can handle increased traffic without compromising efficiency.

4. Reduction of the time of execution of works:

Description: A-CDM focuses on reducing the time an aircraft spends on the ground between arrival and departure flights. This is critical to improving overall work efficiency.

Example: Airlines and ground handling services work together to streamline processes such as passenger drop-off, refueling, cleaning and boarding. By minimizing the time an aircraft is on the ground, airlines can increase the productivity of their fleet.

5. Increasing predictability:

Description: A-CDM promotes operational predictability by providing stakeholders with accurate and timely information. This predictability is critical to planning and resource allocation.

Example: Air traffic controllers, airlines and ground handling services exchange information about possible delays or disruptions. Armed with this knowledge, stakeholders can adjust schedules and resources ahead of time to minimize the impact on overall airport operations.

6. Improving communication and coordination

Effective communication and coordination among stakeholders are important components of A-CDM. This involves using common tools and platforms to facilitate information sharing.

Example: A centralized communication platform allows airlines, ground operators and airport management to share updates, coordinate actions and resolve any issues that may arise during the operational process.

By implementing A-CDM principles, airports can achieve better overall efficiency, reduce operating costs and improve the passenger experience by minimizing delays and disruptions. This joint approach to decision-making contributes to a more simplified and optimized operation of the airport.

2.4. Reducing the time of work in the process of joint decision-making at the airport (A-CDM)

Reducing flight times is an important aspect of A-CDM, which emphasizes the efficient use of time between aircraft arrival and departure. The goal is to minimize the time the aircraft spends on the ground, contributing to overall operational efficiency. Shortening lead times not only increases airline productivity, but also improves airport throughput and passenger service quality.

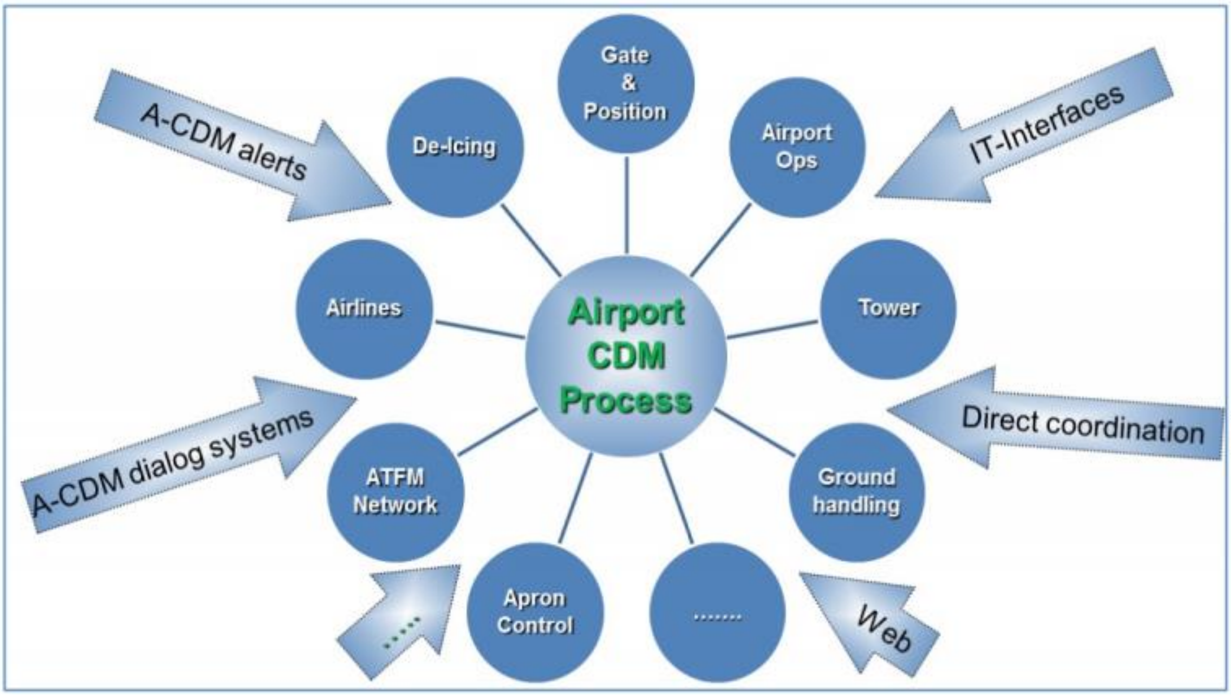

Figure 2.4 - Example of A-CDM

Example: Airlines and ground handling services work closely together to optimize various processes during the repair phase. Here's a breakdown of how this collaboration works:

1. Disembarkation of passengers:

Airlines provide real-time information on the expected arrival time of flights.

Ground handlers use this information to prepare to quickly disembark passengers upon arrival.

Efficient passenger drop-off ensures faster turnaround.

2. Refueling:

Airlines provide advance notice of refueling requirements, allowing ground services to prepare for timely refueling.

Ground operators coordinate with refueling services to minimize refueling time without compromising safety standards.

3. Cleaning and maintenance:

Airlines share information about any specific cleaning or maintenance needs during repairs.

Ground handling schedules cleaning and maintenance activities around the aircraft's time on the ground, ensuring these tasks are completed quickly.

4. Landing:

Airlines provide ground operators with boarding and departure times.

Ground handling prepares for the boarding process, ensuring a smooth and timely boarding of passengers.

Simplifying the landing procedure helps minimize the time the plane spends on the ground before departure.

5. Optimization of resources:

A-CDM facilitates the coordination of resources such as gates, boarding bridges and ground handling equipment.

Airlines and ground handling services work together to efficiently allocate resources, reducing the time it takes for aircraft to access the facilities they need.

6. Real-time updates:

Constant communication between airlines, ground operators and other stakeholders ensures that everyone has the most up-to-date information on the status of the aircraft.

Real-time updates allow you to quickly adjust operational plans, helping to overcome unexpected challenges and maintain a stable turnover process.

7. Integrated technology:

A-CDM often involves the use of integrated technologies and platforms for collaboration.

Automated systems and digital tools allow stakeholders to share and access information in real time, reducing manual coordination and potential errors.

By focusing on these collaborative activities, A-CDM helps airlines and airports optimize turnaround processes, resulting in reduced landing times, increased aircraft utilization and improved overall operational efficiency. This, in turn, benefits both airlines and airports, while increasing the punctuality and reliability of air travel for passengers.

2.5. Optimization of waiting time on the runway

Time consumption: One of the important time costs at the airport is the time the plane spends in line on the runway before departure. This cost is especially critical during peak load periods, when the number of flights increases significantly, which can lead to delays and increased waiting times.

Optimization: Effective management of flight schedules and the allocation of time between pilots to prepare for departure can be decisive factors in reducing waiting time on the runway. In addition, the use of modern tracking and reporting systems can facilitate the coordination and optimization of this process.

1. Management of flight schedules:

Airports can use algorithms and systems that automatically analyze flight schedules and determine the optimal order of their departure.

An airport can use software to automatically plan the departure sequence, taking into account factors such as the size of the planes, their destinations and schedules.

Flight schedule management is a key aspect of optimizing airport operations, aimed at the efficient distribution of flights in time. To achieve this goal, airports use algorithms and special software that automatically analyzes complex flight schedules and determines the optimal order of their departure.

These algorithms are based on a number of factors, including the size of the aircraft, their destination and scheduled departure times. They also take into account current airport conditions, availability of waiting areas, other flights, and possible disruptions or delays that may occur.

This software allows you to automatically optimize the flight sequence to maximize the use of available time and resources. For example, it can queue aircraft to avoid conflicts, provide an optimal schedule for each type of aircraft, and efficiently use airport infrastructure availability.

This approach not only helps to reduce waiting time at the runway, but also improves the overall punctuality of flights, reduces the risk of delays and improves the allocation of airport resources. As a result of effective management of flight schedules, the airport can optimize its productivity and provide more comfortable and efficient accounting of passenger and cargo flights.

2. Distribution of time between pilots:

Splitting time between pilots allows crews to prepare for departure in advance, which can reduce the amount of time an aircraft spends in line in front of the runway.

With time allocation, the airport may allow pilots to prepare for departure earlier, such as starting engines or performing safety checks.

Timing between pilots is a strategy aimed at effectively preparing the crew for departure even before the plane takes its place on the runway. This practice helps to reduce the amount of time an aircraft spends in a queue before departure, thus contributing to an improvement in the overall efficiency of airport operations and an increase in punctuality.

Time sharing between pilots means the ability of crews to perform pre-departure preparations, such as starting engines or checking safety systems, in advance. For example, an airport can establish a flexible schedule that allows pilots to start preparing for departure a certain time before the scheduled departure. This may include starting engines, checking instruments and safety systems, and any other tasks necessary to be ready for takeoff.

By providing pilots with an opportunity to begin the preparation process earlier, the airport can ensure a smoother and faster transition of the aircraft from the stand to the runway. This is important, especially during peak load periods, when the speed of flight services becomes critical to prevent delays and increase airport productivity.

3. Tracking and reporting systems:

The use of modern aircraft tracking systems and efficient reporting means allows airports to accurately determine the location of each aircraft and coordinate their actions.

An airport can use radar, GPS systems and automated communication tools to monitor and coordinate the movement of aircraft on the runway.

An effective combination of these techniques can significantly reduce runway waiting times, thereby improving flight punctuality and the overall efficiency of airport operations.

2.6. Involvement of the Private Sector in the Aviation Sector

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8. Joint Projects and Training:

Organization of Trainings and Seminars: Conducting training events and seminars for the purpose of sharing experience and skills between representatives of the private and public sectors.

Involvement of the private sector will not only provide access to the latest technologies, but also create an effective management and development mechanism aimed at meeting the needs of the modern aviation industry.

This indicates the importance of organizing trainings and seminars to share experiences and skills between representatives of the private and public sectors in the aviation industry. Involvement of the private sector in this process has the potential not only to provide access to the latest technologies, but also to form an effective management and development mechanism aimed at meeting the needs of the modern aviation industry.

First of all, the organization of trainings and seminars will provide an opportunity for representatives of both sectors to exchange best practices and innovative ideas. This will contribute to increasing the level of professional competence and qualification of employees at all levels.

Involving the private sector in this process will not only expand the knowledge base, but also create a platform for interaction between companies and government organizations. This can lead to the emergence of strategic partnerships and joint initiatives aimed at the development and improvement of the aviation industry.

Further implementation of the latest technologies provided by the private sector will contribute to increased operational efficiency and safety in the aviation industry. Applying these technologies can improve process automation, reduce risk, and increase overall productivity.

The creation of an effective management and development mechanism focused on the needs of the modern aviation industry will contribute to a balanced approach to solving problems and implementing strategic goals. This mechanism may include tools for monitoring and analyzing market trends, responding to changes in legislation and regulations, and implementing initiatives to improve safety standards and environmental sustainability.

Therefore, the organization of trainings and seminars along with the involvement of the private sector is a key step in creating a platform for the growth and improvement of the aviation industry through the sharing of knowledge, technology and strategic initiatives.

2.7. Artificial Intelligence (AI) in aviation

Artificial intelligence (AI) in aviation is a key area of innovation aimed at using computer systems to perform tasks that normally require human intelligence. Aviation innovation labs can focus on developing and implementing AI systems to automate various aspects of aviation operations.

With innovations in the field of Artificial Intelligence (AI) and constant research, the aviation industry is witnessing extraordinary development, which opens up prospects for even more use of these systems. The implementation of AI in aviation technologies leads to a significant expansion of automation capabilities and an increase in the overall level of safety and efficiency in the field of aviation activity.

The use of AI in aviation allows the development of systems that are able to adapt to changing conditions and challenges that may arise in the airspace and on the ground. Modern machine learning algorithms allow AI systems to learn on the basis of data, taking into account the large volume of information accumulated in the aviation field.

One of the key benefits of using AI is to improve safety systems in aviation. AI systems can analyze large streams of data, detecting anomalies and predicting potential risks. This increases the ability of systems to respond in time to potential threats and avoid emergency situations.

The further development of AI in aviation also helps to increase the efficiency of operations. The use of AI systems in managing logistics, flight scheduling, aircraft maintenance and other aspects of aviation infrastructure helps airlines plan and execute optimal operations.

In general, the development of AI promises to transform the aviation industry, providing not only a high level of safety, but also increased efficiency and convenience for passengers. This sets the stage for a new stage in the development of aviation technologies, based on intelligent solutions and automation.

Development and application:

1. Flight safety:

Accident prediction: AI can analyze vast amounts of data, including weather conditions, aircraft technical condition, and other factors to predict possible risks and prevent accidents.

The introduction of Artificial Intelligence (AI) into the aviation safety system opens up new possibilities for predicting and preventing accidents. AI can use the analysis of vast amounts of diverse data, such as weather conditions, aircraft technical condition, aeronautical parameters and other factors, to identify possible risks and hazards.

This technology makes it possible to create systems that not only respond to current conditions, but also predict possible problems before they occur. For example, AI can analyze weather dynamics and aircraft response to different atmospheric conditions to determine optimal routes and safety zones.

Another important function of AI is the detection of anomalies in the technical condition of aircraft. AI systems can analyze data collected from the aircraft's sensors and monitoring systems to detect any deviations from normal operation and automatically generate warnings or maintenance recommendations.

In addition, AI-based prediction systems can take into account a variety of factors, such as flight planning, piloting skills, and airlines' safety history. This allows aviation organizations to make informed decisions about flight safety and risk management.

This approach to aviation safety helps to improve the prediction and prevention of possible hazards, reduce risks and increase the level of safety in the aviation industry.

2. Flight planning:

Route Optimization: AI can analyze data on weather, air traffic and other factors to automatically select optimal routes, which reduces fuel consumption and shortens flight time.

The use of Artificial Intelligence (AI) in the field of aviation flight planning opens up new opportunities for route optimization and flight management. AI can analyze large amounts of data, including information on weather conditions, air traffic, aircraft technical condition and other factors, to automatically determine optimal flight routes.

One of the key functions of AI in this context is the ability to adapt to changing conditions, such as changes in weather or air traffic. AI systems can take these factors into account in real time, automatically rerouting aircraft to optimize paths and avoid dangerous situations.

Automatic selection of optimal routes with the help of AI contributes not only to reducing flight time, but also to efficient use of fuel. This ensures a reduction in fuel consumption and emissions into the atmosphere, which meets modern environmental standards and contributes to the sustainable development of the aviation industry.

The use of AI in flight planning also takes into account the individual characteristics of aircraft, their load and the specifics of flights, which allows you to create optimal routes, taking into account all the necessary parameters. This helps increase the efficiency of airlines and ensures comfortable and efficient flights for passengers.

In general, the use of AI in flight planning is identified as an important step in improving aviation operations, contributing to the efficient exploitation of resources and improving the overall productivity of departments and airlines.

3. Passenger service:

Personalized Services: AI can use passenger data to create personalized offers and improve service from check-in to boarding.

Artificial intelligence in the field of passenger service in the aviation industry opens wide opportunities for creating a unique and personalized experience for each traveler. With the use of AI, it is possible to effectively analyze and use passenger data from the moment of their check-in to the moment of boarding the plane.

AI can analyze information about individual preferences, flight history, and passenger behavioral data. Based on this data, personalized offers and recommendations are created for each passenger. For example, the system can provide recommendations for choosing a seat in the cabin, offer individual menus for dinner or take into account specific preferences for in-flight entertainment.

At the time of check-in or when booking a ticket, AI can also automatically take into account certain requests or suggestions of passengers, such as the need for additional equipment for passengers with disabilities or special conditions for passengers with children.

In addition, AI can contribute to improving the interaction with passengers during their stay at the airport by providing information about the flight, baggage status, as well as suggestions for additional services and entertainment in the airport terminal.

Through the use of AI, airlines can improve passenger satisfaction by providing them with a personalized and unique flight experience. This contributes to the retention and attraction of customers, and also has a positive effect on the reputation of airlines in today's competitive environment of the aviation industry.

4. Aircraft maintenance:

Diagnostics and Repair: AI can use sensors and data from aircraft to automatically diagnose the state of systems and prevent possible breakdowns.

Artificial Intelligence (AI) in the aviation industry plays a key role in improving aircraft maintenance by providing automated diagnostics and prevention of possible breakdowns. This approach expands the capabilities of technical services and increases the efficiency of aircraft maintenance at all stages of their life cycle.

AI systems use sensors located on various parts of the aircraft to constantly monitor the state of its systems and components. These sensors collect a variety of data, including temperature, pressure, vibration, equipment condition, and other parameters.

AI analyzes this data in real time using machine learning and artificial intelligence algorithms. This allows the system to detect anomalies, predict potential breakdowns, and recommend necessary maintenance actions.

For example, if the system detects changes in engine performance, it can automatically suggest that those systems be checked or serviced. Such a reasonable approach avoids the occurrence of serious technical problems

problems, providing scheduled maintenance and increasing aircraft reliability.

Additionally, AI systems can take into account the history of breakdowns and repairs to analyze risks and suggest pre-maintenance strategies. This allows airlines to plan maintenance in a way that maximizes aircraft uptime and minimizes downtime.

Considering all the advantages, the use of AI in aircraft maintenance is a promising direction for the development of the aviation industry, contributing to the improvement of safety, efficiency and cost-effectiveness of aviation operations.

5. Cargo monitoring:

Tracking and Security: AI can track the location of cargo in real time and help optimize logistics processes.

Artificial Intelligence (AI) in the field of cargo monitoring is transforming the way in which the movement of goods is controlled, providing important advantages in the field of cargo tracking and security. The use of AI in this context allows tracking the location of cargo in real time and optimizing logistics processes.

AI systems can be equipped with various sensors, such as GPS trackers, temperature and humidity sensors, as well as devices for monitoring the condition of the cargo. These sensors collect data and transmit it to accounting systems, where AI algorithms are used to analyze this data.

One of the key advantages is the ability to track cargo in real time. This not only ensures accuracy in the location of the cargo, but also allows operators to respond in time to any unforeseen circumstances or deviations from the schedule.

AI can also use analytics and forecasting to optimize logistics processes. For example, the system can analyze data about the path of cargo movement, taking into account various parameters, such as traffic, weather conditions and other factors, to determine the optimal route and predict possible delays.

Cargo security is enhanced by AI capabilities to detect anomalies or unwanted interference during transportation. Systems can automatically detect unusual conditions, such as temperature changes or unexpected shutdowns, and alert operators for further action.

All of these aspects of using AI in cargo monitoring contribute to improving the efficiency and security of logistics chains, which is key to optimizing global supply chains in today's world.

6. Management of large data flows:

Big Data Processing: AI helps organize and analyze the large volumes of data generated during aviation operations.

Artificial intelligence (AI) plays a critical role in dealing with the large volumes of data generated during aviation operations, ensuring the efficient management and analysis of these large streams of information. Through intelligent algorithms and analytical tools, AI facilitates the organization, processing and use of data to improve various aspects of aviation operations.

Big data includes information from various sources, such as flight data, sensor data, passenger and cargo information, meteorological data, aircraft technical parameters, and others. AI allows automated processing of this data, highlighting key relationships and trends, as well as timely detection of anomalies or potential risks.

Big data analytics using AI can provide significant benefits in many aspects of aviation operations. For example, in the field of security, AI can detect deviations from standards and predict possible threats to flights. In logistics, the use of AI allows you to effectively solve tasks related to freight transportation, taking into account various influencing factors.

It is important to note that AI can also use machine learning to continuously improve its analytical capabilities and adapt to changes in the environment. This contributes to the continuous development of data management systems and ensures their relevance in the rapidly changing world of aviation technology.

In conclusion, AI in the aviation industry plays a key role in rationalizing and using large volumes of data, which leads to increased efficiency, safety and innovation in aviation operations.

Development and implementation of AI systems in aviation require solving ethical, security and regulatory issues.

The application of AI can significantly improve the efficiency, safety and comfort of aviation services, reducing costs and risks.

Future development: As technology advances and research in AI advances, the aviation industry can expect to see even greater use of these systems to expand automation capabilities and improve overall safety and efficiency.

2.8. Risks of introducing artificial intelligence in aviation

The implementation of artificial intelligence (AI) in aviation can significantly contribute to the improvement of efficiency, safety and innovation in the industry, but at the same time it is associated with certain risks and challenges. Here are some of the main risks:

1. Security and Reliability:

The use of AI in critical aviation systems requires a high level of reliability and safety. Any errors or vulnerabilities can have serious consequences for flight safety.

2. Training and Adaptation:

AI needs a significant amount of data to train effectively. Insufficient or inadequate data can lead to incorrect or unpredictable results.

3. Ethical Issues:

The use of AI in aviation may raise ethical questions, particularly in the areas of autonomous flights, the resolution of important emergency situations, and the collection and use of personal data of passengers.

4. Necessity of Human Intervention:

In aviation, there may be the problem of requiring human intervention in complex situations or in conditions that AI may view as ambivalent.

5. Liability and Regulation:

Determining responsibility for AI actions in accidents, errors, or security incidents can be a difficult task. Regulation of the use of AI in aviation needs careful study and improvement.

6. Failure of technology and Dependency:

Dependence on AI can become a problem, especially if the system fails or technical problems arise.

7. Cyber security:

The increased use of AI creates new attack vectors for cybercriminals, which can lead to cyber threats and breaches of aviation security systems.

To minimize these risks, thorough testing, improvement of algorithms, regular audits and establishment of effective mechanisms of control and interaction with AI in aviation systems are necessary.

CONCLUSIONS TO CHAPTER 2

In this chapter, the methods of increasing the throughput capacity of the airport were considered. There are quite a few factors that can help increase throughput. It is important to note the development of artificial intelligence (AI) in aviation. AI technologies have great prospects and can greatly help the aviation sector. Different strategies for increasing airport capacity and their examples were proposed.

CHAPTER 3.
INCREASING THE CAPACITY OF THE ZHULYANY AIRPORT

3.1. Multiagent Systems and Infrastructure Integration

The issue of Zhulyany airport is quite difficult, because the design and location was created back in 1924. At that time, there was no idea that it would be necessary to receive large passenger and transport aircraft, so the runway was designed for the aircraft of that time. However, today, the most common aircraft are Boeing 737, 747,757; Airbus A320 and 380. Therefore, the task was to increase the size of the runway. Before the reconstruction, the length was 1800 m and the width was 49 m. After the reconstruction, the length became 2310 m and the width was 45 m.

However, the capacity issue is not only one runway, but also the number of taxiways, the number of aprons and the main services that serve the aircraft.

According to unofficial sources, the number of planes that the airport can serve per hour is 10 units. According to an average calculation, there can be from 50 to 150 people on board one plane. I suggest taking the average number of 100 people, as the airport accepts international transportation and domestic flights. 10x100 = 1000 passengers per hour. The most difficult task at the moment is going through registration and passport control. Therefore, we have to think not only about the planes and the ground infrastructure, but also about the comfort and speed of the stages before boarding. If before the war, the number of passenger traffic was 1,418,000 passengers, then after the end of the war this figure may reach 2,000,000 and even 2,500,000 passengers per year. Therefore, the question is quite relevant and has a serious nature.

The use of multi-agent systems, which include the interaction between different services and systems of the airport, contributes to the coordination and optimization of work processes. The integration of infrastructure, including terminals and check-in points, allows creating a single, efficient space for passengers.

Multiagent Systems (MAS)

Multi-agent systems in airports are computer systems where agents are autonomous computing entities that have the ability to perceive their environment, make decisions, and interact with each other. In an airport environment, agents can represent various services and systems, such as check-in, security, maintenance, etc (Figure 3.1).

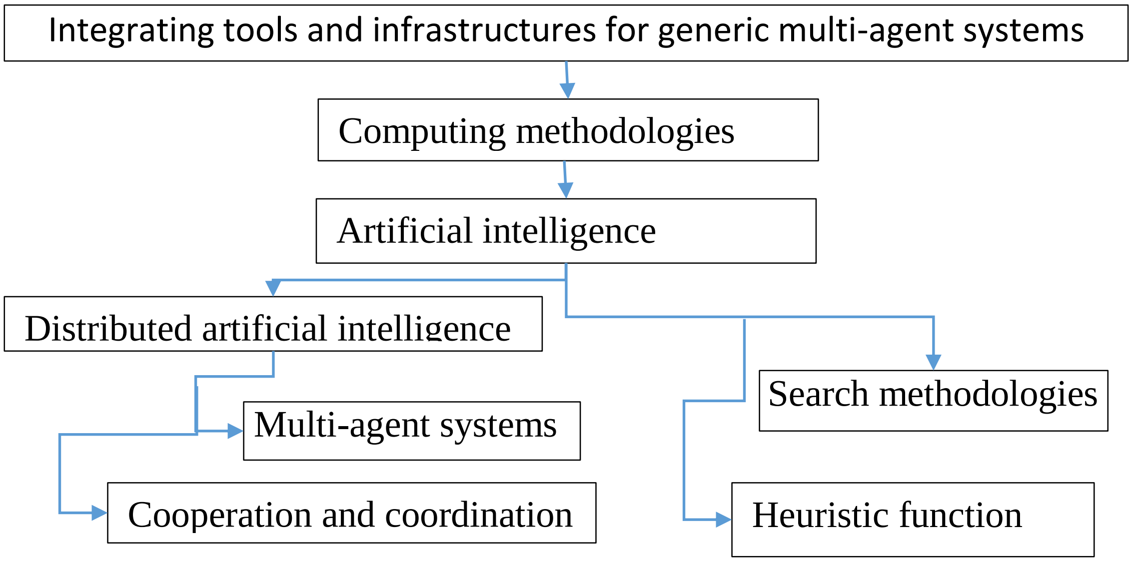

Figure 3.1. - Multi-agent systems general components

2. Interaction and Coordination:

Multi-agent systems interact and coordinate their activities to achieve common goals. For example, a check-in agent can work with a security agent to streamline screening processes and expedite passenger service.

3. An example of the operation of multi-agent systems:

Let's imagine a situation when a passenger has changed his flight and needs a quick re-registration. A check-in agent can alert a security agent, who in turn prepares for a rapid security screening for that passenger. At the same time, maintenance service agents can be informed of the need for fast baggage service for a new flight.

4. Infrastructure integration:

Infrastructure integration includes bringing together different aspects of the airport environment, such as terminals, check-in counters, security areas, and others. Multi-agent systems can provide communication between these parts, which allows creating a single, efficient space for passengers.

Example of Integration:

A passenger who has checked in quickly can use one single access card, which allows him to go through all stages, starting from the terminal and ending with security areas and boarding the plane. Agents in different parts of the airport interact, jointly solving tasks and optimizing the passenger's time. The general approach is based on the understanding that the integration of multi-agent systems and infrastructure allows creating a more efficient and user-oriented environment at the airport.

The given code (ed. appendix 1) demonstrates exactly how our development should work. The result of this code in practice is shown in Figure 3.1

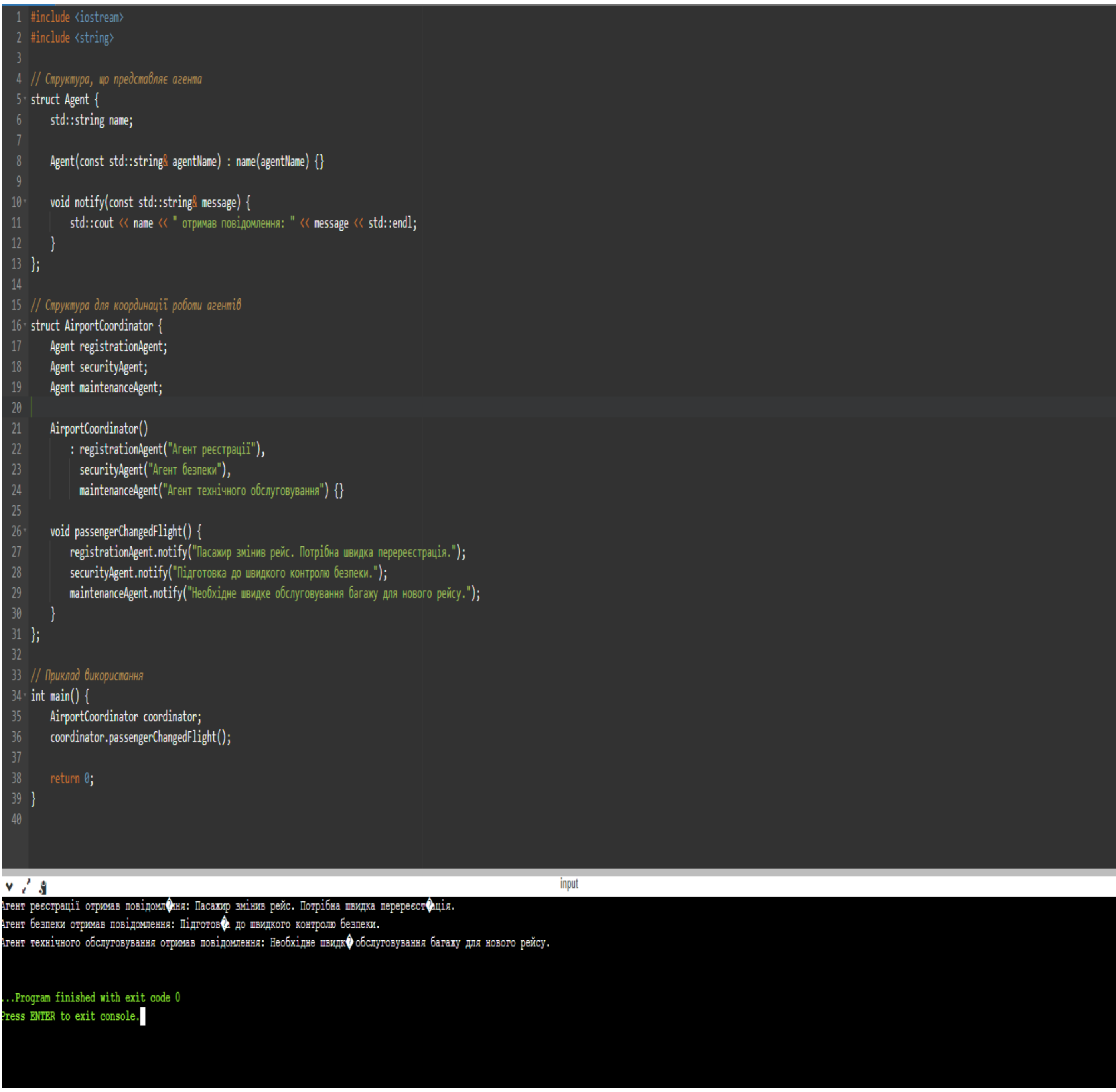

Figure 3.2 – Screenshot of an example of the program in C++

This code is just a simple example that illustrates the possible use of multi-agent systems to coordinate the actions of different airport services in a situation where a passenger has changed his flight.

The development of a multi-agent system in reality could help airports in the following aspects:

1. Efficiency of passenger service: A multi-agent system can automate and coordinate various aspects of passenger service during flight changes, which reduces waiting time and improves overall comfort.

2. Optimization of work processes: The system can increase the efficiency and coordination of services, providing a faster response to changes in the scenario of passenger needs.

3. Increased security: The ability to quickly notify security and maintenance services can facilitate rapid response to non-standard situations, ensuring security and service continuity.

4. Information management: Automatic notification and exchange of information between agents helps manage data and events in real time, making processes more transparent and efficient.

5. Increased capacity: Automation and coordination of services can lead to reduced service times, which in turn can have a positive impact on airport capacity.

Of course, this is only one aspect of the possible use of multi-agent systems. In reality, the development of a more complex and adapted to specific needs system may include many other functions and capabilities.

Creating a full-fledged multi-agent system is an extensive and complex task. However, we also created a sample of such a program in the Python programming language, which illustrates the basic principle of agent interaction. a simple Python code is presented using the multiprocessing library to simulate agents that exchange information (see Appendix 2):

The result of this code in practice is shown in Figure 3.3

```python
import multiprocessing
import time

def registration_agent(queue, passenger_name):
    time.sleep(2)  # Симуляція реєстрації
    queue.put(f"Пасажир {passenger_name} зареєстрований")

def security_agent(queue, passenger_name):
    time.sleep(3)  # Симуляція контролю безпеки
    queue.put(f"Пасажир {passenger_name} пройшов контроль безпеки")

def baggage_agent(queue, passenger_name):
    time.sleep(4)  # Симуляція обробки багажу
    queue.put(f"Багаж пасажира {passenger_name} готовий до відправлення")

if __name__ == "__main__":
    passenger_name = "Semenenko Oleksii"

    # Створення черги для обміну інформацією між агентами
    communication_queue = multiprocessing.Queue()

    # Створення процесів-агентів для реєстрації, контролю безпеки та обробки багажу
    registration_process = multiprocessing.Process(target=registration_agent, args=(communication_queue, passenger_name))
    security_process = multiprocessing.Process(target=security_agent, args=(communication_queue, passenger_name))
    baggage_process = multiprocessing.Process(target=baggage_agent, args=(communication_queue, passenger_name))

    # Запуск процесів
    registration_process.start()
    security_process.start()
    baggage_process.start()

    # Очікування завершення роботи процесів
    registration_process.join()
    security_process.join()
    baggage_process.join()

    # Отримання та виведення інформації від агентів
    while not communication_queue.empty():
        print(communication_queue.get())
```

input

```
Пасажир Semenenko Oleksii зареєстрований
�асажир Semenenko Oleksii пройшов контроль безпеки
Багаж па�ажира Semenenko Oleksii готовий до відправлення


...Program finished with exit code 0
Press ENTER to exit console.
```

Figure 3.3 – Screenshot from an example of the program in Python

This example uses multiprocessing to create separate processes for each agent that simulates check-in, security, and baggage handling. A queue is used to exchange information between agents. Of course, in a real multi-agent system, information sharing and coordination would be much more complex.

Each airline on the territory of the Zhulyany airport will use a variety of information systems for the interaction of various services and departments. Electronic reservation systems, automated baggage handling systems, security control systems and others interact to provide efficient passenger service and flight safety.

Experience with implementing integrated systems at some of the busiest airports suggests that they allow passengers to feel more comfortable and move through various stages faster, from check-in to boarding.

CONCLUSION TO THE CHAPTER 3

This section is devoted to the topic of multi-agent systems research. An application program has been developed using C++ and Python based software that can help passengers quickly resolve issues related to ticket replacement.

Elements of multi-agent systems and infrastructure integration already exist in modern aviation, although not necessarily in a format similar to the example given. However, many aspects of aviation maintenance and management could benefit from such an approach.

However, the development of multi-agent systems and infrastructure integration in the field of aviation continues, and in the future we can expect even more extensive use of these technologies.

CHAPTER 4.

ENVIRONMENTAL PROTECTION AND OCCUPATIONAL HEALTH

4.1. Environmental Protection

Environmental protection in aviation is important given the potential impact of aviation activities on climate, air quality, noise pollution and resource use. To ensure the sustainable development of the aviation industry and minimize the negative impact on the environment, various measures and strategies are used

Environmental protection strategies in aviation:

1. Improvement of Fuel Efficiency:

Using new technologies and improving the aerodynamic characteristics of aircraft to reduce fuel consumption.

Improving fuel efficiency in aviation is a key strategy for reducing greenhouse gas emissions and optimizing economic productivity. This strategy involves the introduction of new technologies and improvement of the aerodynamic characteristics of aircraft in order to reduce fuel consumption. A more detailed description of this approach is provided below.

Use of New Technologies:

One of the key strategies for improving fuel efficiency is the use of advanced technologies in aircraft manufacturing. This may include the development and implementation of more efficient engines, the use of lighter materials for aircraft construction, and the implementation of innovative flight control systems.

Optimization of aerodynamic characteristics:

Improving the aerodynamic characteristics of the aircraft plays an important role in reducing air resistance and, therefore, fuel consumption. This can be achieved by introducing changes to the aircraft design, such as improved wings, larger actuators and other aerodynamic improvements. The use of computer modeling and testing of virtual prototypes allows engineers to optimize the shape and structure of the aircraft to achieve maximum efficiency.

Electrification and hybrid technologies:

One of the innovative trends is the development of electric aviation and hybrid technologies. The introduction of electric or hybrid systems can help reduce dependence on traditional fuels, as well as increase the efficiency of energy consumption in various phases of flight.

These strategies aim to not only reduce operating costs for airlines, but also minimize aviation's environmental impact, creating a more sustainable and efficient infrastructure for the future.

2. Use of Biofuel:

The introduction of biofuels in the composition of fuel for aircraft, which can reduce emissions of CO2 and other pollutants.

Use of Biofuel in Aviation:

The introduction of biofuels in the aviation industry is one of the key strategies to reduce CO2 emissions and other pollutants, contributing to the growth of the environmental sustainability of the aviation sector. This initiative is aimed at transitioning to more sustainable and environmentally friendly energy sources for aircraft. Below is a detailed description of the use of biofuel in aviation.

Biofuel sources:

Biofuels are made from various biological sources such as plants, algae, food waste and other organic materials. The main types of biofuels used in aviation include biodiesel and renewable jet kerosenes.

Advantages of using biofuel:

1. Reduction of CO2 emissions: Using biofuels can significantly reduce greenhouse gas emissions compared to traditional hydrocarbon fuels. This helps limit the impact of aviation on climate change.

2. Promoting Sustainable Agriculture: Growing plants for biofuel production can be an additional incentive for sustainable agricultural development and reducing dependence on unsustainable sources of oil.

3. Promoting Innovation: The introduction of biofuels requires the development of technologies for efficient production and processing, promoting innovation in the energy sector.

4. Diversification of Energy Sources: The use of biofuels contributes to the expansion of energy sources and makes the aviation industry less dependent on traditional fuels.

Challenges and Obstacles:

1. Competition with Food: Competition for land resources between the cultivation of biofuel plants and food crops may occur, requiring a balanced approach.

2. Technological Challenges: Some technological challenges related to production efficiency and energy consumption in the production of biofuels require further research and development.

Conclusion: The use of biofuels in aviation opens up prospects for creating more environmentally sustainable and responsible air transport, contributing to the global effort to reduce emissions of gases that affect the climate. Achieving these goals requires the cooperation of aircraft manufacturers, aviation companies and government organizations to create a sustainable and competitive infrastructure for biofuels in the aviation industry.

3. Optimization of Routes:

Use of modern navigation systems and technologies to optimize routes, which allows to reduce fuel consumption.

Optimization of Routes in Aviation:

Route optimization in modern aviation plays an important role in reducing fuel costs and increasing flight efficiency. The use of modern navigation systems and technologies allows airlines and pilots to analyze and choose optimal routes in real time, taking into account various factors. Below is a detailed description of this process.

Main Elements of Route Optimization:

1. Modern Navigation Systems: The use of GPS technologies and modern navigation systems allows airlines to accurately determine the location of aircraft and receive a real-time analysis of atmospheric conditions, traffic and other parameters.

2. Weather Considerations: Route optimization includes analyzing weather conditions to choose a path with less air resistance, avoid turbulence, and use favorable winds to save fuel.

3. Traffic Flow Analysis: Modern navigation systems also consider air flow and traffic to avoid congestion and ensure efficient and safe traffic.

4. Optimizing Flight Altitude: Taking into account the optimal flight altitude allows aircraft to effectively use air layers and reduce air resistance, which leads to fuel savings.

Benefits and Results:

1. Reduction of Fuel Costs: Route optimization allows you to minimize fuel costs, which is an important factor in reducing costs for airlines.

2. Reduction of Flight Time: Effective route selection can also lead to reduction of flight time, which improves passenger service and increases competitiveness.

3. Environmental Benefits: Reduced fuel consumption leads to reduced emissions of CO2 and other pollutants, contributing to environmentally sustainable aviation.

The use of route optimization technologies is a key factor in achieving greater efficiency and sustainability in the aviation industry.

4. Environmentally Clean Airplanes:

Development and implementation of environmentally friendly technologies and materials for aircraft, as well as improvement of emission cleaning systems.

Environmentally Clean Airplanes in Aviation:

The development and implementation of environmentally friendly technologies and materials for aircraft is an important step in the direction of creating a more sustainable and environmentally responsible aviation. This process includes not only the improvement of engines, but also the improvement of various aspects of aircraft and their production.

Main Elements of Environmentally Clean Aircraft:

1. Improved Engines: Development and use of efficient and environmentally friendly engines, such as turbojets or turbofans, with higher thrust and lower emissions.

2. Light and Strong Materials: Application of new materials such as composites or aluminum alloys in aircraft construction to reduce the weight of the aircraft and improve its aerodynamic characteristics.

3. Aerodynamic Optimization: Improving the design of the wings and fuselage to reduce air resistance and optimize flight.

4. Emissions Cleaning Systems: Development and implementation of effective emission cleaning systems that reduce the amount of pollutants released into the air as a result of aviation operations.

5. Electric and Hybrid Technology: Implementation of electric and hybrid systems for some parts of the aircraft, which can reduce fuel use and improve its fuel efficiency.

Benefits and Results:

1. Reduction of Environmental Impact: The use of environmentally friendly technologies leads to a reduction in emissions of toxic gases and other pollutants.

2. Fuel efficiency: Improvements in engines and aerodynamic performance lead to reduced fuel consumption.

3. Responsibility and Reputation: Airlines implementing environmentally friendly technologies can improve their reputation and meet modern sustainability standards.

Manufacturers and airlines are actively working on the introduction of environmentally friendly technologies in order to make the aviation industry more sustainable and environmentally responsible.

5. Noise-reducing technologies:

- Implementation and development of technologies aimed at reducing noise pollution in airports and during flights.

Noise-reducing Technologies in Aviation:

Noise reduction technologies are a key area for improving the quality of life of the population, particularly those living near airports or in areas with heavy air traffic. These technologies cover various aspects of aviation activities aimed at reducing noise in airports and during flights.

Main Aspects of Noise Reduction Technologies:

1. Engine Modernization: Development and use of more efficient and less noisy engines. This may include new blade designs and reduced air turbulence in the jet stream.

2. Aerodynamic Changes: Implementation of aerodynamic solutions aimed at reducing the noise that arises from the interaction of air with the surface of the aircraft.

3. Anti-noise Designs: Use of new materials and designs that reduce the spread of noise from engines and other aircraft components.

4. Active Noise Management Systems: Implementation of systems that analyze and manage aircraft noise characteristics in real time to minimize environmental impact.

Advantages of Noise Reduction Technologies:

1. Reducing the Impact on Health: Reducing the noise level helps to avoid negative effects on the health of residents, in particular, problems with sleep and stress.

2. Compliance with Environmental Standards: Reducing noise pollution meets environmental standards and helps the aviation industry meet its environmental obligations.

3. Improving Public Perception: The use of noise reduction technologies helps airlines and airports maintain a positive perception among the public.

Innovations in noise reduction technologies play an important role in improving the sustainability and environmental responsibility of the aviation industry.

6. Emissions Management:

Development and implementation of strategies to manage emissions of CO_2 and other pollutants, including participation in emission quota programs.

Aviation Emissions Management:

In today's increasingly environmentally conscious world, the aviation industry is focusing on developing and implementing strategies to manage emissions, particularly CO_2 and other pollutants. This becomes a key task to achieve environmental sustainability and compliance with strict standards.

Main Components of Emissions Management Strategies:

1. Environmentally Clean Aircraft Technologies: Development and use of new, more efficient engines and aerodynamic solutions that reduce CO_2 emissions during flights.

2. Use of Biofuels: The introduction of biofuels obtained from renewable sources into jet fuel to reduce emissions and dependence on traditional fuels.

3. Emissions Monitoring and Measurement: Development and use of monitoring systems that accurately measure emissions of CO2 and other pollutants for effective management.

4. Emissions Allowance Programs: Participation in emission allowance programs where companies receive a limited number of emission allowances and can trade them on the market.

5. Research and Development: Funding research and development to find new innovative solutions that will further reduce the impact of aviation on the environment.

Advantages of Emissions Management Strategies:

1. Reduction of Impact on Health: Minimization of emissions contributes to the improvement of air quality and health of people living near airports.

2. Compliance with Environmental Standards: Carrying out emissions within the limits of established norms allows airlines and airports to meet strict environmental standards.

3. Economic Benefit: Reducing the use of traditional fuels and participating in emission quota programs can lead to reduced environmental taxes and other benefits.

Emissions management is a strategic focus for the aviation industry as it seeks to achieve greater environmental sustainability and responsibility.

7. Secondary Use of Aviation Equipment:

Promotion of secondary use and recycling of aviation equipment to reduce waste production.

Secondary Use of Aviation Equipment:

In today's world, where sustainability and resource conservation are becoming the main challenges, the secondary use and recycling of aviation equipment are becoming key components of sustainable development in the aviation industry. This approach helps reduce waste production and has a positive impact on the environment and social responsibility.

Main Aspects of Secondary Use of Aviation Equipment:

1. Recycling and Recycling: Subjecting used equipment to recycling processes where the materials can be recovered and used to produce new equipment or other products.

2. Disassembly and Removal of Components: Specialized companies can disassemble old aviation equipment into separate components that can be used in other industries or secondary in the aviation field.

3. Upgrading and Upgrading: Some obsolete equipment can be refurbished and upgraded for future use, reducing the need to produce new equipment.

4. Stimulation of Innovation: Creation of incentives and support for companies that introduce new technologies and approaches to secondary use, which promotes innovation in this direction.

Advantages of Secondary Use of Aviation Equipment:

1. Reduction of Waste Production: This approach allows you to reduce the amount of waste and reduce the negative impact on the environment.

2. Efficient Use of Resources: The use of already existing materials and components contributes to a more efficient use of natural resources.

3. Cost Reduction: Recycling and reuse can result in cost reductions compared to manufacturing new equipment.

4. Energy Conservation: Using existing materials requires less energy compared to mining and processing new materials.

The secondary use of aviation equipment is an important step in the direction of sustainable development that takes into account the environmental and economic challenges of the aviation industry.

8. Innovations in Technologies:

Development of new technologies such as electric aviation and hybrid aircraft that can be less explosive and environmentally friendly.

Innovations in Technology in Aviation: Moving to Electric and Hybrid Aviation

The growing interest in sustainable development and reducing the negative impact of aviation on the environment has led to a great focus on innovation in technology, particularly in the development of electric and hybrid aircraft. These technologies are aimed at creating less explosive and environmentally friendly aircraft, which could revolutionize the future of aviation.

Electric Aviation:

1. Principle of Operation: Electric aircraft operate on the principle of using electric motors powered by batteries or other sources of electricity, instead of traditional engines that run on fuel.

2. Environmental Benefits: Electric aviation allows you to significantly reduce emissions of harmful substances and greenhouse gases, since it does not use traditional types of fuel.

3. Energy Savings: Electric engines use energy more efficiently compared to traditional aircraft engines, which can lead to significant savings in fuel costs.

Hybrid aircraft:

1. Engine Combinations: Hybrid aircraft use a combination of traditional fuel-powered engines and electrical systems.

2. Fuel economy mode: The hybrid design allows the use of electric mode during standard flight phases, which reduces fuel consumption.

3.Improving Explosion Hazards: The use of electrical technologies can reduce the risk of explosion hazards and provide a safer mode of operation.

Common challenges and benefits:

1. Technological Challenges: The development of light and powerful batteries that can provide sufficient flight range is a key challenge in the implementation of electric aviation.

2. Stimulating Innovation: State and industry initiatives are aimed at stimulating research and development in the field of electric and hybrid aviation.

3. Prospects for Sustainable Development The use of electric and hybrid technologies in aviation can contribute to sustainable development and reduce the impact on the environment.

Innovations in electric and hybrid aviation are an important direction of development aimed at creating efficient, environmentally friendly and safe vehicles for the future.

9. Effective Use of Resources:

Implementation of measures for efficient use of water, energy and other resources in airports and related infrastructures.

Effective use of resources in aviation: the path to sustainability

Efficient use of resources at airports and related infrastructures is a key component of the sustainable development of the aviation industry. Application of appropriate measures can significantly reduce environmental impact and ensure rational use of limited resources.

Use of water:

1. Collection and recycling: Airports can implement rainwater collection and treatment systems for further use in irrigation, cooling and sanitation systems.

2. Water-saving Technologies: The use of technologies that allow efficient use of water in sanitary facilities and other areas contributes to the rational use of this resource.

Energy efficiency:

1. Solar and Wind Power Plants: The installation of solar and wind power plants on the territory of airports contributes to the production of energy from renewable sources.

2. Energy-efficient Lighting Systems: Replacing conventional lamps with energy-efficient LEDs and automating lighting help reduce electricity consumption.

Use of Other Resources:

1. Implementation of Recycling: Airport recycling systems can process waste, ensuring the secondary use of materials and reducing the volume of garbage.

2. Effective Use of Space: Optimizing the spatial plan of the airport allows reducing the loss of resources and providing comfortable conditions for passengers and staff.

Efficient use of resources is an important part of a sustainable development strategy in the aviation industry. Consistent implementation of these measures can lead to significant reductions in aviation's environmental impact and improved resource management within the industry.

The implementation of these strategies requires cooperation between airlines, manufacturers, regulators, airports and the public in order to achieve a balance between the needs of the aviation industry and the preservation of the environment.

4.2. Occupational health

Occupational safety is a system of methods for preventing accidents and incidents in the aviation industry. An accident or incident is rarely random. There are many signals that can be easily identified to promptly prevent situations of industrial injuries and accidents in aviation.

Occupational health and safety in the aviation industry is critical to ensuring the safety and health of workers, as well as to maintaining high standards of flight safety.

The Aviation Safety Foundation estimates that there are 27,000 aviation accidents and incidents worldwide each year, resulting in about 243,000 injuries, according to data compiled by the International Air Transport Association (IATA).

To ensure the safety of passengers and crew during and after a flight, health and safety must be a top priority. The health of workers is important because human lives are involved in every aircraft operation.

In the airline industry, issues related to the health of passengers and crew are critical to most activities: aircraft operations, passenger transport, cargo, etc. They cover issues as diverse as the problem of long working hours, the transmission of infectious diseases and disinfection.

An accident is rarely the direct result of a single mistake. It is the combination of various cause-and-effect factors that develop sequentially and converge at a single point in time, where the final trigger leads to dangerous incidents.

Safety is paramount, whether people are involved in customer service, in the workplace, or in the cockpit of an airplane.

In aviation, safety determines the very existence of the industry. Aviation is a complex business and involves people in many areas.

Flight crew members and ground workers are exposed to a number of risks and hazards due to physical factors and poor working conditions. Shift work, psychological stress, and hazardous physical factors negatively affect the health of workers and lead to violations in the field of labor protection.

Thanks to improved working conditions, aviation safety is constantly improving. This is made possible by sharing knowledge between manufacturers, operators and regulators.

Working conditions in air transport are improved through a collaborative approach between organizations involved in the design and production of aircraft and their equipment, regulatory oversight, aircraft operations, air traffic control, and airport infrastructure.

This collaborative approach is more effective than regulatory measures alone because it continually improves safety in all aspects of the global air travel system.

Identifying security risks and implementing best practices is a comprehensive solution to improving aviation security.

From the aircraft manufacturer, maintenance, ground support, to the flight crew and even the passengers, every factor plays a role in a safe takeoff and landing. This is achieved through complex procedures that prevent errors and omissions, as well as processes that exist to capture such errors (Figure 5.1).

Figure 5.1 - Labor protection when operating cargo trolleys

People work with complex equipment and in environments that themselves pose potential dangers. Occupational health and safety involves not only the safe operation of aircraft, but also the safety and well-being of personnel involved in the operation of ground infrastructure.

According to safety regulations, it is necessary to carry out the following types of briefings in accordance with GOST 12.0.004-79:

introductory - general concepts and basic provisions, internal regulations, behavior on the territory and facilities of the enterprise; carried out upon hiring by a labor protection engineer or a person replacing him, with registration in the journal;

primary at the workplace - familiarization with technology, equipment, hazardous areas, work safety methods, etc.; carried out before the start of work for newly hired employees, as well as for those transferred from another service, from one job to another, from one equipment to another, including during temporary transfer;

repeated - consolidation and assimilation of initial knowledge; is carried out for all employees, regardless of their qualifications and experience, at least once every six months (to the extent of initial training);

unscheduled - carried out when the technological process changes, or violations of training requirements;

current - upon admission to a specific job;

primary, repeated and unscheduled briefings are carried out by an official subordinate to the employee (head of warehouse, laboratory, etc.) with registration in the journal. Routine training is carried out by the official responsible for performing this specific job.

The main aspects of labor protection in aviation include:

1. Flight Safety and Training:

Simulators: Providing pilots with the opportunity to regularly train on simulators to prepare for various situations and emergencies.

Simulators play an important role in pilot education and training. They provide an opportunity to realistically reproduce various scenarios and situations, including emergency circumstances that may arise in the air. This allows pilots to improve their skills, solve critical situations and respond to unforeseen circumstances.

Assessment of Physical and Psychological Readiness: Systematic assessment of the physical and psychological state of pilots, which allows timely detection of possible problems. Regular assessment of the physical and psychological state of pilots is an important element of the safety system. This process includes medical examinations and psychological tests aimed at identifying any problems that may affect the pilot's ability to safely perform his duties.

The overall objective of these activities is to ensure that pilots have a high level of professional competence, physical fitness and psychological resilience to safely fly in all conditions.

2. Technical Condition of Aircraft:

Regular Technical Inspections: Carrying out regular technical inspections and maintenance of aircraft to identify and eliminate potential problems.

Regular technical inspections are a fundamental component of maintaining the safety and efficiency of aircraft in the air. These inspections are carried out according to a strict schedule and include a comprehensive inspection of the various systems, components and structures of the aircraft. Inspections are performed in accordance with the established norms and standards of aviation safety.

The stages of regular technical reviews include:

Visual Inspections: Examination of the exterior of the aircraft for visible damage, corrosion or other malfunctions.

Functional Tests: Checking the operation of aircraft systems and equipment during various operating modes.

In-Depth Inspections: Detailed technical inspections that may include disassembly and inspection of internal components.

The result of regular inspections is to ensure that aircraft are in good technical condition, which is important to prevent accidents and ensure the safety of passengers and crew.

Equipment Condition Monitoring: Use of monitoring systems to monitor the operation of various aircraft systems.

The use of modern monitoring systems is a key element of aircraft maintenance. These systems are embedded in various parts of the aircraft and constantly collect data on their operation and condition.

The main aspects of monitoring include:

-Sensor Systems: Using sensors to measure parameters such as temperature, pressure, vibration and others.

-Reporting Systems: Automated systems capable of generating reports and notifications of any anomalies or deviations from standard values.

- Software Diagnostics: Using software to analyze data and predict possible problems.

Equipment condition monitoring allows you to quickly identify and solve potential problems, which contributes to increasing the safety and efficiency of aircraft in operation.

3. Prevention of Occupational Diseases:

Anti-Fatigue Measures: Development and implementation of policies aimed at preventing fatigue among crew and other personnel.

Control of Exposure to Harmful Substances: Protection of workers from the harmful effects of various substances that may be used in aviation activities.

4. Safety on Earth and at Airports:

Ground Safety Systems: Ensuring a high level of safety for personnel working on the ground through effective safety systems and instructions.

5. Health Protection of Passengers and Staff:

Medical Assistance Systems: Provision of appropriate medical assistance both on board the aircraft and on the territory of the airports.

6. Sanitary and Hygienic Standards:

Compliance with Sanitary Standards: Regular inspection and compliance with sanitary standards in all areas of airports and on aircraft.

The general safety and health of workers in the field of aviation is determined by a set of measures and technical innovations aimed at preventing possible risks and negative effects on their health.

7. The influence of computer technology on the health of dispatchers.

The impact of computer technology on the health of air traffic controllers can include both positive and negative aspects. Some of these impacts are discussed below:

Positive aspects:

1. Automation and Convenience of Work: The use of computer technology can facilitate and automate many processes related to the dispatcher's work. This can reduce physical and psychological stress, as well as improve the speed and accuracy of information processing.

2. Modern Tools and Systems: The use of modern dispatching systems and tools allows dispatchers to quickly and efficiently interact with various elements of the aviation system, which can increase the overall level of safety and efficiency of aviation service.

3. Training and Simulation Opportunities: The use of computer systems for training and simulations allows dispatchers to improve their skills and respond to unforeseen situations without real risks.

Negative aspects:

1. Stress and Psychological Load: High responsibility and the need to make quick and accurate decisions can lead to stress and psychological strain in dispatchers.

2. Physical health: Long hours of computer work can lead to physical problems such as eye strain, back and neck pain, and muscle problems.

3. Monotony of Work.

4. Fatigue and risk of errors: Long shifts and periods of work without rest can increase the risk of fatigue, which can lead to reduced concentration and an increased likelihood of errors.

To reduce the negative impact of computer technology on the health of dispatchers, it is important to implement ergonomic solutions, organize regular breaks and train staff in effective stress management strategies.

CONCLUSIONS TO CHAPTER 4

Environmental protection in the field of aviation is a vital necessity, as aviation activities can have potential impacts on climate, air quality, noise and the use of natural resources. Various measures and strategies are used to achieve sustainable development of the aviation industry and minimize negative impacts on the environment.

Environmental protection in aviation is recognized as an important task for several key reasons.

First, aviation activities have potential impacts on climate, air quality and noise pollution. Emissions of greenhouse gases and other pollutants can lead to climate change and negatively affect air quality, which is a serious concern for the health of the population and ecosystems.

Second, noise generated by aviation sources can have harmful effects on people and wildlife living in areas where airports and air routes operate.

Thirdly, the huge volume of fuel consumption by aircraft engines leads to a significant use of natural resources, especially oil. Ensuring the sustainability of these resources and the development of more environmentally friendly alternatives are important aspects for the preservation of natural ecosystems and global energy development.

Thus, the implementation of effective measures to preserve the environment in the field of aviation is critical to ensure environmentally responsible development and minimize the negative impact of aviation on the planet.

Ensuring the safety and health of aviation workers is a critical aspect that determines the quality of working conditions and ensures high safety standards in the aviation industry. Occupational health and safety plays a crucial role in ensuring flight safety and maintaining high standards in this area.

Ensuring the safety and health of aviation workers is important for many reasons. This is directly related to flight safety, which is a priority in the aviation industry. The health and well-being of workers directly affects their ability to effectively perform their duties and interact in the extremes of the aviation environment.

In addition, ensuring high safety and occupational health standards in the aviation industry contributes to the creation of a reliable and stable work environment. This affects the quality of working conditions, reduces the risk of accidents and occupational diseases, thereby improving the overall health of employees.

Ensuring high standards of safety and labor protection in aviation is not only a moral and social responsibility of enterprises and airlines, but also a key element for maintaining the efficiency and stability of the sector as a whole. This contributes to increasing the professional level of employees, reducing losses from accidents and has a positive effect on the reputation of companies in the aviation industry.

GENERAL CONCLUSIONS

The work considered the factors affecting the airport capacity, as well as the methods of increasing the airport capacity, the importance of optimizing the airport capacity, in particular in Kyiv, to increase the efficiency of the transport process and reduce costs in the aviation industry. Increased capacity can improve the airport's competitiveness and help address the various challenges arising from the expected growth in air travel demand.

An example of a multi-agent system was demonstrated, which makes it possible to increase the throughput of the terminal. This process can lead to reduced service times, which in turn can have a positive impact on airport capacity.

The results of the research can be used in planning to increase the throughput capacity of the airport, to improve and modernize the terminals, to create a multi-agent system in Ukraine.

REFERENCES

1. Магістерська дипломна робота. Методичні рекомендації до виконання магістерських дипломних робіт. URL: http://www.ans.nau.edu.ua/thesis_ua

2.https://ru.wikipedia.org/wiki/%D0%9A%D0%B8%D0%B5%D0%B2_(%D0%B0%D1%8D%D1%80%D0%BE%D0%BF%D0%BE%D1%80%D1%82)

3. File:Kyiv Zhuliany International Airport.jpg. Website URL: https://commons.wikimedia.org/wiki/File:Kyiv_Zhuliany_International_Airport.jpg?uselang

4. Runway (from Wikipedia the free article) URL https://uk.wikipedia.org/wiki/%D0%97%D0%BB%D1%96%D1%82%D0%BD%D0%BE-%D0%BF%D0%BE%D1%81%D0%B0%D0%B4%D0%BA%D0%BE%D0%B2%D0%B0_%D1%81%D0%BC%D1%83%D0%B3%D0%B0

5. Website URL http://dorogimosti.org.ua/files/upload/21_Dasha%20Maliarenko_26

6. Website URL https://dspace.nau.edu.ua/bitstream/NAU/45649/1/272_%D0%9E%D0%9F%D0%A02020_%D0%92%D1%82%D0%BE%D1%80%D0%B8%D1%85_%D0%A3%D0%9F%D0%A0%20%D0%B2%20%D0%B0%D0%B2%D0%B0%D1%80%D1%96%D0%B9%D0%BD%D0%B8%D1%85%20%D1%82%D0%B0%20%D0%BD%D0%B5%D1%81%D1%82%D0%B0%D0%BD%D0%B4%D0%B0%D1%80%D1%82%D0%BD%D0%B8%D1%85%20%D1%81%D0%B8%D1%82%D1%83%D0%B0%D1%86%D1%96%D1%8F%D1%85.pdf7.

8. Website URL https://er.nau.edu.ua/bitstream/NAU/45699/1/Kononenko%20A.S.

9. Website URL Dynamic_Boundary_Optimization_of_Free_Route_Airspace_Sectors https://www.researchgate.net/publication/366293216

10. Article Skybrary "Accident and Serious Incident Reports: LOS (Loss of Separation)" URL https://www.skybrary.aero/accident-and-serious-incident-reports

11. Skip Navigation Links ICAO Air Navigation / Capacity and Efficiency URL https://www.icao.int/airnavigation/Pages/default.aspx

12. Airport CDM (A-CDM) URL https://ifatca.wiki/kb/wp-2016-157/

13. Prediction of Aircraft Waiting Time at Airport During Immediate Response to Disaster by Sunkyung Choi andShinya Hanaoka. URL https://www.mdpi.com/2226-4310/6/4/40

14. Повітряний кодекс України URL https://zakon.rada.gov.ua/laws/show/ 3393

15. Airport capacity and quality (An official website of the European Union. URL https://transport.ec.europa.eu/transport-modes/air/airports/airport-capacity-and-quality_en

16. Website URL https://www.icao.int/Meetings/AMC/MA/2006/atfm/pres12.pdf

17. Website URL https://www.aviationfile.com/airport-capacity-management/

18. Airport capacity and performance URL https://www.eurocontrol.int/service/airport-capacity-and-performance

19. Skybrary Article: Capacity Management URL https://skybrary.aero/articles/capacity-management

20. Website URL https://www.hubperformance.com/en/airport-capacity-planning/

21. TAV Technologies: Slot Coordination and Capacity Management System URL https://www.airport-technology.com/products/slot-coordination-capacity-management/

22. Website URL https://www.ainonline.com/aviation-news/aerospace/2023-06-14/beyond-automation-how-ai-transforming-aviation

23. Website URL https://www.eurocontrol.int/artificial-intelligence

24. Website URL https://www.airbus.com/en/innovation/industry-4-0/artificial-intelligence

25. Andy Graham "AI In Aviation Maintenance: How It's Changing The Industry" URL https://www.qoco.aero/blog

26. Skybrary Article: Airport collaborative decision-making URL https://skybrary.aero/articles/airport-collaborative-decision-making-cdm

27. Airport Collaborative Decision-Making URL https://www.eurocontrol.int/concept/airport-collaborative-decision-making

28. Airport Collaborative Decision-Making (from Wikipedia, the free encyclopedia) URL https://en.wikipedia.org/wiki/Airport_Collaborative_Decision_Making

29. Multi-agent_systems_ design_for_aerospace_applications URL https://www.researchgate.net/publication/253914404

30. Website URL https://www.sciencedirect.com/science/article/pii/S0921889023001197

31. A Multi Agent System for Airline Operations Control URL https://www.researchgate.net/publication/220988558

Fragment of a working program in C++

```
#include <iostream>
#include <string>

// Структура, що представляє агента
struct Agent {
    std::string name;

    Agent(const std::string& agentName) : name(agentName) {}

    void notify(const std::string& message) {
        std::cout << name << " отримав повідомлення: " << message << std::endl;
    }
};

// Структура для координації роботи агентів
struct AirportCoordinator {
    Agent registrationAgent;
    Agent securityAgent;
    Agent maintenanceAgent;
    AirportCoordinator()
        : registrationAgent("Агент реєстрації"),
```

```
        securityAgent("Агент безпеки"),
        maintenanceAgent("Агент технічного обслуговування") {}
    void passengerChangedFlight() {
        registrationAgent.notify("Пасажир змінив рейс. Потрібна швидка перереєстрація.");
        securityAgent.notify("Підготовка до швидкого контролю безпеки.");
        maintenanceAgent.notify("Необхідне швидке обслуговування багажу для нового рейсу.");
    }
};

// Приклад використання
int main() {
    AirportCoordinator coordinator;
    coordinator.passengerChangedFlight();

    return 0;
}
```

Fragment of a working program in Python

```
import multiprocessing
import time


def registration_agent(queue, passenger_name):
    time.sleep(2)  # Симуляція реєстрації
    queue.put(f"Пасажир {passenger_name} зареєстрований")


def security_agent(queue, passenger_name):
    time.sleep(3)  # Симуляція контролю безпеки
    queue.put(f"Пасажир {passenger_name} пройшов контроль безпеки")


def baggage_agent(queue, passenger_name):
    time.sleep(4)  # Симуляція обробки багажу
    queue.put(f"Багаж пасажира {passenger_name} готовий до відправлення")


if __name__ == "__main__":
    passenger_name = "Semenenko Oleksii"

    # Створення черги для обміну інформацією між агентами
    communication_queue = multiprocessing.Queue()
```

```
# Створення процесів-агентів для реєстрації, контролю безпеки та обробки багажу
registration_process = multiprocessing.Process(target=registration_agent, args=(communication_queue, passenger_name))
security_process = multiprocessing.Process(target=security_agent, args=(communication_queue, passenger_name))
baggage_process = multiprocessing.Process(target=baggage_agent, args=(communication_queue, passenger_name))

# Запуск процесів
registration_process.start()
security_process.start()
baggage_process.start()

# Очікування завершення роботи процесів
registration_process.join()
security_process.join()
baggage_process.join()

# Отримання та виведення інформації від агентів
while not communication_queue.empty():
    print(communication_queue.get())
```