Air Transportation Management Department

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"_____" _____2020

MASTER THESIS
(EXPLANATORY NOTES)

Theme: «Methods of air cargo transportation organization»

Done by: Ivan M. Varava

Supervisor: Phd in Economic**,** Associated Professor of the air transport management department Yuliya V. Shevchenko

Standards Inspector: Phd in Economic**,** Associated Professor of the air transport management department Yuliya V. Shevchenko

Kyiv 2020

ДОПУСТИТИ ДО ЗАХИСТУ
завідувач кафедри

_____Г. Юн

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ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ «МАГІСТР»

Тема: «Методи організації вантажних перевезень авіаційним транспортом»

Виконавець: Варава Іван Михайлович

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Faculty of Transport Logistics and Management

Air Transportation Management Department

Major (specialty): 6.070101-02 "Air Transportation Technology"

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TASK

of completion the master thesis

Ivan M. Varava

1. Theme of the bachelor thesis entitled "Methods of air cargo transportation management" was approved by a decree of the Rector order № _2401/st of October 17, 2019.

2. Term performance of thesis: from 14.10.2019 to 29.10.2019 and from 20.01.2020 to 09.02.2020.

3. Output data (project): informational data of airlines, analytical literature showing modern trends in the airports worldwide, financial reports of airports, statistics of international organizations.

4. The content of the explanatory note: analysis of the problems of the technology of cargo handling, introduction of new methods of automation, implementation of a new model of domestic and international cargo terminals.

5. List of required graphic (illustrative) material: analysis of the problems of cargo handling technology in Ukraine, airport software projects, the results of calculating the model of constructing domestic and international warehouses.

6. Planning calendar

№	Assignment	Deadline for completion	Mark on completion
1.	Collection and processing of statistical data	20.10.19 - 10.11.19	done
2.	Writing of the theoretical part	11.11.19 – 20.11.19	
3.	Writing of the analytical part	21.11.19- 06.12.19	done
4.	Writing of the design part	07.12.19- 23.12.19	done
5.	Writing of the introduction and summary	24.12.19- 28.12.19	done
6.	Execution of the explanatory note, graphic matters and the presentation	20.01.20- 29.01.20	done

7. Given date of the task: October 14, 2019.

Supervisor of the bachelor thesis: Yuliya V. Shevchenko

Task was accepted for completion: Ivan M. Varava

EXPLANATORY NOTE

Explanatory note of the thesis "Methods of air cargo transportation management", 113 pages, 42 figures, 5 tables and 19 sources used.

KEYWORDS: AIRPORT, AUTOMATED MANAGEMENT SYSTEMS OF TECHNOLOGICAL PROCESSES, REGISTRATION, MASS SERVICE THEORY, AUTOMATIZATION, CARGO HANDLING TECHNOLOGY, AIRPORT, CARGO TERMINAL, UNLOADING STATIONS, AUTOMATED SYSTEMS OF MANAGEMENT OF TECHNOLOGICAL PROCESSES.

The purpose of the thesis is to develop proposals for improving the methodology for evaluating the effectiveness of automated passenger service systems at the airport, taking into account current trends in the development of information technologies.

The object of the study is cargo air transportation in Ukraine, model for assessing the effectiveness of automated control systems of technological processes at the airport.

The subject of the study is the contemporary technologies of cargo handling at the airport, development of proposals for improving the methodology for assessing the effectiveness of automated cargo handling service systems at the airport, taking into account the current trends in the development of information technology.

Methods of research: methods of system analysis in constructing methodological approaches to studying the object and subject of research, methods and techniques of economic analysis in assessing the development of freight aviation transport in Ukraine.

In the project part of the thesis there are calculations of cargo terminal that can serve as effective model for implementation into domestic or international cargo terminal prototype.

Materials of the thesis work are recommended to be used in the implementation of new automated systems in the operation of airports and for conducting scientific research and practical activities of airlines.

CONTENTS

LIST OF ABBREVIATIONS

1. ACT - Air Cargo Terminal
2. DAL - Domestic Airlines
3. IAL - International Airlines
4. VLB - Vehicle With A Lifting Body
5. ULD - Unite Load Devices
6. GDP - Gross Domestic Product
7. IATA - International Air Transport Association
8. DC – Distribution Center
9. AWB –Air Waybill
10. ETV - Elevating Transfer Vehicles
11. CCTV - Closed-Circuit Television
12. RFID - Radio-Frequency Identification
13. NFC - Near Field Communication
14. DCS –Delivery Control System
15. ACS - Automatic Control Systems
16. BRS - Baggage Control System
17. WCO - World Customs Organization
18. ACI - Advanced Cargo Information
19. TACT - The Air Cargo Tariff and Rules
20. E-CSD - Air Cargo Digital Connectivity & Data Exchange Methodologies
21. MIP - The Message Improvement Program
22. TEU - Twenty-foot Equivalent Units
23. CM - Complex Mechanization

INTRODUCTION

The attractiveness of a transportation facility to its users is determined by factors such as safety, speed of service, and comfort. Sometimes it is possible to represent the combined effect of all these factors into one general measure of performance which we will call level of service. A facility which provides a high level of service is a facility which is quick, cheap and comfortable to use and which is perceived as safe by its users. When the level of service can be translated into monetary units, one defines instead a generalized price (or generalized cost) which can be used for economic evaluation purposes and feasibility analyses.

Air freight services are currently used all over the world, with many global businesses turning to using air freight services to transport their goods from one side of the country to another. Global businesses understand the importance of getting your goods from one location to another as quick as possible, so turn to using air freight services as a reliable way to get your cargo transported quickly and safely.

A set of mechanized, automated and technical equipment designed to perform passenger services, internal cargo handling and premises cleaning processes, shall provide a technically feasible and cost-effective level of work and corresponding employee productivity.

Air cargo plays an important role in the global economy. The growth and expansion of air cargo services is beneficial for the sustainable development of air transport, and contributes significantly to global trade and economic development.

When determining the type of mechanization, automation and technical equipment, the technical plan of the freight organization should be considered by the type of aircraft served by the airport, the terminal space planning solution, the concentration of funds for technical purposes (inside services and between services), the area and height of the site, the type of enclosed structure, the operational quality of the materials used for the venue decoration.

The selection of the types of mechanization, automation and process equipment should be based on the results of technical and economic comparisons of the selection of mechanization schemes, but should consider serial methods with

the best technical and operational indicators and developed methods that can be delivered when the terminal is put into operation.

When designing large airports, automatic cargo management systems and automatic control systems should be provided to inform airlines and customers.

The automated cargo management system performs the following functions:

- Customs clearance and cargo clearance;

- Introducing a computer complex of key information from different departments of freight services;

- Intermediate and final results of the loading process are obtained from the operational staff at their request;

- Inform passengers, various services and employees of airport terminals about the time and place of flight technical operations.

The automated information management system provides the following functions:

- Information process management;

- Inform the customer of the time and cause of the flight delay, the location and time of the flight, the flight that has been announced for boarding, the boarding time.

Airports around the world are actively introducing modern information systems, implementing large-scale plans to improve the service quality of goods of all categories and airlines, and adopting a series of measures to ensure flight safety. At the airport, the main production and business processes are automated, new navigation and electronic information systems are introduced in the terminal (touch screen), and online booking and online product registration are organized.

The automated control system should be based on a single computing system. The computer system of the automatic control system should be located in the information and computer centre (IVC) of the airport. The automated customer information management system can operate autonomously or as part of the passenger traffic automation control system.

The main task for us in this thesis paper is to learn how to design and build brand new Air Cargo Terminal in Boryspil airport considering all standards and recommendations. Our calculations will highly depend on the range of product/service functions, the industrial environment and the volume of components, etc.

ACT is based on the analysis of goods flow structure, amount of mechanized means and on rationally designed technology operations on processing of cargo. Having all the given data, we would be able to develop a plan of processing of different cargo categories.

1. THEORETICAL PART

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Done by:	Varava I.M.				*Letter*	*Sheet*	*Sheets*
Supervisor:	Shevchenko Yu.V.					D	13	24
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1.1. TRENDS OF SERVICE DEVELOPMENT IN THE TRANSPORT INDUSTRY

1.1.1. Quality in a service industry

The concept of quality can be viewed from both the supplier and the receiver. When these two perspectives overlap and are consistent with each other, the result is quality. So quality means the set of characteristics of a group of products or services that affect a product's ability to meet established or implicit needs" (ISO 8402 standard). The relationship between customers and service providers is dynamic and changes with each batch of requirements. In multimodal transport, a transport company defines quality service as:

- Reliable;
- Cost effective;
- Dependable;
- Innovative;
- Flexible.

The definition of quality in the service structure can include a management system that establishes a feedback network to control the level and quantity of services provided, input from external sources (suppliers / subcontractors) to the system, and marketing services to customers.

In the transport sector, output corresponds to the use of services. Therefore, services can be planned in advance, but not in advance (then investigated, tested, and modified).The quality of service must meet customer requirements, service levels of goods and supplier expectations.

For customers, hard work and careful planning of services are not important. The satisfaction criterion is the actual service received. If customer expectations are met, satisfaction can be expected. The goal of any quality system should be to use this level of service on the basis of continuous improvement, taking into account the needs of customers and the organization.

Providing transportation services is a matter of meeting dynamic needs. Competition leads to continuous development of services. Management must strike a balance between the value of the services provided and the benefits (revenues) derived from those services. Although the quality system helps establish the required level of service, management should monitor the effectiveness of the product to provide this service at the lowest cost.

1.1.2. Importance of Quality in Transport services

With the globalization of production, increased production, increased international trade, and reduced scale, but the increase in the frequency of transportation (due to the reasons of just-in-time and low inventory), the demand for increasingly complex logistics services continues to grow, and the level of information exchange between shippers, carriers, regulators is very high, model exchange points, recipients and commercial interests (banks, etc.). This, in turn, increases the need for control and systematization of the transportation process.

A logistics service project should consider all the factors that service consumers are looking for and the characteristics of the processed product. This includes the density of the value of the goods, the dangerous nature of the goods, if applicable, and the risks associated with transportation, sensitivity to operating hours, and the ability to provide the services required. Generally, the process of providing services can be described as:

- management developing the concept of the service to be provided, including the equipment and manpower to be used, and budgetary planning and control to be exercised;

- operations executed as planned, feedback received from the staff involved as well as from customers, comparing the levels of service performed with the standards set and identifying areas for improvement; and

• follow-up to the performance of the service, which will help improve standards and, possibly, develop new services. Budgetary planning and control, in conjunction with the feedback received, is an important factor in assessing not only the continued ability to provide the service but in identifying the margins available to improve and enhance it.

The quality of the service performed depends not only upon the design and control of procedures involved but also upon the human factor - the commitment of the staff actually performing the service.

Commercially, organizations may control the total service under one management or set up separate elements of the service as independent entities with the aim of identifying - or in response to having identified - profit or loss making elements (e.g. equipment maintenance, market research, or operational staff management may be contracted out). The organization, in providing a complete service is therefore actually providing a collective input of various service providers (sub-contractors) and managing this assembly into a single output.

Quality systems can form an excellent base on which to build this management control.

1.2 THE DEMAND IN AIR CARGO TRANSPORTATION

1.2.1. The share of air freight transportation

Air freight services are currently used all over the world, with many global businesses turning to using air freight services to transport their goods from one side of the country to another. Global businesses understand the importance of getting your goods from one location to another as quick as possible, so turn to using air freight services as a reliable way to get your cargo transported quickly and safely.

Air cargo is a trade facilitator that contributes to global economic development and creates millions of jobs. The global economy depends on the ability to deliver high-quality products at competitive prices to consumers worldwide. Air cargo transports over US $6 trillion worth of goods, accounting for approximately 35% of world trade by value.

Air cargo plays an important role in the global economy. The growth and expansion of air cargo services is beneficial for the sustainable development of air transport, and contributes significantly to global trade and economic development. Air cargo is oriented towards high value or time sensitive products. For example, the express industry has enabled the widespread adoption of just-in-time practices by many businesses, which saving countless dollars in inventory and logistical costs. That said, air cargo continues to expand its clientele and now serves a diverse range of businesses and consumers.

Professional mobility, second to tourism and leading to migration flows, remains an important driver of air transport demand. Moreover, professional mobility is supported by the EU as a channel for developing the future European economic model. Emerging economies attract business activities, which act as a catalyst for more transport and travel movements until levels of wealth begin to reach toward those in developed nations. In the future, there is likely to be very strong growth along these lines, comparable with the doubling of air traffic every 20 years as observed in the West.

The areas with outstanding growth are Asia (especially China), Russia, and Latin America. These are emerging economies seeking access to the same travel modes and behaviours as the developed countries. This may lead to significant growth in demand, that is, unless environmental constraints impede this growth. Although a view not shared by all, there is a significant body of opinion that business travel might decrease as an outcome of the development and accessibility of communications technology.

Over the long-term air transport continue to experience growth markets for freight. The visions of long-term challenges have been clustered and organised in

three themes as shown in Fig. 1.1. [1]. Both raise environmental issues that must be addressed. Yet air transport allows for just-in-time delivery. The share of freight is therefore growing in air transport. Lufthansa has built a huge freight hub in Central Asia, linking South East Asia, South Asia and Europe.

Freight has a huge potential for increased traffic, which will add stress to the system. Freight has not been looked at sufficiently, and represents a small share of European traffic compared with passenger transport.
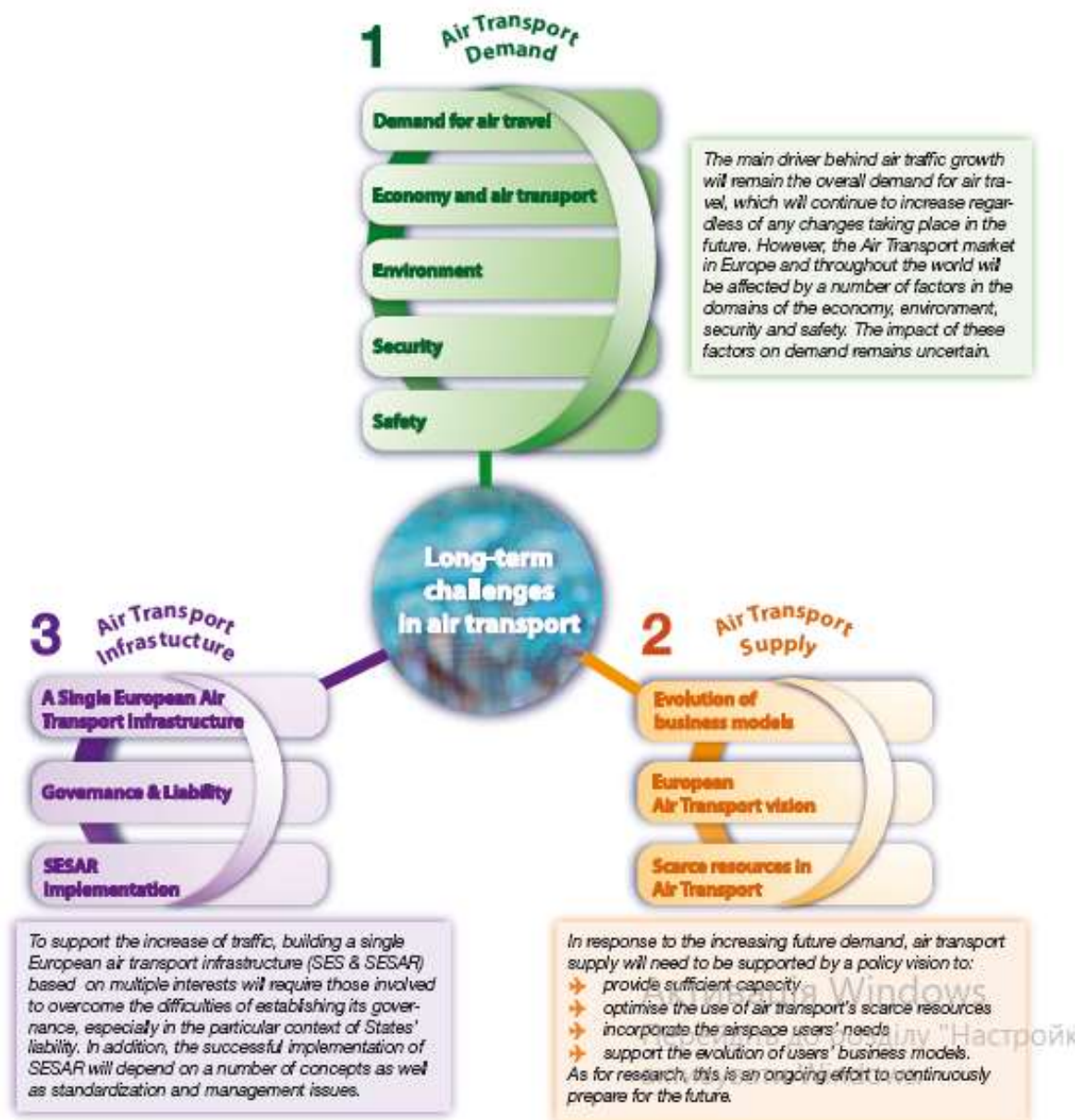

Fig. 1.1 Challenges in air transport industry

1.2.2. Peculiarities of cargo classification by different means of transportation

Classification of Cargo   *Table 1.1*

Type of Classification	Example
According to the physical state: *solid, liquid, gaseous*	**Solid:** trees, cars, bricks **Liquid:** milk, water, oil **Gaseous:** oxygen, methane, propane
According to the physical and chemical properties	**Explosives:** ammunition/cartridges, fireworks/pyrotechnics, flares, blasting caps/detonators fuse, primers explosive charges **Gases:** aerosols, compressed air, oil gas, helium **Radioactive materials:** Americium radionuclides, Uranium radionuclides **Toxic substances:** clinical waste, motor fuel anti-knock mixture, alkaloids
According to the space and weight characteristics in air transportation (*for usual, heavy, volume, long, large-sized, oversized cargo*)	**Usual cargo:** mobile phone **Heavy cargo:** refrigerator **Volume cargo:** wine barrels **Long cargo:** armature **Large-sized cargo:** windmill blades **Oversized cargo:** «Buran» on «Mriya» aircraft
According to the types of packaging	**Sack:** cement **Box:** audio-system **Cask:** beer **Packet:** flour
According to the modes of transportation: *massive, general, extra-secure*	**Massive:** grain, powder, coal **General:** clothes, microwave etc. **Extra-secure:** live animals, gold
According to the conditions and ways of storing: *cargoes of covered, semi-covered, uncovered storing*	**Covered:** cement **Semi-covered:** metal **Uncovered:** scree
According to attitude of loading/unloading operations	**SGS (Société Générale de Surveillance)**

Practice of transportation process management requires the classification of cargo depending on different properties:

- according to physical state;
- according to physical and chemical properties;
- according to space and weight characteristics;
- according to types of packaging;
- according to modes of transportation and storing;
- according to attitude to loading/unloading operations.

There isn't the unique classification of cargo for all means of transportation. Each means of transportation has its own differences in cargo classification.

In general, according to the modes of transportation and reloading there are the following categories of cargo:

- massive;
- general;
- extra-secure.

Massive cargo is called uniform cargo which is transported by huge consignments. Massive cargo includes fluid (oil products, liquid chemical cargo); bulk (different construction materials, technical equipment, coal, ore); poured (grain, powder); timber.

Peculiarities of massive cargo:

- considerable number of cargo in 1 consignment;
- necessity to have special transportation means;
- huge amount of loading/unloading works;
- necessity to use special reloading equipment.

Massive cargo is transported by marine, railway, automobile and pipeline transport. It is not transported by air because of specificity of transportation means.

General cargo is piece goods which don't require special modes of transportation and consists of separately packed consignments.

According to the character of packing general cargo is divided into sack; box; cask and packet.

General cargo comprises significant part from the total amount of freight turnover on various means of transportation, including air transport.

Extra-secure cargo is goods which require special conditions of transporting and storing. While transporting such cargo special requirements to their state, package, technological processes should be provided. Extra-secure cargo is transported with observance the established sanitary, temperature and fire requirements. This category includes perishable goods; dangerous goods; live animals; valuable goods. Extra-secure cargo is transported in great amounts by all means of transportation.

According to the air transportation regulations, goods that require special transporting conditions are called "special categories of goods".

1.2.3. General concept of transportation of valuable goods

Valuable cargo is a shipment which has a declared value for carriage costing minimum $1000 or more per 1 kg, or which contains one or more of the following commodities:

- Articles in gold and/or platinum, excluding articles covered by gold or platinum;
- Platinum, metals of the platinum group (palladium, iridium ruthenium osmium and radium) and platinum alloys in the grain form, sponge, bar, ingot, sheet, stick, net, tube, and strip excluding the radioactive isotopes of these metals and alloys that are subject to dangerous goods type of labelling;
- Legal bank notes, "travelers checks", titles, rubies, emeralds, and genuine pearls;
- Jewels constituted of diamonds, rubies, emeralds, or genuine pearls;

- Jewel and watches made of silver and/or gold and/or platinum;
- Any article with a declared value above USD 1000 or equivalent (United Kingdom UKL 450 or higher by kg-gross weight);
- In addition, the following articles must be considered as valuable cargo:
- Narcotics (stupefacient, drugs such as: opium, morphine, cocaine, heroin, marijuana, soporiferous, etc);
- Ivory.

Valuable cargo requires special handling, so certain restrictions may apply. Precious shipments need special attention to ensure safe and secured transport. They are handled under specific security measures from acceptance to delivery in accordance with local regulations and conditions both at origin and destination.

Recently, the cargo transport market has been impacted by the adverse effects of external forces. Nevertheless, road cargo transportation has kept its leading positions in the segment. High volumes of freight transportation by road are caused by several factors. Trucks can make efficient deliveries 24 hours a day regardless of airport, railway, and port operating schedules. Truck usage allows flexible routing and cargo tracing with data from modern GPS navigation systems and GLONASS. In case of short-distance goods delivery, transportation by trucks minimizes financial costs.

1.2.4. Packaging and labelling

There are the following packing requirements for valuable cargo transportation:
- The special handling code 'VAL' must be used in all information;
- The waybill must show accurate entries for weight and package dimensions; No actual value of goods should be shown in the WB. It must show words "Valuable Cargo";
- Packages shall be adequately packed in such manner that it becomes immediately apparent when the outside wrapping is broken. It is the shipper

responsibility to assure that packaging is tamper evident ant that the packages are sealed with adequate seals; Inadequately packed or damaged shipments are not accepted for transport, e.g. transparent plastic materials that reveal the contents of the shipment or other wrapping materials of poor quality;

- All packages are to be carefully examined at the time of acceptance for any sign of defect. Each package is to be check-weighed and weights verified against documents. All packages are to be securely closed and contents tightly packed. Packages must not bear labels or marks calling attention to the nature of the contents;

- There are labels, which should be marked on the package, as follows (Fig. 1.2) [2].

Certificate of storage means a waybill or any other document on which must be mentioned the date of receipt, number of packages as well as their contents, dimensions, weights and special instructions which the principal has brought to the knowledge of the depositary when concluding the storage contract and further all that the principal and the depositary think fit. The absence, irregularity or loss of the certificate of storage shall not affect the existence or the applicability of these conditions.

	Fragile, Handle with care		Perishable cargo		Tropical packaging
	Keep Away from Heat (solar radiation)		Hermetic packaging		Stacking prohibited
			Do not use hooks		Open here
	Keep dry		Sling here		Protect from heat and radioactive
	Protect from emission		No hand truck here		No rolling
	Temperature limitations		Top		Stacking limitation
			Center of gravity		Clamp here

Fig. 1.2 Labels for valuable cargo

1.2.5. Storage of valuable goods

The obligations of the depositary are as following:

1. To receive, store-in, store and store-out the contract goods at the agreed place, time and in the agreed manner, accompanied by the necessary documents to be supplied by the principal and to deliver the goods in the same order and condition as in which they were received or in the agreed order and condition.

2. *a.* To hand a signed copy of the certificate of storage back to the principal when receiving the goods and the certificate of storage.

b. To check, when receiving the goods, the correctness of the number of goods and the apparant good order and condition of the goods and their packing, and in case of discrepances, to mention these on the certificate of storage. This obligation does not apply if in the judgement of the depositary this would delay receipt considerably.

c. To ask instructions from the principal prior to receiving goods which are visibly damaged. If no such instructions can be obtained in time, the depositary is entitled to refuse receiving the goods. The depositary is likewise entitled to refuse receiving the goods if, when applicable, they are presented in inadequate or damaged packing.

d. The certificate of storage constitutes evidence, except for proof to the contrary, of the conditions of the storage contract and the parties to the contract, of the receipt of the goods and their packing in apparant good order and condition, of the weight and of the number of goods. If the depositary has no reasonable means to check the correctness of the mentionings as meant in para 2b of this article, the certificate of storage does not constitute evidence of these mentionings.

3. To designate one of more contact persons and to mention the(ir) name(s) in writing to the principal.

4 To perform storage in the agreed spaces. If no space has been agreed, the depositary will store the goods in a space fit for the purpose.

5. To inform the principal of possible displacement of goods. The depositary is entitled to move the goods to some other fit space as and if required within the framework of his business operations.

6. To take, with regard to the goods, all necessary measures for account of the principal, including those which do not follow directly from the storage contract, and before doing so if possible, to consult with the principal.

7. To take out insurance of his third party liability as well as his liability as following from the General Storage Conditions with a reliable insurer and furnish on request a photocopy of the insurance policy to the principal.

8. On written request of the principal and indication of the cover desired for his account and to his benefit, to take out insurance of the goods with a reliable insurer and to furnish on his request to the principal a photocopy of the insurance policy.

9. To allow admission to the spaces where the goods are stored for the principal and persons designated by him at his and their risk, but only in the presence of the depositary; if a request has been made in time; if the visit is effected in accordance with the home rules of the depositary.

10. To guarantee the fitness of the material which the depositary uses in executing the contract of storage.

11. To observe secrecy opposite third parties concerning facts and data known to him through the contract of storage.

12. To deliver the goods only after having been so ordered in writing by the principal. The depositary may deliver the goods exclusively to the person who has been designated as receiver by the principal's written order.

1.3 NECESSITY OF AUTOMATION PROCESSES IMPLEMENTATION IN AIR TRANSPORT INDUSTRY

1.3.1. General concept of automation in the airports

Automation is system of manufacture designed to extend the capacity of machines to perform certain tasks formerly done by humans, and to control sequences of operations without human intervention.

The term automation has also been used to describe nonmanufacturing systems in which programmed or automatic devices can operate independently or nearly independently of human control.

In the fields of communications, aviation, and astronautics, for example, such devices as automatic telephone switching equipment, automatic pilots, and

automated guidance and control systems are used to perform various operations much faster or better than could be accomplished by humans.

Automation has been applied in various ways in the transportation industries. Applications include airline reservation systems, automatic pilots in aircraft and locomotives, and urban mass-transit systems. The airlines use computerized reservation systems to continuously monitor the status of all flights. With these systems, ticket agents at widely dispersed locations can obtain information about the availability of seats on any flight in a matter of seconds. The reservation systems compare requests for space with the status of each flight, grant space when available, and automatically update the reservation status files. Passengers can even receive their seat assignments well in advance of flight departures.

Nearly all commercial aircraft are equipped with instruments called automatic pilots. Under normal flying conditions, these systems guide an airplane over a predetermined route by detecting changes in the aircraft's orientation and heading from gyroscopes and similar instruments and by providing appropriate control signals to the plane's steering mechanism.

Automatic navigation systems and instrument landing systems operate by using radio signals from ground beacons that provide the aircraft with course directions for guidance. When an airplane is within the traffic pattern for ground control, its human pilot normally assumes control.

Complex automation implies referring of complicated management functions in the technological production processes to machines. Automation of production processes highly promotes the productivity of labor.

The main condition of complex automation lies in taking the following measures: current management of all production operations, improvement of technology, equipment, transport that are utilized in production, and promotion of complex mechanization of technological processes.

Automated control systems should be based on a single computer system. The computer complex of automated control systems should be located in the information and computer center (IVC) of the airport. An automated passenger

information management system can operate autonomously or as part of an automated control system for passenger transportation.

The world's airports are actively introducing modern information systems, implementing large-scale programs to improve the quality of service for all categories of passengers and airlines, as well as a set of measures to ensure flight safety. At airports, automation of the main production and business processes takes place, the latest navigation and electronic information systems are introduced in terminals (touchscreens), web-reservations and on-line check-in are organized, self-check-in kiosks, etc.

The latest global study by SITA, one of the leading companies in the field of information technology in aviation, showed that airports continue to invest in IT during the crisis, demonstrating their readiness to increase the number of passengers. In 2016, the size of investments in IT increased to 3.6% of profit, and in 2018 78% of airports planned to increase or maintain their IT budgets. It is customary to consider cost reduction as the efficiency of investments in technology. Thus, according to research [3], the main incentive for investment is "reducing the cost of business operations" (52% of respondents indicated this), as well as "improving the quality of customer service" (48%).

1.3.2. Airport Automated Baggage Handling Market Overview

Developments of the manufacturer of automated systems LAS-1

The engineering and industrial company LAS-1 carries out the design, manufacture, supply and installation of baggage handling systems in passenger terminals of airports. Such systems are developed individually, in accordance with the architectural solution of the terminal on the basis of typical installations of various capacities.

Installations for conveyor processing of baggage up to 600 units baggage / hour.

Baggage handling conveyor systems are designed to handle departing baggage in the passenger terminal with a capacity of up to 2.5 million passengers / year.

When using two installations, the terminal throughput also doubles.

The units are a typical automated complex of special conveyor belts and inspection equipment using in-line baggage screening technology.

An automatic control system based on non-contact sensors and PLC controllers implements both technological and technical control algorithms without human intervention.

Installation performance up to 600 units baggage / hour is fully ensured by the use of belt conveyors and conventional linear introscopes with in-line options and does not require more complex and expensive solutions.

The composition of the installations:

• Automated check-in workstation (check-in workstation) - includes a passenger check-in counter, weighing and marking conveyors with an autonomous functioning control system.

• Weighing conveyors - designed to weigh the mass of baggage and direct it to the marking conveyors.

• Marking conveyors - are intended for marking units of baggage and its input (injection) onto the collector (collecting) conveyor.

• Collector conveyors - collecting luggage into the stream.

• Transportation conveyors - delivering baggage flow to the place of further processing.

• Queue conveyors - designed to ensure the rhythmic and uniform flow of baggage to the places of processing (inspection, sorting) without unreasonable shutdown of the system.

• Discharge conveyors - designed to separate units of baggage on a belt in a dense flow without interruption.

• Screening conveyors - designed to remove baggage that has been rejected for safety reasons from the main stream.

• Sorting conveyors (linear or carousels) - are intended for sorting units of baggage from the stream according to departure directions.

• Swivel conveyors - designed to turn the direction of baggage flow.

• Gravity roller tables - designed to accumulate items of luggage that have common features - rejected or at the destination.

• Introscopes - devices for X-ray television inspection of baggage for safety.

• Management system - designed for automatic implementation of operational actions algorithms.

• Power supply system - designed for power supply of the unit's drives. The maximum installation performance is determined by the average luggage inspection time in the introscope. The technical performance of modern devices allows scanning up to 1,500 units of baggage per hour, i.e. 2.4 sec for 1 baggage. However, such performance is only possible with the use of automatic controls (EDS-technology).

The actual time of inspection depends on the experience of the inspectors, "baggage cleanliness" and the organization of the inspection process (introduction of additional steps). The real achievable time using two introscopes averages 6 seconds. per unit of baggage. That is, the installation capacity will be 600 luggage per hour. And with an average check-in time of 60 racks, the maximum number of racks in a line is ten.

If this performance is redundant, the plants can have a simplified configuration. There are typical modifications of installations for 150, 300 and 450 pass/hour. They involve fewer check-in counters, a different set of conveyors, slower and less automated introscopes.

To ensure the necessary productivity of the plants, the main technological speeds and the capacity of the main tape of the system, as well as the capacity of the sorting carousel, were selected. Below are diagrams showed in Fig. 1.3-1.6 of installation for 600 units baggage / hour with two introscopes operating at the Pulkovo airport, as well as typical schemes of less productive modifications [3].

Fig. 1.3 Installation for 600 units baggage / hour
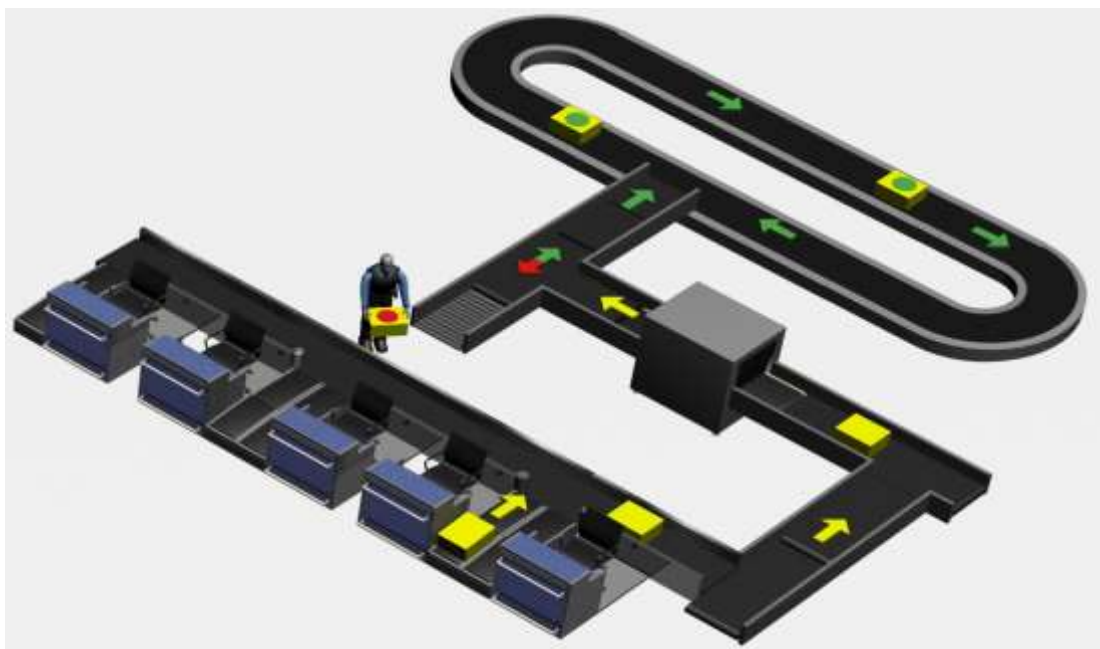
Fig. 1.4 Installation for 300 units baggage / hour

Fig. 1.5 Installation for 150 units baggage / hour

To ensure high reliability and reduce peak loads, it is recommended to use two mirror-paired installations, so that their total productivity matches the declared one (for example, 300 + 300 units baggage / hour, or 600 + 600 units baggage / hour). Moreover, specially formatted reversible manifold conveyors of both units will be interconnected. Then, the baggage flow from the check-in desks of one installation, in whole or in part, can be directed to the baggage flow line of another installation. This makes it possible to more evenly load inspection and sorting capacities of plants. And in case of failure of one of the elements to have double redundancy, albeit with a decrease in performance.
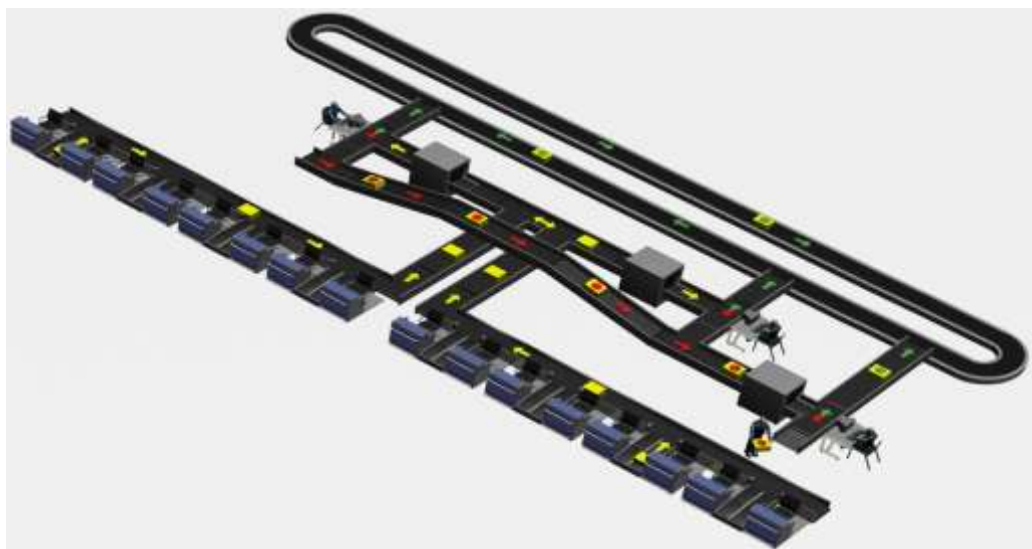
Fig. 1.6 Example of a twin installation with reverse

In-line - control. Depending on the need and load in the installation, two and three-stage baggage control for safety can be implemented.

Passenger sets luggage on a weighing conveyor. After weighing, the operator gives a command to move to the marking conveyor. After completing the marking and registration of baggage, the operator gives an authorizing command for sending it to the collector conveyor. This is where the operator's actions end.

The marking conveyor automatically injects baggage into the collector conveyor stream as soon as there is free space in that stream. The collector conveyor collects baggage from all the racks and through the conveyor conveyor delivers the flow of baggage to the safety control point.

For baggage to be inspected in non-stop mode, queue conveyors are installed at the entrance to the introscope. After checking for safety, the baggage falls onto a reversible reject conveyor. According to the inspecting team, the "clean" baggage is sent to the sorting carousel by the conveyor belt. Suspicious baggage is re-fed to the entrance to the introscope for additional scanning (second stage of control). When removing suspicions, it returns to the stream, and when confirming suspicions, baggage is sent to the third step (for visual inspection with an autopsy).

Baggage allowed for transportation is placed on the sorting carousel, where it is identified and selected at its destination (sorting).

The design of the conveyors is typical, developed on the basis of jib and sectional belt conveyors, unified by basic solutions, parts, assemblies and purchased components. All electric drives and conveyor belts of the system are used in one installation from one manufacturer.

The design of the installation provides for various transport widths of belts, elevations, tilts, turns, frames, fences and guides, which provide coordinated interaction and docking of all conveyors into a single transport system.

The non-standard properties of baggage as an object of movement determines the design features of conveyor baggage systems. Various dimensions and weight, surface (hard or soft, slippery or rough), volume structure (tight or loose), the

presence of wheels, folds, lacing and belts, makes it necessary to use specially equipped transitions between conveyors, pivots, tippers and other devices for careful processing.

In order to carry out manipulations with baggage in the stream at separate places - input to perpendicular belts, change of direction, discharge or accumulation of units of baggage, belt speeds for these places will differ from the main one.

To create visual attractiveness, the outer lining of conveyors in the passenger area, as well as the necessary elements for their arrangement (entrances, closures, dividing walls) are performed using polished stainless steel, aluminum and glass.

Protective walls and beams are provided in the baggage area to prevent damage to conveyors by moving vehicles.

The specific topology of the system is determined by the location of the main technological zones of the terminal, communications between them, as well as the building structure.

Linear or island configurations of registration zones, floor, inclined or two-level designs, various options for arranging conveyors through walls with separation of zones according to fire, climatic and technological requirements are possible.

The typical sizes of registration counters and conveyors are tied to the typical sizes of building structures of buildings (column spacing, wall thickness, room height).

The following types can be recommended as a linear apparatus for installation in a conveyor baggage system:

For installation with a productivity of 150 - 300 units. baggage per hour:

• SmithHeimann, HI-SCAN100100T, with "Hand Shake" or "Start-Stop" options, opening size 1000x1000 mm, belt speed 0.22 m / s.

• Rapiscan 527 or 528 with the Inline Kit option, opening size 1000x1000 mm, belt speed 0.24 m / s;

• L3 Communications Security, PX231 with the INLINE option, opening size 1000x800 mm, tape speed 0.24 m / s.

For installation with a productivity of 300 - 600 units. baggage per hour:

- Rapiscan 527 with InLine Kit option, opening size 1000x1000 mm, belt speed 0.33 m / s;

- L3 Communications Security, PX231 with the INLINE option, opening size 1000x800 mm, tape speed 0.5 m / s.

Facilities for returning the baggage

To issue baggage to passengers, plate conveyors with hard or soft ("overlap") bearing plates with a closed track are recommended. The conveyor route can have O, G, T or P-shaped configurations (Fig. 1.7).
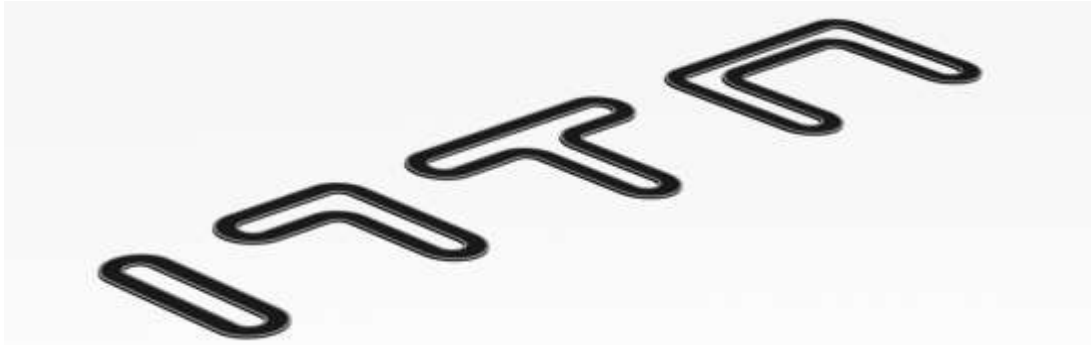
Fig. 1.7 Baggage claim conveyor configurations

The capacity of such conveyors, the front of loading and the front of baggage claim are determined on the basis of the volume, intensity and structure of transport. In the passenger zone, the railings and frames of the conveyors are made of polished stainless steel and can be made with both open and closed central part.

The control system by the start command provides automatic opening of openings and a smooth start of the conveyor. After the issue (removal of the last baggage) is completed, the conveyor automatically stops and the openings are closed.

The conveyors are equipped with emergency stop buttons, as well as warning sound and light signals to start operation.

For small terminals, you can use linear belt conveyors with the accumulation function on the storage roller table (Fig. 1.8)
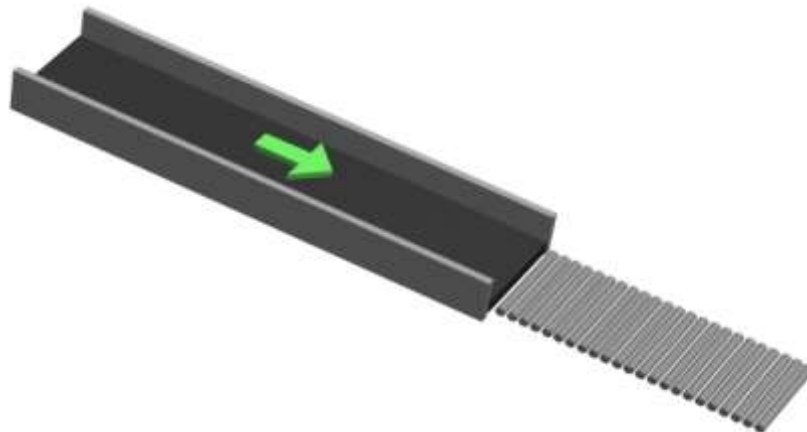
Fig. 1.8 Belt conveyor with collecting roller table

1.3.3. Top cargo airports in 2018

There was no change among the world's top five cargo gateways in 2018 but there was movement further down the table, reported Airports Council International.

Hong Kong International Airport, Memphis International, Shanghai Pudong, Incheon and Ted Stevens Anchorage all held their positions from the previous year as the top five cargo hubs.

But among the smaller gateways, Los Angeles jumped three places from 13th to 10th this year and Doha International advanced five places from 16th, last year, to 11th.

Rockford in the US was the fastest-growing airport in 2018 for airports that handled more than 250,000 tonnes of cargo, thanks to the expansion of its e-commerce business for online retail giant Amazon, which helped traffic grow 56.6%.

The next fastest growing of the 250,000 tonnes-plus airports was Nairobi, Kenya which saw cargo increase 25.2% to over 342,000 tonnes and Liege, Belgium, up 21.6% to 871,596 tonnes. Xi'an in China and Philadelphia in the US were up by 20.3% and 20% respectively.

ACI added that in total, the world's airports accommodated 122.7m tonnes of cargo – a 1.4% increase. This is down on the 6.8% year-on-year increase recorded in 2017-2018 years as ia shown in Fig. 1.9[4].

Rank 2018	Rank 2017	Airport City / Country or Area / Code	Cargo (Metric tonnes)	
			(Loaded and unloaded)	% Change
1	1	Hong Kong, HK (HKG)	5,121,029	1.5
2	2	Memphis TN, US (MEM)	4,470,196	3.1
3	3	Shanghai, CN (PVG)	3,768,573	-1.5
4	4	Incheon, KR (ICN)	2,952,123	1.0
5	5	Anchorage AK, US (ANC)	2,806,743	3.5
6	6	Dubai, AE (DXB)	2,641,383	-0.5
7	7	Louisville KY, US (SDF)	2,623,019	0.8
8	9	Taipei, Chinese Taipei (TPE)	2,322,823	2.4
9	8	Tokyo, JP (NRT)	2,261,008	-3.2
10	13	Los Angeles CA, US (LAX)	2,209,850	2.4
11	16	Doha, QA (DOH)	2,198,308	8.8
12	12	Singapore, SG (SIN)	2,195,000	1.4
13	11	Frankfurt, DE (FRA)	2,176,387	-0.8
14	10	Paris, FR (CDG)	2,156,327	-1.8
15	14	Miami FL, US (MIA)	2,129,658	2.8
16	15	Beijing, CN (PEK)	2,074,005	2.2
17	18	Guangzhou, CN (CAN)	1,890,816	6.2
18	20	Chicago IL, US (ORD)	1,807,091	5.0
19	17	London, GB (LHR)	1,771,342	-1.3
20	19	Amsterdam, NL (AMS)	1,737,984	-2.7
		TOTAL	51,313,665	1.4

Fig. 1.9 Top cargo airports in 2018

2. ANALYTICAL PART

2.1. AIR CARGO HANDLING QUALITY MENEGEMENT

2.1.1. Implementing quality in transport

The reasons for any transport organization's decision to implement a formal quality system may vary. In interviews with the heads of various organizations in various transportation departments, it was found that the most frequently cited reason was pressure from customers. Other reasons include:

- quality as a marketing tool;
- better control on operations;
- attracting large customers;
- better control on supplier input to own output;
- better control on company-wide processes.

Quality falls under the broader umbrella of management aims, which also include:

- efficient use of resources;
- improved ability to make use of market opportunities;
- increased reliability of performance;
- protection of the public from the impact of unplanned variance in operation performance;
- protection of the internal customers from the impact of operations;
- protection of the environment from the impact of operations; and, of course,
- increasing profits.

Quality of transport systems can make a significant contribution to profits by controlling processes and reducing variable costs. If they don't, they will absorb the economic health of the organization and should take appropriate measures.

Transport services are not only applicable to cargo in containers, but also to cargo in bulk, loaded into containers and transported by land to recipients.

Service quality in transport includes:

- on time pick up and delivery;

- equipment condition;

- cleanliness and availability;

- compliance with environmental standards;

- effective communications;

- competence;

- courtesy and appearance;

- internal monitoring of service;

- accuracy in billing;

- prompt handling of claims;

- ISO certification;

- financial stability.

In the "total cost" paradigm, "general" or "global production" and "access to international markets" transportation are essential. In this case, the distribution includes not only the transportation functions of land / air / sea transportation, but also the processing, storage and value-added services provided by the terminal, warehouse, such as marketing, packaging, inventory management, etc.

When considering a large percentage, it becomes critical to choose a carrier, which is the logistics cost from the final price. Any waste or inefficiency in the system must be transferred to the shipper (affecting profitability) or the customer (affecting market share). It is the responsibility of the carrier to deliver the goods at the time and at the agreed place on the terms sent or agreed by the shipper.

An important part of international multimodal transport is the provision of subcontracting services. For operators, this can be a difficult area, because customer satisfaction (continuous business) here depends on the quality of services provided by third parties.

Transport service items, such as packaging, the suitability of the materials used, and the protection and protection of the items may affect the condition of the

cargo being transported. For companies that have a formal quality system and strive to provide quality assurance to customers, the use of transportation services that may affect their products is an important factor to consider. However, the carrier's use depends on the terms of the contract of carriage.

If the customer instructs the carrier, the shipper shall not use an approved carrier. If the carrier is not specified, the terms of sale of the goods will clarify the obligation to transport. Usually, the shipper is responsible for delivering the goods before shipment. At this time, responsibility for the condition of the goods is transferred to the carrier. Other terms of sale may include freight, insurance, and freight paid by the sender of the goods. Sometimes, packaging, consolidation, packaging or other value added takes place under the responsibility of the carrier.

The shipper or manufacturer may not be responsible for delivering the package or goods to the customer (if they transfer this responsibility to another business subcontractor), but they remain responsible for the order the customer receives. Even if it is the fault of the shipping company, the seller (not the carrier) is not satisfied with the buyer. Therefore, the seller should seek assurance of the quality of the services provided by the carrier.

2.1.2. Transportation system analytics

The methodological challenge of transportation systems is to conduct a systematic analysis in a particular situation which is valid, practical, and relevant and which assists in clarifying the issues to be debated. The core of the system analysis is the prediction of flows, which must be complemented by the predication for other impacts. Refer to Fig. 2.1 [5] Predication is only a part of the process of analysis and technical analysis is only a part of the broader problem, and the role of the professional transportation system analysis is to model the process of bringing about changes in the society through the means of transport.
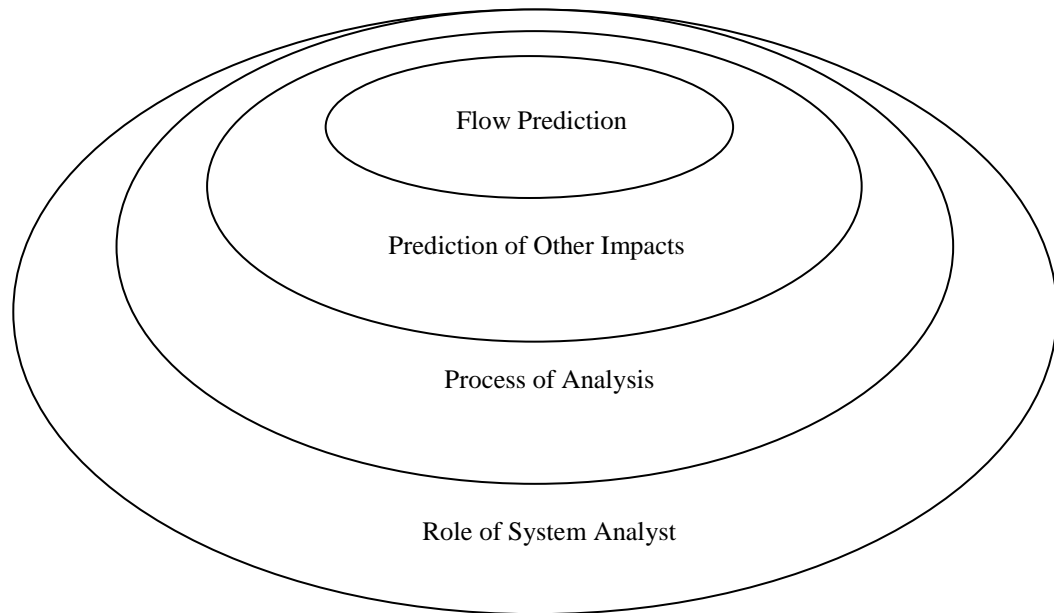
Fig. 2.1 Role of transportation system analyst

Influence of TSA: Applications

Transportation system analysis can lead to different application specialties and they include:

- highway engineering;
- freight transportation;
- marine transportation;
- transportation management;
- airport planning;
- port planning and development;
- transportation regulation;
- transportation economics;
- environmental impacts.

Influence of TSA: Methodologies

Transportation system analysis can also lead to different methodological specialties and they include:

- demand analysis, estimation and forecasting;
- transportation system performance like delays, waiting time, mobility, etc.;

- policy analysis and implementation;

- urban planning and development;

- land-use management;

Finally, transportation system analysis can lead to different professional specialties and they include:

- technical analyst;

- project managers;

- community interaction;

- policy analyst.

2.1.3. Air cargo transportation in Ukraine

According to the National Bureau of Statistics of Ukraine, international air cargo volume accounted for most of the total air cargo volume (about 99.9%) in 2015.

From January to May 2016, air cargo turnover reached 94.4 million kilometres, an increase of 3.5% from January to May 2015. Air cargo was 32.2 tons, an increase of 14.1% from January to May 2015.

From January to June 2016, transportation companies transported 291 million tons of goods, or 15.208 billion tons of goods, with an average annual growth rate of 3.9%.

Although the volume of freight traffic fell by 16.8% between 2013 and 2015 (from 379,045.0 million kilometres to 315,341.8 million kilometres), from January to June 2016, freight traffic in Ukraine resumed its growth rate.

From January to June 2016 as showed in Fig. 2.2 [6], rail transportation accounted for more than 82% of total freight (excluding pipelines).
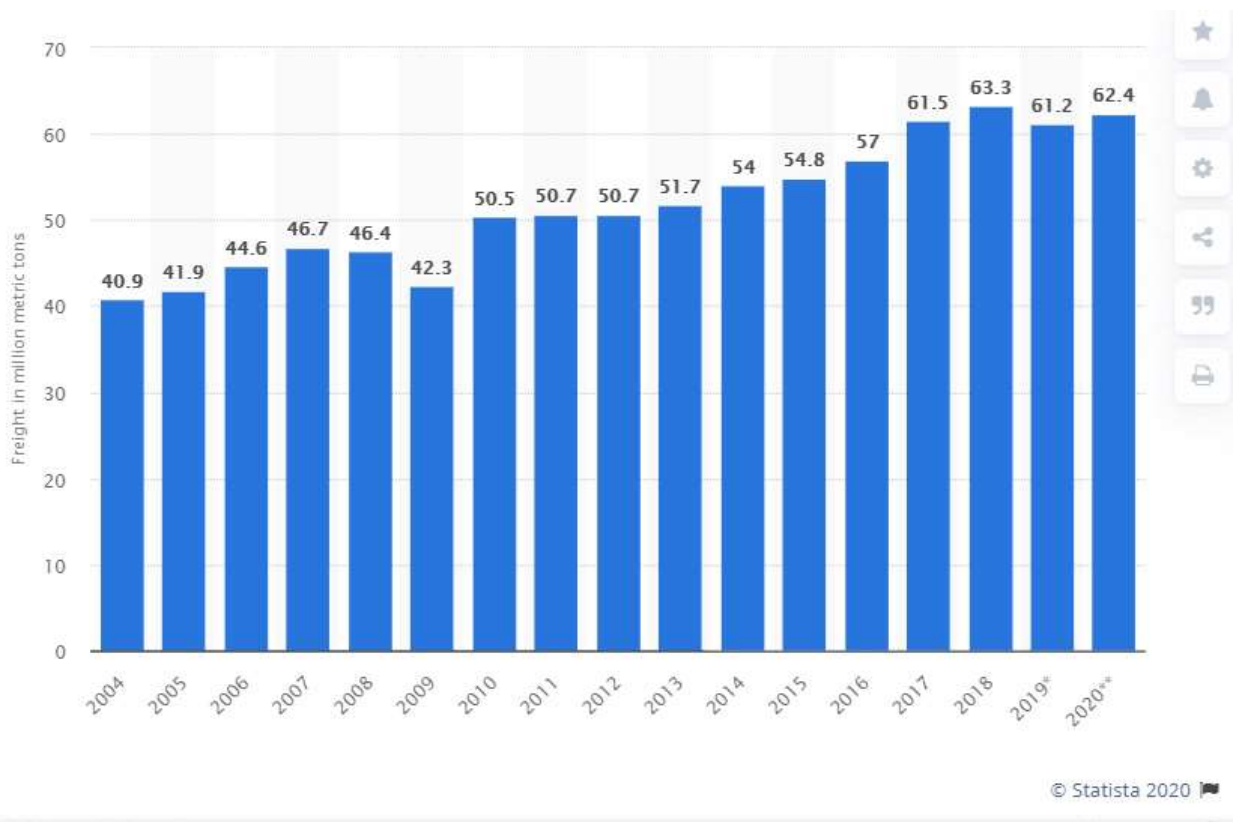
Fig. 2.2 Worldwide air freight traffic from 2004 to 2019

Ukraine International Airlines (UIA) is the flag carrier and the largest airline of Ukraine, with its head office in Kiev with its main hub at Boryspil International Airport. It operates domestic and international passenger flights and cargo services to Europe, the Middle East, the US and Asia.

The airline was established on 1 October 1992, and started operations on 25 November 1992 with a Kiev-London flight. It was one of the first "joint ventures with foreign capital" in Ukraine and the first airline in the former Soviet Union to use new Boeing 737-400 aircraft. The founding shareholders were the Ukrainian Association of Civil Aviation and Guinness Peat Aviation (GPA), an Irish aircraft-leasing company. In 1996, Austrian Airlines and Swissair became shareholders, investing US $9 million in new equity.

The airline began cargo operations with a Boeing 737-200 aircraft on 13 November 1994 to London and Amsterdam, and today operates a Boeing 737-300F as a dedicated aircraft for freight operations.

UIA provides cargo services around the clock. Airline transport cargo on all UIA scheduled flights and offer services for cargo and handing agents. UIA provides fast and safe carriage of different cargo types: perishable, fragile, valuable, dangerous goods, as well as diplomatic mail and live animals.

Working partnership with other airlines allows UIA to arrange cargo transportation from Ukraine to any airport worldwide. For oversized cargo UIA offers scheduled flights operating five times per week on the route Kiev – Liege – Kiev.

Moreover, air carrier provides services for organization and implementation of charter cargo flights. The Fig. 2.3 [7] shows main cargo flight destinations of the airline. Their proficient staff possesses up-to-date knowledge to provide extensive services for aviation management and aircraft handling.

Ukraine International Airlines has codeshare agreements with the following airlines (as of November 2015): airBaltic, Air France, Air Moldova, Austrian Airlines, Azerbaijan Airlines, Belavia, Brussels Airlines, Dniproavia, Iberia, KLM, S7 Airlines, Swiss International Air Lines, TAP Portugal, Turkish Airlines.

UIA transports various cargo types on all its scheduled flights, as well as on its cargo Boeing 737-300SF aircraft. In order to cover every customers' need, UIA introduced a complete portfolio of cargo services including the following six solutions: Time Definite, Sensitive, Fresh, Live, Valuable and Economic.

Fig. 2.3 UIA Cargo Flight Destinations

2.2. EXPERIENCE IN THE IMPLEMENTATION OF AUTOMATED SYSTEMS

2.2.1. Automated systems at the airport of Leonardo Da Vinci (Rome)

Each year, more than 25 million passengers travel through the Leonardo Da Vinci Airport in Rome. This is approximately 70,000 arriving and departing passengers on local and international flights per day. Aeroporti di Roma (ADR) manages and coordinates the airport infrastructure. ADR directs all efforts to increase the efficiency of services and to achieve maximum satisfaction of passengers with the provided service. The ADR already had a BHS baggage handling system for the automated management and control of its movement. Despite the fact that the whole system worked successfully, there were a number of certain problems that could not be effectively resolved. The new Psion Teklogix wireless system provided an opportunity to solve these problems and helped ADR maximize the level of service [8].

The BHS at Leonardo Da Vinci Airport has proven to be reliable and efficient. This is a complex system, consisting of scanners, conveyors and temporary storage areas, automatically forwarding baggage marked with labels with a barcode from the check-in desks to the cargo hatches of aircraft. Similarly, baggage is transferred from arriving aircraft to the baggage carousel and between aircraft during a transit flight.

However, the usual practice at the airport is the possibility of any changes when loading luggage at the last minute. Registration for latecomers may occur until the plane has flown away; flight delays can minimize loading times; finally, passengers can arrive for boarding with hand luggage that cannot be placed in the cabin. BHS was not a flexible enough system for such cases. To achieve maximum efficiency, it was necessary to ensure the possibility of manual intervention in the actions of the system by loaders and aircraft crew.

The goal of ADR was to make manual baggage handling as quick and reliable as possible. A system was needed to check the barcodes on baggage with data from a central database. It is necessary that the system can work in all areas from check-in counters to cargo compartments of aircraft. And of course, the manual processing system must be compatible with BHS.

Now for manual baggage handling at any point in the airport, Psion radio terminals operating in the Narrowband range and equipped with a built-in barcode scanner are used. The scanned barcode is transmitted through a local wireless network built on the basis of Psion access points. Information is processed in the central BHS database and a message is sent back indicating the flight number and other necessary data, such as, for example, special loading conditions. Two Psion Teklogix network controllers provide secure data transfer between terminals and the local network.

ADR chose the NarrowBand technology, since this radio range allows you to cover a large area. The vast airport area is covered by only three Psion access points, providing reliable communications and data transfer speeds ideal for transmitting short data packets.

ADR chose Psion for the following reasons:

- All changes during pre-flight preparation should be immediately and clearly recorded. The reliability of Psion Teklogix systems is guaranteed and proven repeatedly;

- Psion Teklogix network controllers provide data security;

- Psion Teklogix terminals are protected, shockproof equipment, which is very important for harsh conditions at the airport;

- Large, high-contrast LCD screens on the terminals allow operators to read information easily.

ADRs used Psion terminals and access points to reduce baggage errors. The system gave ADR the ability to make quick and reliable changes when loading

aircraft, and the Psion wireless solution made it possible to increase the level of cargo handling accuracy.

2.2.2. Airport baggage handling robots: Grenzebach company offers

Grenzebach specializes in industrial automation and is a pioneer in the full automation of baggage handling and offers reliable and efficient solutions for automated baggage handling.

Thanks to the modular design, the automated baggage loading system can be designed to meet any requirements and specifications.

The scanner analyzes baggage parameters, such as size and type, as well as position and orientation in space. Additionally, baggage can be weighed or identified using a barcode or RFID tags.

The second scanner measures the free space in the loading trolley.

The software uses this data to automatically determine the optimal position of the load within the trolley ULD / inclined. When loading into several containers at the same time, sorting criteria such as the destination of the flight and the selected class are also taken into account.

In fact, loading is done by a standard industrial robot equipped with special devices for loading luggage.

Grenzebach decision at Amsterdam Schiphol Airport

Each year, Schiphol handles about 50 million items of luggage. This is about 120,000 packages per day during quiet periods and 180,000 packages per day during peak periods, such as, for example, at the beginning of the summer season - the holiday season. Of the total amount of baggage, approximately 41.5% is transfer baggage. The share of transfer baggage is large because KLM and its partners, who together constitute the main users of Schiphol, use the airport as a hub.

A fully automated and flexible baggage handling system is essential for the proper passenger service process. That's why Schiphol constantly invests in the expansion and innovation of the luggage system. The airport, therefore, has the world's most advanced baggage handling system.

Loading and unloading suitcases involves hard work. Since the summer of 2006, employees at Terminal E have received assistance from a robot to load trolleys. The robot was used for the first time in the world and was replaced by a new version in 2008. Six robots are working in the new South Hall. The mechanical unloading module (MMV) as shown on the Fig. 2.4 [8], or the automatic unloading system, has been in operation in Hall D since August 2009. This system raises the container, flips it and empties it. The human effort required for both baggage handling systems comes down to working on the operating control panel. To manage robots and IIM, employees undergo special training.

Fig. 2.4 Mechanical unloading module

More than 2000 employees working in shifts 24 hours a day, seven days a week, are working to ensure that the luggage is properly handled. About 125 of these are Amsterdam Airport Schiphol employees who are responsible for the development, management and operation of all baggage systems, including computers, software and control systems.

Handling companies carry out physical baggage handling. The largest of these is KLM, with approximately 1,100 luggage employees. Other handling companies are Aviapartner, Servisair. Together, these companies serve more than 100 airlines.

The new Luggage Room "South" (officially opened on March 16, 2011) is part of a program to increase airport capacity by 40% or up to 70 million baggage. Efficient use of space, an efficient, reliable and fast baggage handling process, as well as providing ergonomic working conditions, were the main requirements for the project concept and technology.

The six robotic baggage handlers developed by Grenzebach which are shown of the Fig. 2.5 [8] are a key component of the advanced baggage handling system supplied by Vanderlande Industries and IBM. The baggage storage system is used to collect a "batch" of baggage for loading into one container or trolley. These packages are sent to a robotic loader, which is supposed to handle up to 60% of all baggage in the South Hall of the airport.
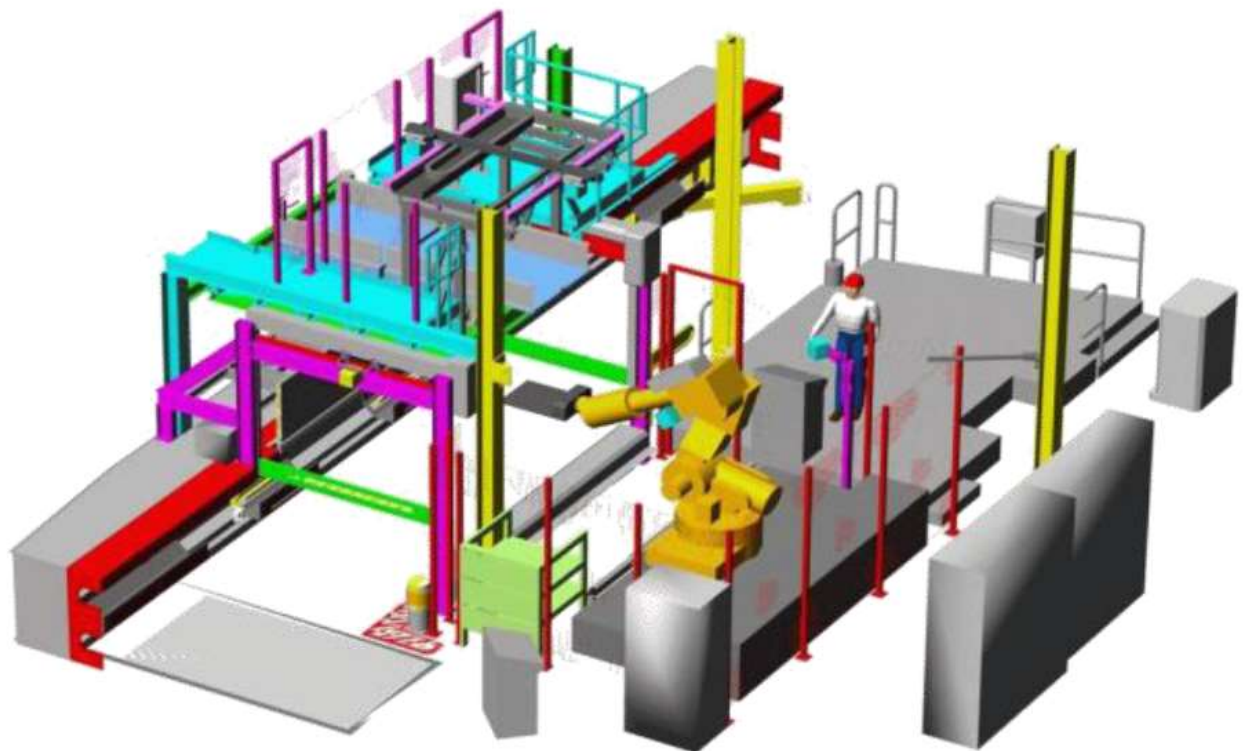
Fig. 2.5 Grenzebach robotic luggage handlers

Project History:

- 2005: installation of a pilot system at Schiphol Airport;

- 2008: first operational loader begins service at Schiphol Airport;

- 2009: installation of six robots in the new South Hall;

- 2010: system integration and preparation for operation of the South Hall;

- March 16, 2011: the official opening of the South Hall.

Operational parameters of an automated system:

6 robotic loaders- Layout of a flexible production cell:

- 1 baggage claim, 1 loading position;

- Co-location final control / pivot position;

- Equipment for automatic loading positioning device.

Supported loading units:

- Containers: AKE, AKH;

- Carts: ramp trolleys KLM, SLUS.

Baggage handling:

- All types of luggage carried;

- Max. weight: 50 kg;

- Max. dimensions: 100 x 95 x 80 cm3.

Performance:

- Technical cycle time: <15 sec;

- The coefficient of automated filling:

  o   Container: 80% - 90%

  o   Carts: 100%

- productivity: up to 200 pieces of luggage per hour per 1 bag.

2.3. THE CONCEPT OF AIR CARGO TERMINAL STRUCTURE

2.3.1. Analysis of goods flow structure and grounding of Air Cargo Terminal Structure

The main task for us in this part of design part is to learn how to design and build Air Cargo Terminal considering all standards and recommendations. Our calculations are highly depend on the range of product/service functions, the industrial environment and the volume of components, etc.

Air Cargo Terminal is based on the analysis of goods flow structure, amount of mechanized means and on rationally designed technology operations on processing of cargo. Having all the given data, we would be able to develop a plan of processing of different cargo categories.

Airport Cargo Terminal - a collection of buildings that are designed for the reception, temporary storage, processing and delivery of goods, as well as to accommodate staff, Road Transport, mechanization and equipment.

Bulk cargo - loose, unpackaged, non-containerized cargo (such as cement, grains, ores) carried in a ship's hold, and loaded and discharged through hatchways.

Cargo - all articles, goods, materials, merchandise, or wares carried onboard an aircraft, ship, train, or truck, and for which an air waybill, or bill of lading, or other receipt is issued by the carrier.

Cargo apron - performed for loading and unloading cargo from/to aircrafts.

Cargo manifest - a shipping document used by customs personnel reviewing a particular transport vehicle's intended trip that summarizes all bills of lading that have been issued by the carrier or its representative for that particular shipment.

Domestic airline - are local airlines and generally they only flying in local airspace (as opposed to international and intercontinental); operate within a single country. International airline - are organizations providing aviation services to passengers and/or cargo.

The main element of cargo airport complex is commercial cargo warehouse. Storage of cargo in airports can be categorized by technology of internally handling and cargo handling capacity of the warehouse [9].

According to the daily goods turnover commercial warehouses are divided into:

- *Small* – daily turnover is less than 70 tons;
- *Middle* – daily turnover is 70-300 tons;
- *Big* – daily turnover is 300-1000 tons;
- *Huge* – daily turnover is more than 1000 tons.

According to the capacity of cargo warehouses divided into:

- *Small* – 30-300 tons;
- *Middle* – 300-1000 tons;
- *Big* – more than 1000 tons.

According to the degree of operations mechanization warehouses are divided into:

- *Manual*
- *Semi-mechanized*
- *Fully-mechanized*
- *Automated*

The calculations of technological parameters of warehouses are performed separately for zones:

- *Stack storage of goods (domestic flights – DAL);*
- *Rack storage of goods (international flights – IAL)*

2.3.2. Unit loads

A unit load combines individual items or items in shipping containers into single "units" that can be moved easily with a pallet jack or forklift truck. A unit load packs tightly into warehouse racks, intermodal containers, trucks, and

boxcars, yet can be easily broken apart at a distribution point, usually a distribution center, wholesaler, retail store, etc. The most common unit loads are pallets and components with bases that resemble pallets, such as pallet [9].

A pallet is a low, portable platform constructed of wood, metal, or fiberboard, built to specified dimensions, on which supplies are loaded, transported, or stored in units. Pallets are the most common form of unitizing device. Some of the primary pallet material choices are wood pallet (most common), steel pallet, paper pallet, metal pallet, plastic pallet.

Types of pallets

Palletization is the method of storing and transporting goods stacked on a pallet, and shipped as a unit load. It permits standardized ways of handling loads with common mechanical equipment such as fork-lift trucks. It is a common technique that is used to store or transport goods that have been placed upon a pallet, and then ship it as a unit load. It is easy because it allows the use of mechanical equipment to move large weights.

When the palletization concept was first introduced, however, it had a dramatic impact on the improvement of material handling efficiency.

Then as now, the use of pallets as a base for unit loads offers a number of benefits:

- Palletized products can be moved more quickly than by the manual handling of individual palletized cartons;
- Benefits of this quicker handling include: faster turnaround of delivery vehicle and increasing operational efficiency of transport equipment;
- Quicker availability of the trailer door for the next arrival;
- Dramatically reduced labor requirement versus manual handling;
- Reduced risk of temperature abuse for perishable products on unrefrigerated docks.

Palletized goods require less manual handling, so it is expected to get:

- Less risk of product damage;
- Reduced risk of worker injury;

- Palletized products can be moved more efficiently and stored more efficiently in warehouses;
- Customers often prefer the receipt of palletized goods;
- Pallets are typically easier to handle with material handling equipment than other styles of unit load bases such as slip sheets, which may require specialized equipment;
- Pallets provide drainage and circulation for commodities requiring this, including fresh produce.

Although pallets come in all manner of sizes and configurations, all pallets fall into two very broad categories: "stringer" pallets and "block" pallets. Various software packages exist to assist the pallet maker in designing an appropriate pallet for a specific load, and to evaluate wood options to reduce costs.

Stringer pallets use a frame of three or more parallel pieces of timber (called stringers). The top deck boards are then affixed to the stringers to create the pallet structure. Stringer pallets can have a notch cut into them allowing "four-way" entry.

Block pallets are typically stronger than stringer pallets. Block pallets utilize both parallel and perpendicular stringers to better facilitate efficient handling. A block pallet is also known as a "four-way" pallet, since a pallet-jack may be used from any side to move it.

Perimeter base pallet. All stringer and some block pallets have "unidirectional bases," i.e. bottom boards oriented in one direction. While automated handling equipment can be designed for this, often it can operate faster and more effectively if the bottom edges of a pallet have bottom boards oriented in both directions..

The popularity of wooden pallets allows them to be used universally. Materials, used for manufacturing pallets, are wood, plastic, metal and paper. The majority of pallets are made from wood.

Advantages of using wooden pallets:
- lower cost than most other materials;

- can be repaired/renovated;
- can be painted and easily printed on, stickers can be easily removed.

Disadvantages of using wooden pallets:
- the dimensions can vary slightly;
- can be distorted through rough handling;
- contain metal parts (nails) which could interfere with metal detection (some now are made without nails);
- need to be maintained;
- can become contaminated with unwanted bacteria or pests;
- export pallets need to be heat treated, weight can fluctuate due to wood variations and level of absorbed moisture;
- they can be prone to splintering or have loose nails;
- wooden pallets are not fully washable, they cannot be nested in each other when empty.

Dimensions of pallets

In a pallet measurement the first number is the stringer length and the second is the deck board length. Square or nearly square pallets help a load resist tipping.

Two-way pallets are designed to be lifted by the deck boards. In a warehouse the deck board side faces the corridor. For optimal cubage in a warehouse, the deck board dimension should be the shorter. This also helps the deck boards be more rigid.

Four-way pallets or pallets for heavy loads, or general-purpose systems that might have heavy loads are best lifted by their more rigid stringers. A warehouse has the stringer side facing the corridor. For optimal cubage in a warehouse, the stringer dimension should be the shorter. (See Appendix 1). Pallet users want pallets to easily pass through buildings, stack and fit in racks, forklifts, pallet jacks and automated warehouses. To avoid shipping air, pallets should also pack tightly inside intermodal containers and vans.

Consider the following points for safe use of pallets:

1.   You should have an effective system for pallet inspection. Damaged pallets should be removed from use.

2.   All pallets should be inspected each time before use, to ensure that they are in a safe condition. Withdraw damaged pallets for suitable repair or destruction.

3.   Empty pallets should be carefully handled and not dragged or thrown about. They should not be handled by methods likely to loosen deck boards. Wedging the platform of a sack barrow between top and bottom deck boards can cause damage.

4.   Hand-pallet truck forks of unsuitable length can cause base board damage and be dangerous to workers.

5.   If hand-pallet trucks are used, take care to ensure that the small finger wheels (also known as trail or guide wheels) do not damage the base boards.

6.   Take care when using strapping to secure loads to pallets, as deck boards can be pulled from the bearers.

7.   To avoid damage to pallets and to lift palletized loads safely, the forks of a handling device should extend into the pallet to at least 3/4 of the pallet depth (see Fig. 1.16) [10].
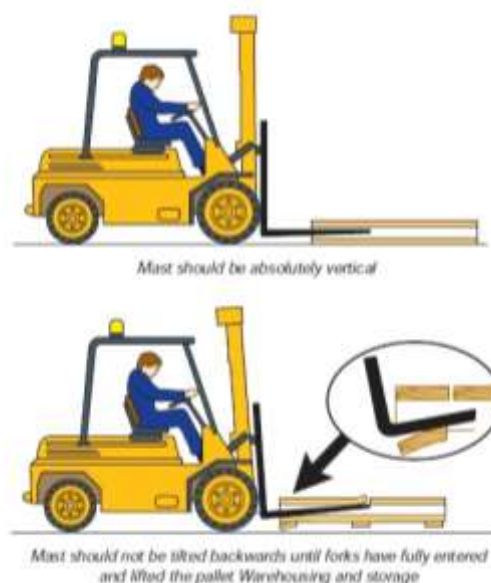

Mast should be absolutely vertical

Mast should not be tilted backwards until forks have fully entered and lifted the pallet Warehousing and storage

Fig. 2.6 Safe pallet use

2.3.3. Technical characteristics of Unit Load Devices (ULDs)

A unit load device (ULD) is a pallet or container used to load luggage, freight, and mail on wide-body aircraft and specific narrow-body aircraft. It allows a large quantity of cargo to be bundled into a single unit. Since this leads to fewer units to load, it saves ground crews time and effort and helps prevent delayed flights. Each ULD has its own packing list (or manifest) so that its contents can be tracked.

ULDs are used for the storage of cargo on the aircraft and are divided into two types: pallets and containers. Pallets are secured by a net, attached to the rim of the pallet. The final shape (contour) chosen in the build-up of a ULD needs to fit the allocated aircraft type. Containers provide the shape (contour) so the contents are secured either by the container doors being closed and bolted, or the door net being secured to the rims of the container walls and floor. [10]

Advantages of using a container
- Faster loading and unloading of the aircraft and container;
- Better protection against weather conditions;
- Better protection against damage to the cargo or to the aircraft;
- Less experienced personnel required for build up as contour is complete.

Why use a pallet?
- Some cargo is difficult to fit into containers;
- There are more options for build-up when using an open pallet;
- Some 'Special Load' cargo can only be loaded on open pallets.

ULDs are owned by individual airlines, therefore ground handling agents are required by their airline customers to keep a regular stock check of these.
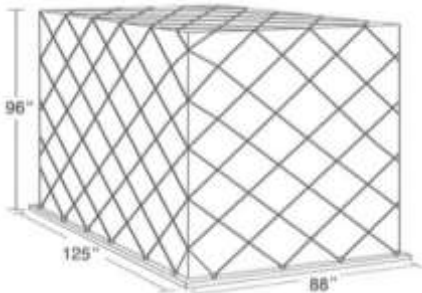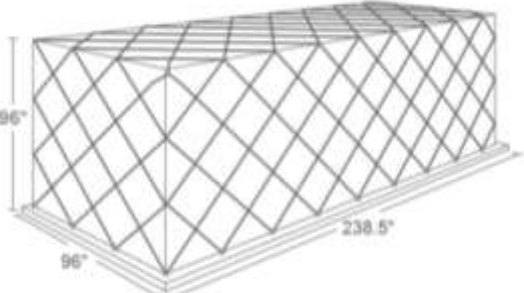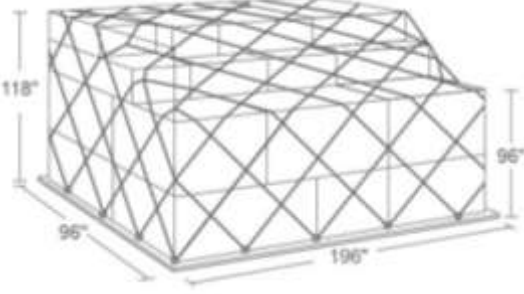
Whenever releasing or accepting ULDs from an agent or airline, a UCR (ULD Control Receipt) report is completed. ULD Control Receipts are vital to determine the responsibility and liability in respect of each unit released or accepted into a warehouse.

Standard ULDs will fit on most aircraft and in most positions, however some aircraft do have odd sizes for ULDs to fit in certain loading positions. The contour

must be correct too if an open pallet is to be used. As well as the points above the maximum loading capacity of the ULD and more importantly the aircraft should be clarified before build up begins.
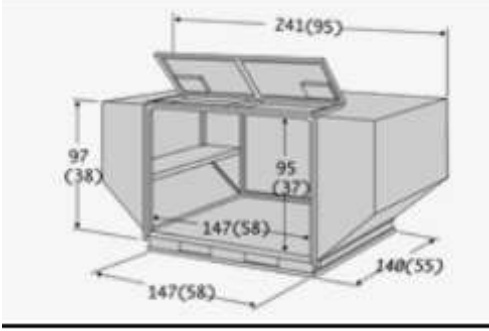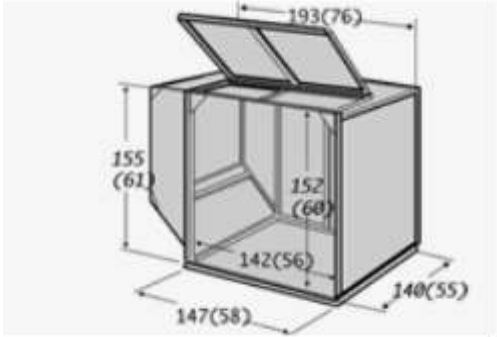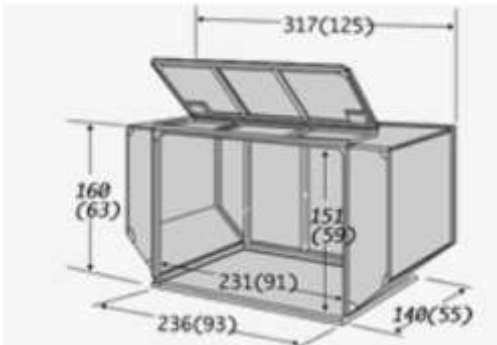
For the most aircraft can be used such types of ULDs as shown in the table 2.1 [11]:

Table 2.1

Diagram	Code	Dimensions LxW (mm)	Max Gross Weight (Kg)
	P1P	2,743 x 2,235	4.536
	PGA, PGE, PGF, PGG	6,058 x 2,438	13.608
	PRA	4,978 x 2,438	11.340

For the cargo aircraft B777-300 ER can be used such type of ULD for main deck (the aircrafts that are usually used by UIA) as is shown in table 2.2 [11]:

Table 2.2

Diagram	Code	Dimensions (LxWxH, cm)	Max Gross Weight (Kg)
	DKH	156×153×114	2,500
	AKE	156×153×163	3,500
	DQF	244×153×163	5 400

Most aircraft are compatible with pallets 88 x 108 and 88 x 125 inches, the example of which is represented in the Fig. 2.7 below [11].

Fig. 2.7 Lighweight nesteble air freight pallet

What do ULD numbers signify? How can we find a certain ULD easily and quickly? This table 2.3 [11] may help for ease of identification:

Table 2.3

CODE	MEANING	CODE	MEANING
A	Certified aircraft container	J	Thermal Non-Certified aircraft container
D	Non-Certified container	U	Non- Structural Igloo
P	Certified aircraft pallet	H	Horse stall
R	Thermal Certified aircraft container	V	Automobile Transport rack

Once a ULD is completed at any transit shed, the ULD needs to be prepared for the flight. To make a ULD available and acceptable for loading at the aircraft

side, every unit loaded onto an aircraft must have all the information the Ramp Agent should need to know, in the form of a ULD Tag.

These tags are very tough and can withstand adverse weather conditions. This information is then cross-referenced with the flight documentation at the aircraft, both must read the same. In general, all airlines should have their own ULD tags with their own logo and requirements stated, however some ground handling facilities use their own Tags so must be acceptable to their airline customers.

The following information is required to enable the Ramp loading staff to successfully load the aircraft correctly:

- Correct tag for the consignments loaded on/in the ULD;
- ULD / number;
- Destination;
- Gross weight;
- Correct Airline;
- Tag completed in full;
- Signature stating the ULD is correctly built and the weight correctly established;
- Staff should make sure the ULD is not overweight for the aircraft position and the ULD itself is within the maximum gross weight for that ULD;
- Tags are usually positioned on the long sides of the pallets by means of wire fasteners or in pocket on container door.

Tags are always located on the side of ULDs so the Ramp Agent can start cross checking information on the tag with the documentation before it is unloaded from the truck. If any discrepancies are found in the information supplied, then that ULD will run the risk of being offloaded and returned to the handling company for rectification.
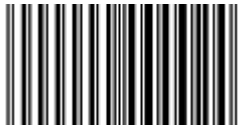
AIRLINE CONTAINER/PALLET		
 DPE 2772 PS	ID CODE	
DESTINATION **AMS**		
NET WEIGHT (Kg) **144**	TOTAL (Kg) **176**	
TARE WEIGHT (Kg) **32**		
LOADED AT **KBP**	FLIGHT **PS 101**	POSITION ON A/C **12 L**
CONTENTS: **PACKED FLOUR (an example)**		
REMARKS:		

Fig. 2.8 Example of ULD Tag
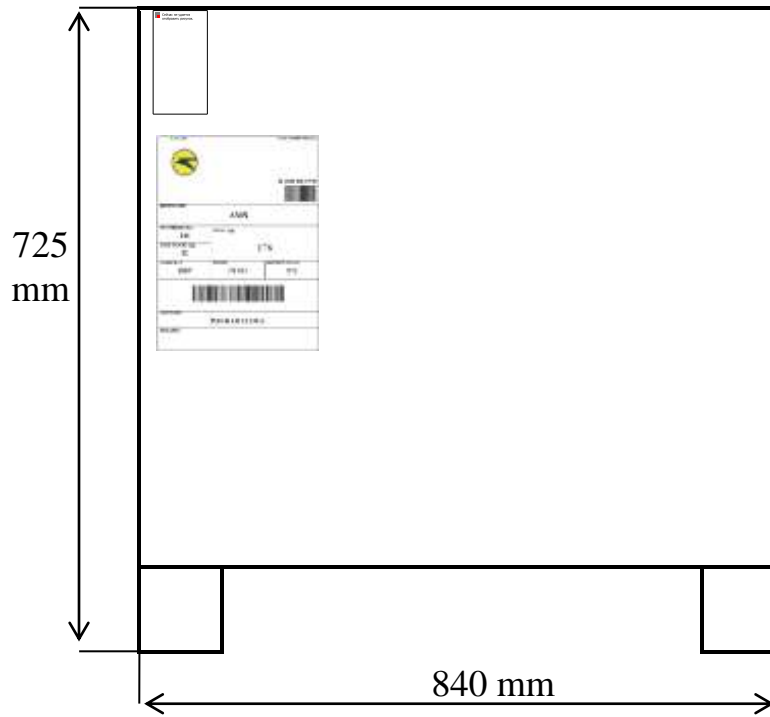
a) Side view
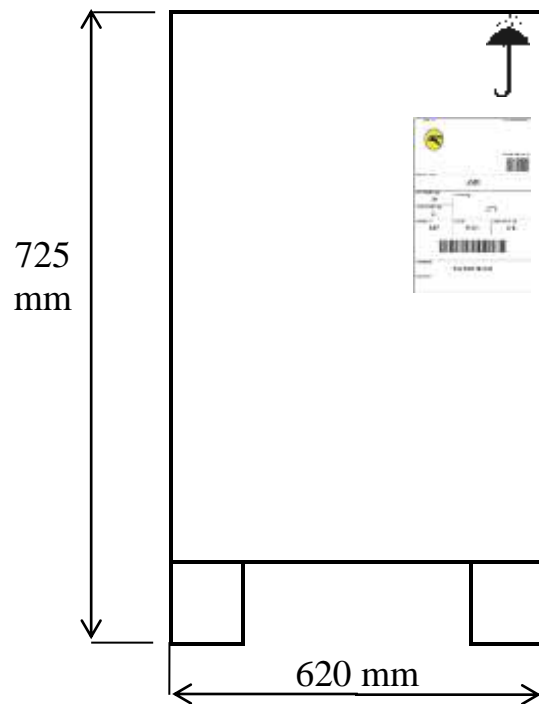
b) Front view

Fig. 2.9 Formed non-certified ULD container

3. DESIGN PART

3.1. DEVELOPMENT OF A METHODOLOGY FOR EVALUATING THE EFFECTIVENESS OF AUTOMATION OF TECHNOLOGICAL PROCESSES OF SERVICE

3.1.1. Evaluation of the efficiency of process automation from the perspective of project analysis

For a long time in practice, the most common approaches to assessing the effectiveness of automation of the process of servicing passengers at airports were: authoritarian, technocratic, or populist. However, top managers came to the conclusion that a rationalistic approach was needed, which included an element of economic feasibility.

The need to assess the economic feasibility of introducing automated systems, or to choose the best from alternative projects, is due to two main reasons. Firstly, the "loss" is very large in the case of an erroneous decision, since these systems are expensive. Secondly, the proven methods of modern management convince that any modernization is most successful if its goals are closely related to indicators / indicators for evaluating the results achieved - that is, the economic benefits of implementing automated systems can be realized only if if they are identified already in the design process and incorporated (directly or indirectly) into the target settings of the project. [12]

Improving the efficiency of solving the tasks assigned to the control system, as well as expanding the range of tasks solved by the control system leads to the emergence of various results from the implementation of the control system (both positive and negative). The results of the introduction of process control systems can affect the economic performance of the airport, the prospects for its further development, the working team of the automated object. The introduction of the process control system entails a number of socio-economic consequences for the automated object (airport) and the region in which it is located.

In these conditions, the issue of evaluating the effectiveness of the implementation of process control systems and developing methodological approaches to assessing the integrated effectiveness of automation of technological processes for servicing passengers at airports becomes especially urgent.

The main economic effect of the application of process control systems is determined by increasing the efficiency of the automated technological process, improving the quality and reliability of management, accompanied by a reduction in losses, an increase in productivity and quality of service.

The annual economic effect from the development and implementation of the process control system, defined as the ratio of the annual savings (annual profit growth) to the reduced lump sum costs for the development and implementation of the process control system, approved in the prescribed manner and recorded in the acceptance certificate for industrial operation, confirmed by the customer (airport) based on actual trial operation data, represents the actual annual economic effect E_a :

$$E_a \ = \frac{P_a}{C} \tag{3.1}$$

where C - capital investments for the creation of ACS;

P_a - the annual profit provided by these capital investments.

Capital costs for the development, implementation of process control systems include:

• costs for the development of process control systems (the so-called pre-production costs);

• capital costs for the acquisition (manufacturing), transportation, installation and commissioning of computer equipment, peripherals, communications, software, auxiliary equipment, office equipment, production and business equipment;

• expenses for the construction (reconstruction) of buildings, structures necessary for the functioning of the process control system;

• change in working capital in connection with the development and implementation of process control systems;

• costs of training (retraining) of personnel.

According to [13], it is possible to determine annual savings (annual profit growth) from the development and implementation of ACS as follows:

1. Annual profit growth caused by an increase in the volume of economic activity (aviation services) in the development and implementation of ACS;

3. Saving current costs for the production of aviation services in the conditions of the functioning of ACS;

4. Saving of other costs not included in the cost of air services provided by the functioning of the automated control system both directly at the implementation site, and in related areas and industries.

Automated process control system cannot automate all processes 100%. Theoretically, such a possibility is allowed, but the cost of the system would be too high. Therefore, you should choose the most cost-effective areas of automation. Consider the solution to this problem.

Let the automation of control in one *i-th* direction have a certain cost $Ц_i$_i, $У_i$ and this cost depends on the level of automation of control in this direction:

$$Ц_i = Ц_i(У_i) \tag{3.2}$$

Revenues from management automation in one i-th direction also depend on $У_i$:

$$Д_i = Д_i(У_i) \tag{3.3}$$

When solving only this problem, it is necessary to comply with the conditions:

$$Ц_i(У_i) = К_i Д_i(У_i) \tag{3.4}$$

where $К_i$ coefficient expressing the ratio of costs and revenues, i.e. payback period: $К_i = \frac{Ц_i(У_i)}{Д_i(У_i)}$

$$. \tag{3.5}$$

Let $У_i(Ц_i, Д_i)$ – is an inverse function $\frac{Ц_i(У_i)}{Д_i(У_i)}$, then it can be defined as:

$$У_i = f(Ц_i, Д_i, К_i). \tag{3.6}$$

When solving this problem, the choice of optimal solutions is possible.

For a system that solves many problems, one should go to the sums over all solvable functions from $i=1$ till n:

$$Ц = \sum_{i=1}^{n} Ц_i(У_i); \tag{3.7}$$

$$Д = \sum_{i=1}^{n} Д_i(У_i); \tag{3.8}$$

$$У = f(Ц, Д, К). \tag{3.9}$$

At the same time, the level of automation of production may vary. The task of choosing U is the task of ensuring the correspondence between the savings and the income from the use of process control systems (Д) and the costs of its creation (Ц). This determines the appropriate level of automation of the service process.

If we consider capital investments in measures that are an improvement of the automatic control system, then, firstly, the profit from the introduced measure is the difference between the profit from the improved object and the profit provided by it before the introduction of the improvement; secondly, in the general case, the introduced improvement can affect both the cost and the cost of annual airport services. In this regard, the coefficient of economic efficiency can be determined by the formula:

$$Э_я = \frac{\Delta П}{K} = \frac{П_2 - П_1}{K} = \frac{(Ц_2 - C_1) - (Ц_1 - C_1)}{K} = \frac{(Ц_2 - Ц_1) + (C_1 - C_2)}{K} \tag{3.10}$$

where $П_1$ и $П_2$, $Ц_1$ и $Ц_2$, C_1 и C_2 — annual profit, cost and cost of annual production of an object, respectively, before and after the introduction of improvement.

Evaluation of the cost-effectiveness of ACS in the early stages of its development is much more important than at the implementation stage, since such issues as the feasibility of developing this system in general, the choice of its structure, layout and configuration are solved here.

If we consider the project to automate the technological process of servicing passengers as a task aimed at improving the management system, then in a competitive market environment it should be treated as an independent investment project, that is, as a way of investing in a qualitative improvement of the service technology at the airport.

In the practice of investment analysis, there are generally accepted approaches to the financial and economic evaluation of investment projects [14]. In general, the financial and economic assessment of the quality of the proposed investment project involves the collection, verification and evaluation of three main financial and economic parameters:

- required investments, broken down by the timing of investments, economic content (capital investments, current assets) and directions of use (equipment, software, construction and installation works, tuning, etc.);
- operating costs at the operational stage of the functioning of the process control system;
- the economic benefits ("effects") of the airport resulting from the introduction of ACS, taking into account the timing of development, directions and economic content (increased profits, reduced working capital, reduced costs, etc.).

3.1.2. Evaluation of the efficiency of technological process automation using queuing theory

The ability to both transform travel time into monetary units (generalized cost) and predict travel time allows one to perform cost-effectiveness analyses in the design of transportation facilities by trading off travel time versus construction and operation cost. This handout provides two important analysis tools for predicting travel time in transportation facilities: Queueing theory and the time-space diagram.

All transportation facilities are subject to rush hours, seasonal variations, and long-time trends in demand. It is not generally economical to provide facilities so as to accommodate the peak demand, because that last increment of capacity which one would provide to serve the peak would be used for essentially zero time. In such case, one would obtain virtually zero benefit per unit of investment.

Queueing theory helps analysts in situations like these by enabling them to estimate user delays at transportation facilities when, occasionally, demand exceeds capacity. The time-space diagram is a tool that is used to study the way in which vehicles overcome distance. Each of these two tools has its specific applications area. For instance, if one realizes that in most transportation systems vehicles are confined to channels and that along these channels there are bottlenecks (i.e., points where flow is restricted), one can visualize queueing theory as the study of bottlenecks and time-space theory as the study of vehicular movement between bottlenecks.

Ground handling of air transport passengers at airport terminals is a typical example of a queuing system with a wait, the state of which varies over time randomly [15].

In the future, the following notation will be used:

n - the number of customers (passengers) in the service system (in line and in service at the control and registration desks);

λ_n - the intensity of entering the client system, provided that the system already has n clients;

μ_n - the intensity of the output stream of served clients, provided that there are n clients in the system;

p_n - probability that there are n clients in the system.

In the general model of the queuing system, a functional dependence of probability is established p_n from λ_n and μ_n. This data is then used to determine the functional characteristics of the service system, such as the average queue length, average latency, and average service utilization rate.

For an airport terminal, the input stream is the stream of passengers arriving at the terminal for formalities, or the stream of passengers arriving at the airport and baggage claim.

Along with the passenger inlet flow, the baggage inlet flow should also be considered, as a rule, separated at the terminals from the passenger flow and undergoing multiphase service.

For passengers of international airlines departing from the airport, or those arriving at it, the service process is multiphase, and passengers are sequentially served at check-in desks or baggage claim points, customs desks, at border and sanitary control points.

For baggage flow, in addition to the check-in desks, service devices are also sorting devices and various transport and handling equipment.

The main parameters of the passenger ground handling system at the terminal, which should be calculated when analyzing their operation, will be: the intensity of passenger and baggage input flows (λn), the intensity of passenger service in the operating rooms of the airport terminal (μn), the optimal number of jobs for passenger registration and baggage reception; the number of baggage claim points and points for customs and border formalities at international airports.

The task of evaluating the effectiveness of automation of passenger service technology and baggage handling using queuing theory is to determine the optimal

relationships between the characteristics of the input flow of passengers, the intensity of their service and the number of servicing devices.

You can judge the results of the automated passenger service system at the airport by the following indicators:

- the likelihood of passenger service automated process control system;

- the capacity of the process control system;

- the probability of denial to the passenger of service;

- the probability of employment of each channel (control and registration points) and all together;

- average busy time of each channel;

- the probability of employment of all channels;

- the average number of busy channels;

- the probability of downtime for each channel;

- the probability of downtime of the entire process control system;

- the average number of passengers standing in line;

- average passenger waiting time in line;

- average passenger service time;

- the average time spent by the passenger in the system.

It is necessary to judge the quality of passenger process control systems obtained by the totality of indicators. When analyzing the simulation results (indicators), it is also important to pay attention to the interests of the passenger and the interests of the airport (airline, handling company), that is, one or another indicator should be minimized or maximized, as well as the degree of their implementation.

Note that most often the interests of the passenger and airport formalities do not coincide with each other or do not always coincide.

3.2. QUEUEING THEORY IN TERMINAL PLANNING

3.2.1. General concept

Queueing theory studies congestion phenomena, i.e., the behavior of objects passing through a point at which there is a restriction on the maximum rate at which they can get through.

A queueing system can be represented schematically as follows on the Fig. 3.1 [15]:
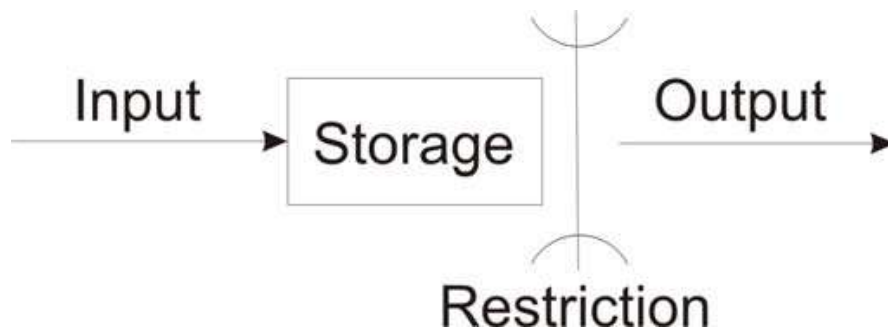
Fig. 3.1 Quering system

Most queueing systems have a storage area upstream of the restriction where the objects that have arrived but have not yet passed through the restriction are queued up. The collection of objects in the storage area is called a queue. Because queueing theory was developed with a certain type of application in mind (such as the analysis of waiting lines at check-out counters) the objects are referred to as customers and the restriction as a server (or service station if it contains more than one server).

Examples of transportation queueing problems are aircraft requiring to take-off, automobiles arriving at a toll gate, passengers waiting for elevators, and ships calling at a port.

With queueing theory one can study the behavior of a queue over time if the input stream (or arrival process) of customers and the characteristics of the restriction (or service mechanism) are known. One is usually interested in the

maximum queue length over a period of time and on typical waiting (or queueing) times. This is explained in the rest of this chapter.

3.2.2. Graphical Representation

Queueing problems arise in other areas of civil engineering. The analysis of water storage over time in a reservoir is a queueing problem in which the water runoff into the reservoir is the customer, the dam is the server, and the reservoir itself is the storage area. Queueing techniques are commonly used to size reservoirs.

The basic principle underlying queueing theory (similar to the conservation principle of mechanics of fluids, hydraulics and physics) is that customers do not disappear; i.e., the increase in the number of customers in the storage area during time Δt equals the number of customers that have arrived in Δt minus the number to have departed. This feature is exploited later on to derive the properties of a queueing system. Suppose, starting with an empty system, objects arrive at the storage at discrete times, and that these times are known $0 \leq t1 \leq t2 \leq \dots$.

This information completely characterizes the arrival process (i.e., it is all we need to know in Fig.3.2 [15]) for queueing theory purposes. It is conveniently summarized in a graph of the cumulative number of customers to have arrived by time t, j, vs. time.
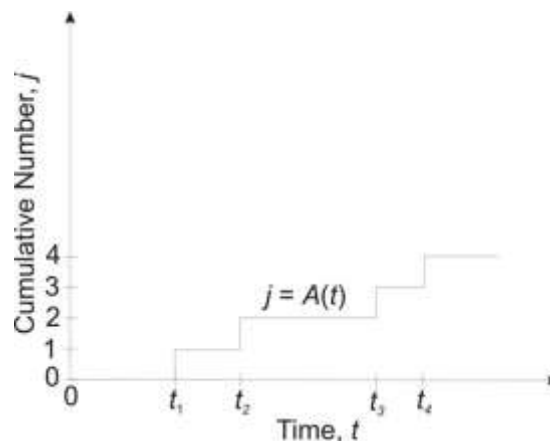
Fig. 3.2 Arrival process in queuing theory

Note that $A(t)$ is a function that increases by 1 at each tj and equals zero at the time we start counting customers.

The inverse function $t = A\text{-}1(j)$ can be visualized as the time at which the jth object arrives. Of course, if j is not integer this interpretation is not meaningful unless we visualize $j = 2.5$ as representing the first two objects and one-half of the third one. In such case, and since objects are indivisible $A\text{-}1(2.5) = t3$ (see Fig. 3.2).

If we know the service mechanism, i.e., how fast customers are processed through the system it is possible to determine the times at which customers leave the system and to draw a curve depicting the cumulative number of customers to have departed by time t, $D(t)$. The way in which the departure curve, $D(t)$ is obtained from the arrival curve and the service mechanism is explored later. For our present purposes we simply suppose that the $D(t)$ curve has been recorded by an observer and proceed to show how one can determine queue lengths and waiting times from the $A(t)$ and $D(t)$ curves when they are plotted on the same graph. This is done in Fig. 3.3.

In this figure 3.3 [15] the departure times are distinguished from the arrival times by primes.
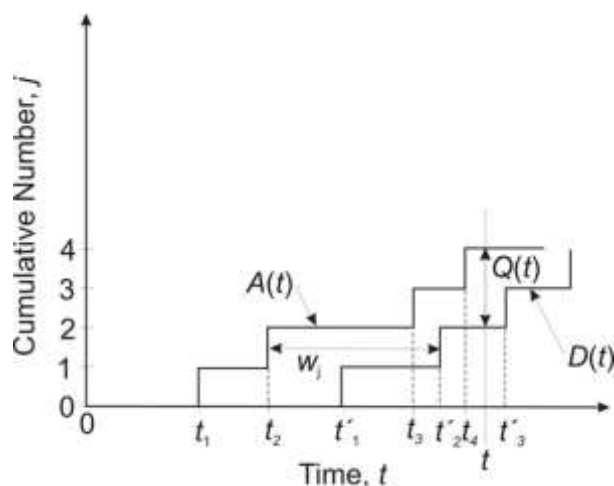
Fig. 3.3 Departure times are distinguished from the arrival times

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If, as in the above figure, the system is empty at time $t = 0$ and we start the $A(t)$ and $D(t)$ counts at $t = 0$, the vertical distance between $A(t)$ and $D(t)$ gives the queue length (the number of people in storage) at time t, $Q(t)$, since by the conservation principle

$$Q(t) - Q(0) = [A(t) - A(0)] - [D(t) - D(0)] \qquad (3.11)$$

and in our case $Q(0) = A(0) = D(0) = 0$. Thus, $Q(t) = A(t) - D(t)$.

Note that $A(t)$ and $D(t)$ can never cross because the number of people in storage cannot be negative. If at time $t = 0$ there is an initial queue $Q(0)$ the formula is instead $Q(t) = Q(0) + A(t) - D(t)$ and the vertical distances no longer represent queue lengths. This can be corrected by shifting the $A(t)$ curve upwards $Q(0)$ units, as in that case $A(0) = Q(0)$ and the conservation equation also yields:

$$Q(t) = A(t) - D(t) \qquad (3.12)$$

In the remainder of this handout we assume that the arrival and departure curves are drawn so that $Q(t) = A(t) - D(t)$.

Horizontal distances also have a simple interpretation. If we consecutively number the customers with labels $j = 1, 2, 3, \ldots$ in the order of arrival, and if customers are served in the same order in which they arrive (First-In-First-Out), the jth cumulative departure is also the object with label j. It leaves at the time of the jth jump of the departure curve:

$$t'j = D\text{-}1(j) \qquad (3.13)$$

Thus for FIFO, the waiting time to the jth customer, wj, (the difference between its departure and arrival times, $t'j - tj$) is given by the horizontal distance between $A(t)$ and $D(t)$:

$$wj = D\text{-}1(j) - A\text{-}1(j) \tag{3.14}$$

As some *global measure of performance*, it is often convenient to evaluate the **total** time spent by objects in the storage. One may be interested in either the total time spent in the system by a specified number of objects, or in the total time spent by all objects during a specific period of observation.

In the former case, for FIFO, we can interpret the *wj* either as the horizontal distance between $A(t)$ and $D(t)$ or as the area of a horizontal strip of unit height and width *wj* (see Fig. 3.4 [15]). The total delay to objects 1, 2, …., *n* is the sum of the areas of strips 1 to *n*, i.e., the total area between $A(t)$ and $D(t)$ and lines at height 0 an *n*.
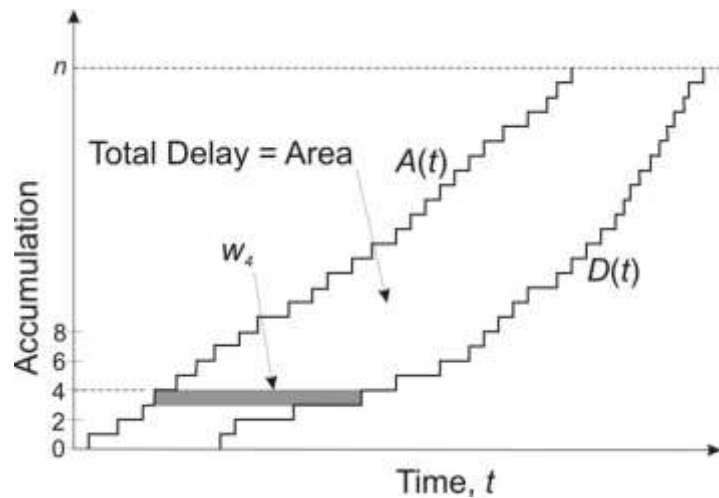
Fig. 3.4 Area of a horizontal strip of unit height and width

The average waiting time to the *n* customers is, thus:

$$\overline{w} = \frac{1}{n} \times \sum_{i=1}^{n} w_j = \frac{\text{Area}}{n} \tag{3.15}$$

If customers are not served according to a first-in-first-out rule, it is difficult to obtain their individual waiting times from the $A(t)$ and $D(t)$ plot and the above arguments (the expressions for *wj* and *w*) are not valid.

In the latter case we can say that the total time spent in the system by customers during a time period *t* to $t + dt$ is $Q(t)dt$ (see Fig. 3.5). Note that this is a

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fact entirely independent of the order in which customers are served. The total time spent in storage by all customers during time 0 to T is:

$$TT = \int_0^T Q(t)dt = \int_0^T [A(t) - D(t)]dt$$

(3.16)

This has the geometrical interpretation of the area between $A(t)$ and $D(t)$, and the two vertical lines at 0 and T as shown on the Fig.3.5 [15].
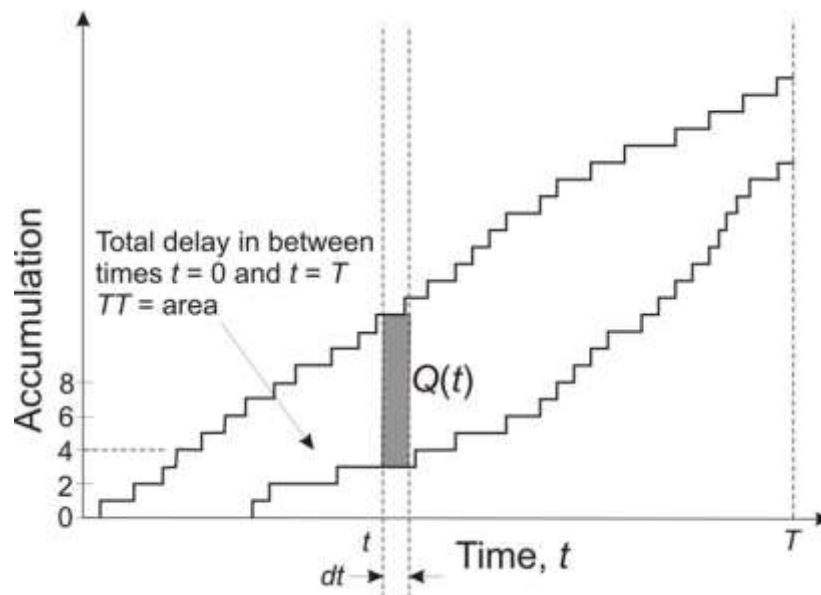
Fig. 3.5 Geometrical interpretation of the area between $A(t)$ and $D(t)$

If storage is empty at time T, when the nth object leaves, the two areas are the same as shown on the Fig.3.6 [15].
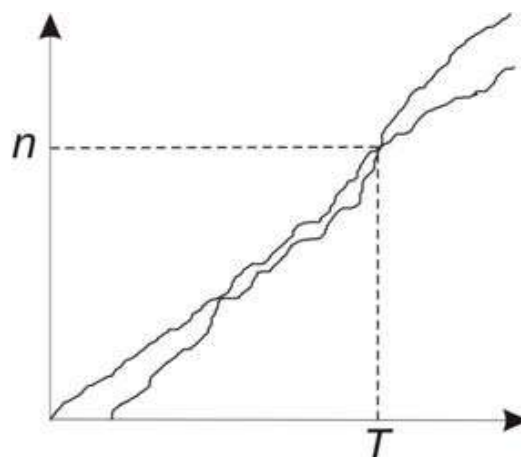
Fig. 3.6 Two areas

$$\overline{Q} = \text{time average number in storage} \equiv \frac{1}{T}\int_0^T Q(t)dt = \frac{\text{area}}{T}$$

(3.17)

$$\overline{w} = \text{average time object spends in storage} = \frac{1}{n}\sum w_j = \frac{\text{area}}{n}$$

(3.18)

Eliminating the area from (1) and (2) we obtain an important relationship between w and Q :

$$n\overline{w} = T\overline{Q} = \text{area}$$
$$\overline{Q} = \frac{n}{T}\overline{w};$$

(3.19)

where $\dfrac{n}{T}$ is interpreted as the average number of arrivals per unit time.

Thus, for any service order and between points where the storage is empty we have:

Average queue length = Average waiting time × Average arrival rate. [15]

3.3. CALCULATION OF AIR CARGO TERMINAL TECHNOLOGICAL PARAMETERS

3.3.1. Calculations of a new warehouse model in Boryspil Airport

In order to construct the ACT we have to understand the flow of different goods and ways of their storage. Here is the initial data:

Table 3.1 Initial data

Number of the option	Daily goods turnover, Q_{day}, t/day	Specific weight of goods on DAL, %	Specific weight of goods arrived by DAL, %	Specific weight of goods arrived by IAL, %	Specific weight of goods transferred by IAL, %	Specific weight of bulk cargo transported by IAL, %	Coefficient of nonunifor-mity Kn
9	500	25	45	60	10	20	1.4

After making the calculations I have obtained such information:

Domestic:

- Specific weight –25% = 125 t/day;
- Goods arrived – 45% of 125 = 56,25 t/day;
- Goods departed – 125-56,25 = 68,75 t/day.

International:

- Specific weight = 500-125 = 375 t/day;
- Goods arrived – 60% of 375 = 225 t/day;
- Goods transferred – 10% of 375 = 37,5 t/day;
- Goods departed – 375-225-37.5 = = 112.5 t/day;
- Bulk cargo – 20% of 375 = 75 t/day;
- ULD cargo – 375-75 = 300 t/day.

Now with the help of gained calculations, we can build the diagrams of the good flow and calculate warehouse parameters.
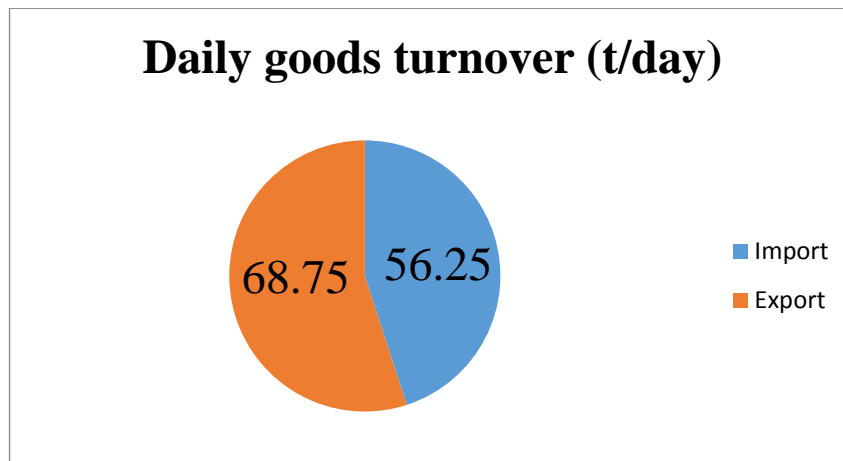
Fig. 3.8 Daily cargo turnover in domestic warehouse
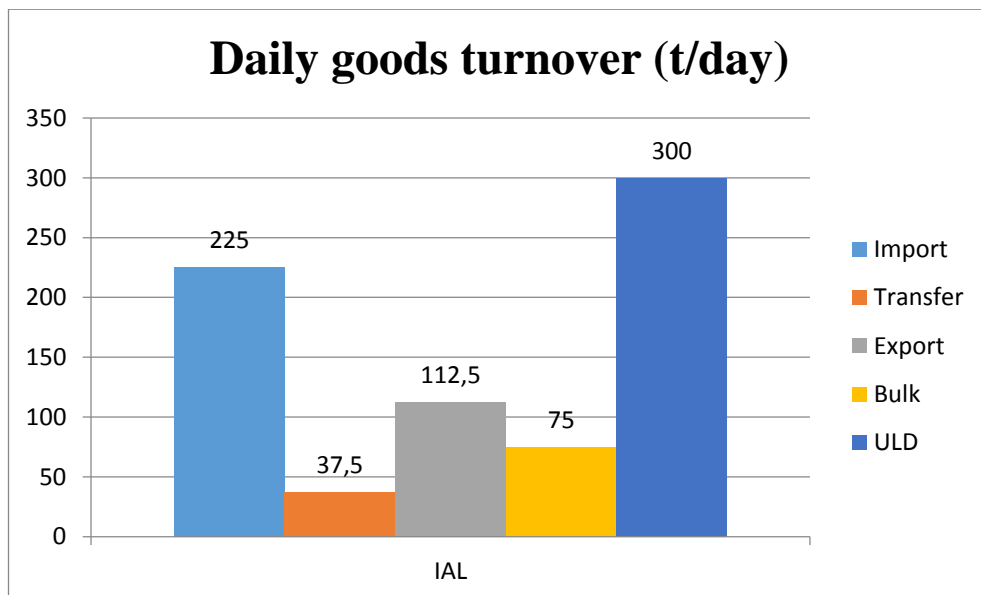
Fig. 3.9 Daily cargo turnover in international warehouse

During designing warehouses the following technological areas should be calculated:

F_{wor} – area, directly occupied by stored goods (working area);

F_{ad} – area necessary for performing operations connected with goods acceptance and delivery (additional area),

F_{aux} – area, occupied by passages (auxiliary area);

F_{of} – area, occupied by offices (office area).

Total area of warehouse is calculated according to the formula:

$$\boldsymbol{F_{tot} = F_{wor} + F_{ad} + F_{aux} + F_{of}}$$
(3.20)

To calculate working area of warehouse first of all **capacity of its premises** is calculated:

$$E_{war} = Q_{day} * K_n * T_{st}^{av} \tag{3.21}$$

where Q_{day} = 125 t/day – daily goods turnover of an airport on goods departure or arriving;

K_n = 1.4 – coefficient that takes into account nonuniformity of goods delivery at warehouse during different seasons and months of a year;

T_{st}^{av} – average duration of goods storage at the warehouse:

$T_{st}^{av}(arriving) = T_{st}^{av}(departure) = 1.5$ days

$T_{st}^{av}(transfer) = 0.5$ day.

So having the data we complete the following calculations.

DOMESTIC WAREHOUSE

$E_{war}^{fl} = 125 * 1.4 * 1.5 = 262,5$ t

Working area of goods, transported by domestic airlines is calculated according to the formula:

$$F_{wor}^{fl} = (E_{war}^{fl} / P^{fl}) * K_{sur.ar} \tag{3.22}$$

where P^{fl} = 0.7 t/m² – specific loading, allowed per 1 m² of warehouse area,

$K_{sur.ar}$ = 1,4 – coefficient of surplus area that takes into account irregularity of goods distribution.

$$F_{wor}^{fl} = (262,5 / 0,7) * 1.4 = \textbf{525 m}^2 \tag{3.23}$$

Number of stacks is calculated in the following way:

$$n_{st} = F_{wor}^{fl} / F_{st} \tag{3.24}$$

where F_{st} – area of one stack and equals to 24.

$N_{st} = 525 / 24 = 21,875 = 22$

Additional area of warehouse includes areas, intended for goods acceptance and delivery.

$$F_{ad} = Q_{day} * K_n * t / P' \tag{3.25}$$

where $P' = 0.6$ t/m^2 – loading per 1 m^2 at a acceptance and consolidation area, $t = 0.6$ day – term of goods storage at the acceptance and consolidation area.

$F_{ad} = 125 * 1,4 * 0.6 / 0.6 = $ **175 m^2**.

Calculation of **auxiliary area of warehouse**, occupied by passages is:

$$F_{aux} = F_{wor} * K_{pas} \qquad (3.26)$$

where $K_{pas} = 0.5$ – coefficient that takes into account necessity in auxiliary area inside warehouse, occupied by passages.

$F_{aux} = 525 * 0.5 = $ **262.5 m^2**.

Calculation of **office area** of warehouse:

$$F_{of} = n * S_n \qquad (3.27)$$

where $n = 12$ – number of workers at the warehouse, $S_n = 3.25$ m^2 – normative area per 1 worker. As we have international airlines warehouse, we should take into account number of the customs employee – 5 workers.

$F_{of} = (12 + 5) * 3.25 = $ **55,25 m^2**.

$F_{tot} = 525 + 175 + 262.5 + 55,25 = $ **1017.75 m^2**.

INTERNATIONAL WAREHOUSE

$E^{fl}_{war} = 375 * 1.4 * 1.5 = 787.5$ t

$E^{rack}_{war} (arr, dep) = 337,5 * 1.4 * 1.5 = 708,75$ t

$E^{rack}_{war} (tr) = 37,5 * 1.4 * 0.5 = 26.25$ t

$E^{rack}_{war} = 708.75 + 26.25 = 735$ t

$$F^{fl}_{wor} = (E^{fl}_{war} / P^{fl}) * K_{sur.ar} \qquad (3.28)$$

where $P^{fl} = 0.7$ t/m^2 – specific loading, allowed per 1 m^2 of warehouse area, $K_{sur.ar} = 1,4$ – coefficient of surplus area that takes into account irregularity of goods distribution.

$F^{fl}_{wor} = (787.5 / 0,7) * 1.4 = $ **1575 m^2**

For determination of required working area for goods, stored in racks we should consider the volume of rack's working cell:

$$v_c = l * b * h \qquad (3.29)$$

where $l = 1.5$ m – length of a cell, $b = 1.2$ m – width of a cell and $h = 1.3$ m – height of a cell.

$$v_c = 1.5 * 1.2 * 1.3 = 2,34 \ m^3$$

Specific capacity of a rack's cell:

$$E_c = v_c * y * K_f \tag{3.30}$$

where $y = 0,8$ t/m³ – volume weight of stored goods,

$K_f = 0.6$ – coefficient of cell filling.

$$E_c = 2.34 * 1.8 * 0.6 = 2,5272 \ t$$

Number of racks working cells, which are necessary for arrangement specific capacity of stored goods, should be determined:

$$N_c = E^{rack}_{war} / E_c = 735 / 2,5272 = 290.8 \sim 291 \tag{3.31}$$

Number of racks tiers is determined according to the formula:

$$K_t = P^{rack} * F_c / E_c \tag{3.32}$$

where $P^{rack} = 3,4$ t/m² – specific loading, allowed per 1 m² of warehouse floor with rack storage of goods, $F_c = 1.5 * 1.1 = 1.65 \ m^2$ – area of 1 cell.

$$K_t = 3.4 * 1.65 / 2,5272 = 2,219 \sim 2$$

Design number of working cells in the lower tier of racks is determined from the condition:

$$Z^l_c = N_c / K_t = 291 / 2 = 145.5 \tag{3.33}$$

Total working area of warehouse section, intended for storage of goods in racks:

$$F^{rack}_{wor} = (l + b') * b * Z^l_c \tag{3.34}$$

where $b' = 0.1$ m – width of gaps between neighboring cells.

$$F^{rack}_{wor} = (1.5 + 0.1) * 1.2 * 145.5 = \mathbf{279.36 \ m^2}$$

Now we can determine the total are of domestic and international warehouses together:

$$F_{wor} = 1575 + 279.36 = \mathbf{1854.36 \ m^2}$$

Additional area of warehouse includes areas, intended for goods acceptance and delivery.

$$F_{ad} = Q_{day} * K_n * t / P'$$ (3.35)

where $P' = 0.6$ t/m² – loading per 1 m² at a acceptance and consolidation area, $t = 0.6$ day – term of goods storage at the acceptance and consolidation area.

$F_{ad} = 375 * 1,4 * 0.6 / 0.6 = **525 m²**.$

Calculation of **auxiliary area of warehouse**, occupied by passages is:

$$F_{aux} = F_{wor} * K_{pas}$$ (3.36)

where $K_{pas} = 0.5$ – coefficient that takes into account necessity in auxiliary area inside warehouse, occupied by passages.

$F_{aux} = 525 * 0.5 = **262.5 m²**.$

Calculation of office area of warehouse:

$$F_{of} = n * S_n$$ (3.37)

where $n = 12$ – number of workers at the warehouse, $S_n = 3.25$ m² – normative area per 1 worker. As we have international airlines warehouse, we should take into account number of the customs employee – 5 workers.

$F_{of} = (12 + 5) * 3.25 = **55,25 m²**.$

$F_{tot} = 1575 + 525 + 262.5 + 55,25 = **2417.75 m²**.$

Determination of warehouses' overall dimensions

DOMESTIC WAREHOUSE

Determination of warehouse overall dimensions is performed at the conditions of given total area. As a rule, width is set according to the construction standard and should be multiple to 3. We choose that width $B_{war} = 24$ m. Length therefore is calculated:

$$L_{war} = F_{tot} / B_{war} = 1017.75 / 24 = 42,41 \ m \sim 42 \ m.$$

The diagonal from one corner to another equals 48,40 m.

The dimensions of the warehouse are 42 m x 24 m.

INTERNATIONAL WAREHOUSE

We choose that width $B_{war} = 36$ m

$$L_{war} = F_{tot} / B_{war} = 2417.75 / 36 = 67.16 \ m \sim 67 \ m.$$

The diagonal from one corner to another equals 73.06 m.

Calculation of length of the front of loading and unloading works:

Optimal number of goods acceptance points and amount of sets of vehicles and equipment for carrying out loading-unloading works and operations, connected with goods acceptance and registration:

$$n_{opt} = \frac{\lambda + \frac{1}{t_d^{giv}} \cdot ln \frac{P_{oc}}{P(t_{real} > t_d^{giv})}}{v} \qquad (3.38)$$

where, $t_d^{giv} = 0.6$ h – average waiting time of truck with goods in queue on loading;

$P_{oc} = 0.95$ – possibility that acceptance points will be occupied and next turn truck with goods will be waiting for unloading;

$P(t_{real} > t_d^{giv}) = 0.05$ – possibility that downtime of truck in queue on unloading can be bigger than the given one;

v - intensity of one shipper servicing (inversely proportional to the average time of one shipper servicing $t_{serv} = 0.4$), so v = 1 / 0.4 = 2.5;

λ - intensity of input flow of trucks, pcs/hour;

$$\lambda = \frac{Q_{day}K_n}{T \cdot q_{c.c.}K_{c.c.}} \qquad (3.39)$$

where, $T = 24$ h/day – working time of warehouse during a day from acceptance and goods from warehouse;

$q_{c.c.} = 5$ t – average carrying capacity of trucks which are used;

$K_{c.c.} = 0.7$ – coefficient of a truck capacity usage.

Domestic Warehouse:

$\lambda = 125 * 1.4 / 24 * 5 * 0.7 = 25.52 \ pcs/h$

$n_{opt} = (25.52 + 1.66 * 3.3) / 2.5 = 12.40 \ pcs$

Length of the front of loading and unloading works:

$L = \boldsymbol{n_{opt}} \cdot l + (\boldsymbol{n_{opt}} -1) \cdot \boldsymbol{l_{res}} \ (m),$

where, l = 6.5 or 3 m – length/width of a truck (depending upon the way of trucks arrangement);

l_{res} = 3 m – reserve distance between neighboring trucks, installed near unloading platform.

l = 12.40 * 6.5 + (12.40 – 1) * 3 = 114.8 m – based on length;

l = 12.40 * 3 + (12.40 – 1) * 3 = 71.4 m – based on width.

International Warehouse:

λ = 375 * 1.4 / 24 * 5 * 0.7 = 76.56 pcs/h

n$_{opt}$ = (76.56 + 1.66 * 3.3) / 2.5 = 28.43 pcs

l = 28.43 * 6.5 + (28.43 – 1) * 3 = 267.085 m – based on length;

l = 28.43 * 3 + (28.43 – 1) * 3 = 167.58 m – based on width.

2.3.3. Calculation of mechanized means number

Mechanized means are used to process any type of cargo. So, we have to calculate their number for obtained dimensions of warehouses and ACC at whole.

Calculation of mechanized means number in warehouse

Number of forklift loaders:

$$N_{load} = \frac{Q_{day}K_n}{P_{h.load}T_{load}K_{us.t}}$$

(3.40)

where, $P_{h.load}$ - is carrying capacity of electric loader, t;

T_{load} - term of electric loader work, hours/day;

$K_{us.t}$ - coefficient of vehicle usage during working time (it should be accepted as 0.7-0.8).

$$P_{h.load} = Q_{load} * K_{us.c.} * Z_{load}$$

(3.41)

where, Q_{load} = 4.5 t – carrying capacity of electric loader;

$K_{us.c.}$ = 0.8 – coefficient of carrying usage;

Z_{load} - number of working cycles of electric loader per hour.

$$Z_{load} = \frac{T_{hour}}{T_{c.load}}$$

(3.42)

where, T_{hour} - duration of hour, min or sec;

$T_{c.load}$ - duration of one working cycle of electric loader, min or sec.

$$T_{c.load} = t_1 + t_2 + t_3 + t_4 + t_5 + t_6 \qquad (3.43)$$

where, t_1 = 20 sec – time of forks placing under goods lifting of goods on forks and loaders turn (is accepted in frame of 20-30 sec);

t_2 – time of loaders movement of goods;

t_3 – time of goods lifting on necessary height;

t_4 = 10 sec – time of goods laying in stack and deviation of forklift loader frame backwards without goods (is accepted in frame of 7-11 sec)

t_5 – time of empty loaders forks down movement (is equal to t_3);

t_6 – time on reverse idle running.

$$t_{2,6} = L_{load} / V_{load} + t_{ac} \qquad (3.44)$$

where L_{load} = 65.7 m – is forklift loader movement track (via diagonal of warehouse);

V_{load} = 20 km/h = 5.5 m/s – is average speed of forklift loader motion;

t_{ac} = 3 sec – time on acceleration and deceleration.

$t_{2,6} = 65.7 / 5.5 + 3 = 14.9\ sec$

$$t_{3,5} = H_{load} / V_{load.f} + t_{ac} \qquad (3.45)$$

where H_{load} = 5.5 m – average height of loader's forks lifting;

$V_{load.f}$ = 0.5 m/sec – speed of loader's forks lifting.

$t_{3,5} = 5.5 / 0.5 + 3 = 14\ sec$

$T_{c.load} = 20 + 13 + 13 + 10 + 14.9 + 14 = 84.9\ sec \sim 85\ sec = 1.25\ min$

$Z_{load} = 60 / 1.25 = 48\ cycles$

$P_{h.load} = 4.5 * 0.8 * 48 = 172.8\ t/hour$

Number of forklift loaders for domestic warehouse:

$N_{load} = 125 * 1.4 / 172.8 * 20 * 0.8 = 0.06\ pcs.$

Number of forklift loaders for international warehouse:

$N_{load} = 375 * 1.4 / 172.8 * 20 * 0.8 = 0.19\ pcs.$

So we need 1 forklift loader for domestic warehouse and one for international.

2.3.4. Calculation of mechanized means number on apron

Main mechanized means used at airports for goods transportation on apron and carrying out (un-)loading works are vehicles with lifting body (VLB) for bulk cargo and diesel tractors with trolleys and ULD loaders. Their amount is calculated according to the formula:

$$N = Q_{day} * K_n / P * K_{tr} \qquad (3.46)$$

where P – is productivity of a device, t/day;

$K_{tr} = 0.7$ – coefficient of technical readiness of a device.

$$P = Q * Z * K_{us.c} \qquad (3.47)$$

where Q is carrying capacity of a device: $Q_{DT} = 30t$, $Q_{VLB} = 5.1t$, $Q_{ULD} = 8\ t$;

$K_{us.c} = 0.8$ – coefficient of carrying capacity usage by apron mechanized mean;

Z – number of devices during a day.

Number of the devices during a day is calculated according to the formula:

$$Z = (T * V_v * k_{us.r} * K_{us.t}) / (L_a + t_{dt} * V_v * k_{us.r}) \qquad (3.48)$$

where $T = 24$ h/day – time of warehouse work;

V_v is average transportation speed of a device: $V_{DT} = 15\ km/h$, $V_{VLB} = 20\ km/h$, $V_{ULD} = 35\ km/h$;

$k_{us.r} = 0.7$ – coefficient of running usage;

$L_a = 2.4$ km – average distance from warehouse to aircraft parking place;

$t_{dt} = 10$ min $= 0.17$ h – duration of vehicle downtime under (un-)loading works during 1 working cycle;

$K_{us.t} = 0.6$ – coefficient of vehicle usage during working time.

After making calculations we found out numbers of vehicles used:

$Z_{DT} = 43\ pcs$;

$Z_{VLB} = 34\ pcs$;

$Z_{ULD} = 46\ pcs$.

Productivity of each device is:

$$P_{DT} = 43 * 30 * 0.8 = 1032 \text{ t/h;}$$

$$P_{VLB} = 34 * 5.1 * 0.8 = 138.72 \text{ t/h;}$$

$$P_{ULD} = 46 * 8 * 0.8 = 294.4 \text{ t/h.}$$

Necessary amount of each vehicle for domestic warehouse is:

$$N_{DT} = 125 * 1.4 / 1032 * 0.7 = 0.52 - \text{for bulk cargo;}$$

Necessary amount of each vehicle for international warehouse is:

$$N_{DT} = 375 * 1.4 / 1032 * 0.7 = 0.73 - \text{for bulk cargo;}$$

$$N_{VLB} = 375 * 1.4/ 138.72 * 0.7 = 5.40 - \text{for cargo, transported in ULDs;}$$

$$N_{ULD} = 375 * 1.4 / 294.4 * 0.7 = 2.55 - \text{for cargo, transported in ULDs.}$$

After making calculations concerning mechanized means number at a warehouse, we can make a conclusion: we will need 1 forklift loader, 1 diesel tractor with 2 trolleys for domestic warehouse, 1 diesel tractor with two trolleys, 6 vehicles with lifting body and 3 ULD loaders for international warehouse.

For our warehouse the appropriate forklift loader would be of JAC production with following characteristics:

For our warehouse the appropriate forklift loader would be of TOYOTA production as shown on the Fig.3.10 with following characteristics:

- Subcategory: Counterbalance Forklift
- By Application: Industrial Forklift
- By Size: Large Forklifts
- By Wheels: 4 Wheel Forklift
- Fuel Type: Electric Forklift
- Operating Type: Ride On Forklift
- Rated Capacity: up to 5.4 t
- 20 m –maximum height of loader's forks lifting

Fig. 3.10 Large Electric Forklift

Vehicles with lifting body should meet the following requirements:

- Transportation speed of 15 km/h.

- Carrying capacity 5 t

Fig. 3.11 Vehicle with lifting body

Characteristics of diesel tractors with 2 trolleys:

- Drop side loading and unloading and tipping type providing with hydraulic system for towing tractor to be operated through oil pressure of gear box.

- Side doors hinged removable type while the rear doors are hinged top or bottom for easy tipping.

- Carrying capacity: 25 t

- Average transportation speed: 30 km/h

Fig. 3.12 Diesel tractor in the airport warehouse Harlan Tug

Fig. 3.13 Cargo trolley for tractors

Fig. 3.14 Container/Pallet Loader

- Capacity of ULD loader – 7-8 t;
- Average transportation speed: 30 km/h.

3.4 ORGANIZATION AND TECHNOLOGY OF AIR CARGO TERMINAL WORK

3.4.1. Technology of goods handling in Air Cargo Terminal

Technological process of departure bulk cargo on domestic warehouse consists of the following operations:

- goods delivery to the airport by the transport of the shipper or transport-forwarding company;
- goods discharge in the cargo reception (warehouse) and transmission of documents to the consignor to handling agent;
- formalities performance, i.e. different types of control and supervision (customs), goods marking, weighting, inspection of pieces, labeling, identifying damages;
- aviation security check and other controls as appropriate;
- cargo registration in a warehouse;
- transportation of cargo to the place of storage in warehouse, temporary storage of goods before shipping;
- consolidation of cargo loading of a flight (warehousing unit shipment);
- transportation of cargo inside the warehouse to the place of consolidation for the flight;
- cargo transportation inside warehouse from the consolidation area to the loading area;
- transportation of the cargo from warehouse to parking place;
- goods loading to the aircraft (giving documents to flight crew responsible for commercial loading, certification of document, issuing of cargo manifest);
- goods transportation inside the aircraft, its consolidation and providing of documents to crew;
- cargo writing-off from a warehouse.

Technological process of arriving bulk cargo to domestic warehouse consists of the following operations:

- unloading from the aircraft, giving documentation;
- checking number of pieces, packaging for damage;
- loading on apron vehicles;
- delivery of goods to the warehouse;
- unloading cargo in a warehouse;
- acceptance and registration of goods in warehouse;
- checking of documents, number of packages, presence of damages, weighting of cargo;
- transportation of cargo inside the warehouse to the place of temporary storage;
- short- term storage of goods before delivery to consignee;
- informing the consignee and conducting the final calculations for transport;
- formalities performance on the arrival of consignee;
- internally warehouse transportation of cargo to the place of cargo delivery;
- arriving of consignee; checking of the payment; certification of the documents;
- delivery of cargo to consignee and cargo writing-off from a warehouse;
- loading of cargo on vehicles of consignee and export of cargo from warehouse.

Technological process of export goods in ULD in international warehouse consists of the following operations:

- delivery of cargo to the airport;
- unloading the cargo to the warehouse;
- formalities performance (custom clearance and other needed inspections);
- goods marking, weighting, inspection of pieces, labeling, identifying damages;
- aviation security control;
- acceptance and registration of goods in warehouse;

- transportation of cargo inside the warehouse to the place of short-term storage;
- storing in warehouse until departure;
- consolidation of cargo loading of a flight;
- transportation of the cargo inside the warehouse to the place of consolidation for the flight;
- internally warehouse transportation of cargo to the place of cargo delivery;
- certification of the documents (checking);
- loading of cargo aircraft, its consolidation and providing of documents to crew;
- cargo writing-off from a warehouse.

Technological process of import goods in ULD on IAL handling consists of the following operations:

- unloading cargo from the aircraft;
- loading of the goods on the vehicle;
- transport of goods to the warehouse;
- stamp "Cargo Customs";
- unloading of cargo at the loading ramp;
- acceptance and registration of goods in warehouse (documents certifications);
- transportation of goods within the warehouse to the place of temporary storage;
- short-term storage of goods before delivery to the consignee;
- informing the consignee and conducting the final calculations for transport;
- arrival of consignee, clearance (customs, veterinary control, etc.)
- checking operations (payments, cargo)
- transportation of goods within the warehouse to the loading ramp;
- loading cargo on a vehicle of the recipient;
- delivery to the consignee.

In the carriage of cargo in containers and on pallets appear manufacturing operations relating to acquisition of containers and pallets, loading and unloading operations with them.

Technological process of transfer goods in ULD in international warehouse consists of:

The Cargo Transfer - is that according to the bill of lading, delivery Transfer to the airport on the same flight, and then transported to another flight same or a different carrier.

Technological scheme provides for the transfer of cargo processing them sequentially as arriving and outgoing cargo except for certain manufacturing operations. The process includes following steps:

- unloading cargo from the aircraft;
- transportation to the warehouse;
- unloading near the warehouse;
- transportation inside a warehouse in the area of transfer cargo;
- short- term storage prior to shipment;
- transportation to the place of recruitment flight load;
- overload on warehouse transport vehicle;
- transportation to the aircraft;
- loading in the sun, laying and mooring.
- Simultaneously with these transactions documents are transmitted.

3.4.2. Structure of Air Cargo Terminal Mail and Goods Handling Department

Air Cargo Terminal Mail and Goods Handling Department provides service of organizations, businesses, commercial organizations and individuals in the preparation, processing of cargo and mail for sending by air.

Main tasks:

- Regularity and safety provision in terms of aircraft handling.

- Increasing of automation and mechanization of technological processes.
- Qualitative and in time clients servicing.
- Improvement of technological processes.

  Main functions:
- Acceptance and handling of mail and cargo in accordance with technology;
- Providing of loading and unloading works.
- Ensuring paperwork for transportation of cargo and mail.
- Providing ground commercial aircraft maintenance.
- Organization of export/import declaration of goods.
- Carrying out of payments for services and cargo transportations.
- Claims and complains handling.
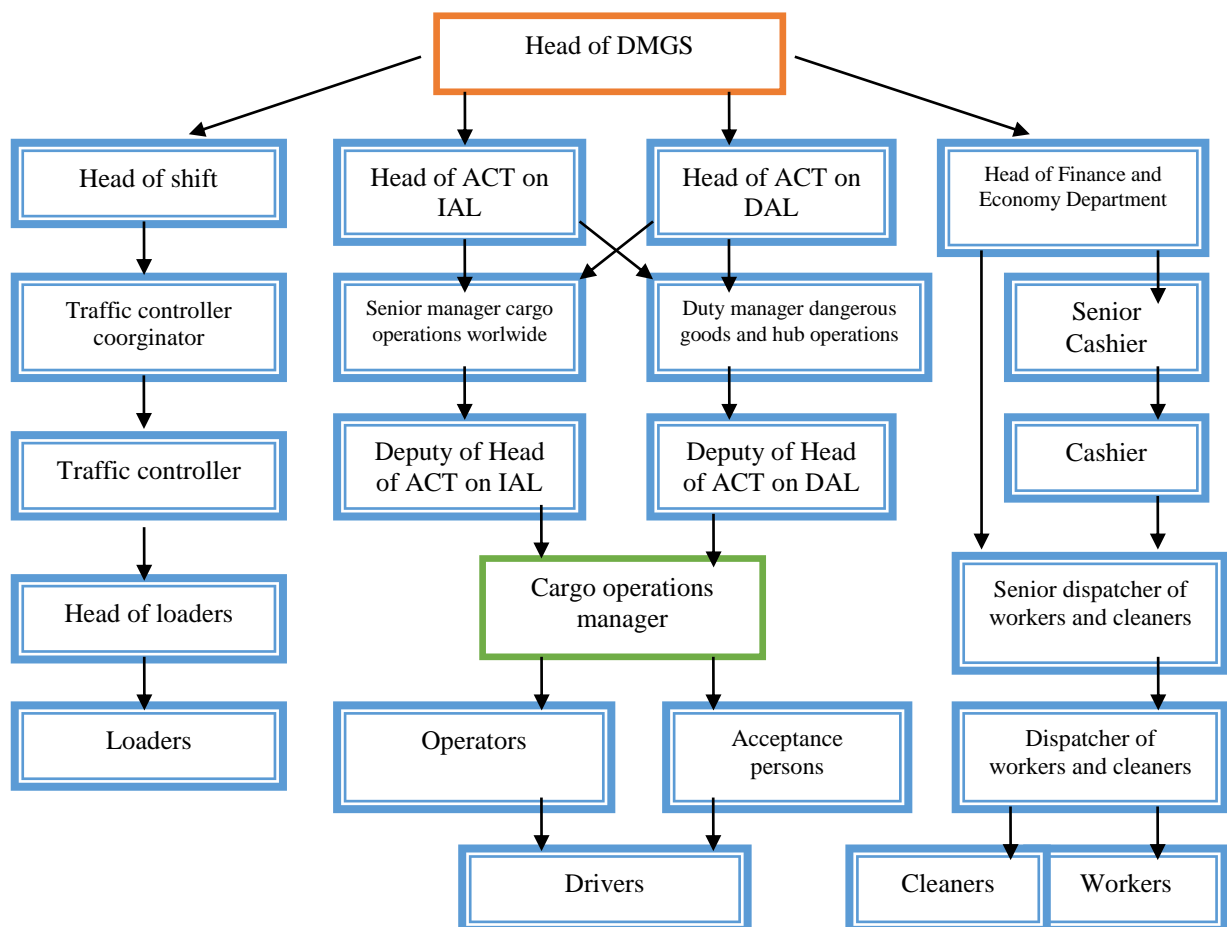- Improving the quality of services.
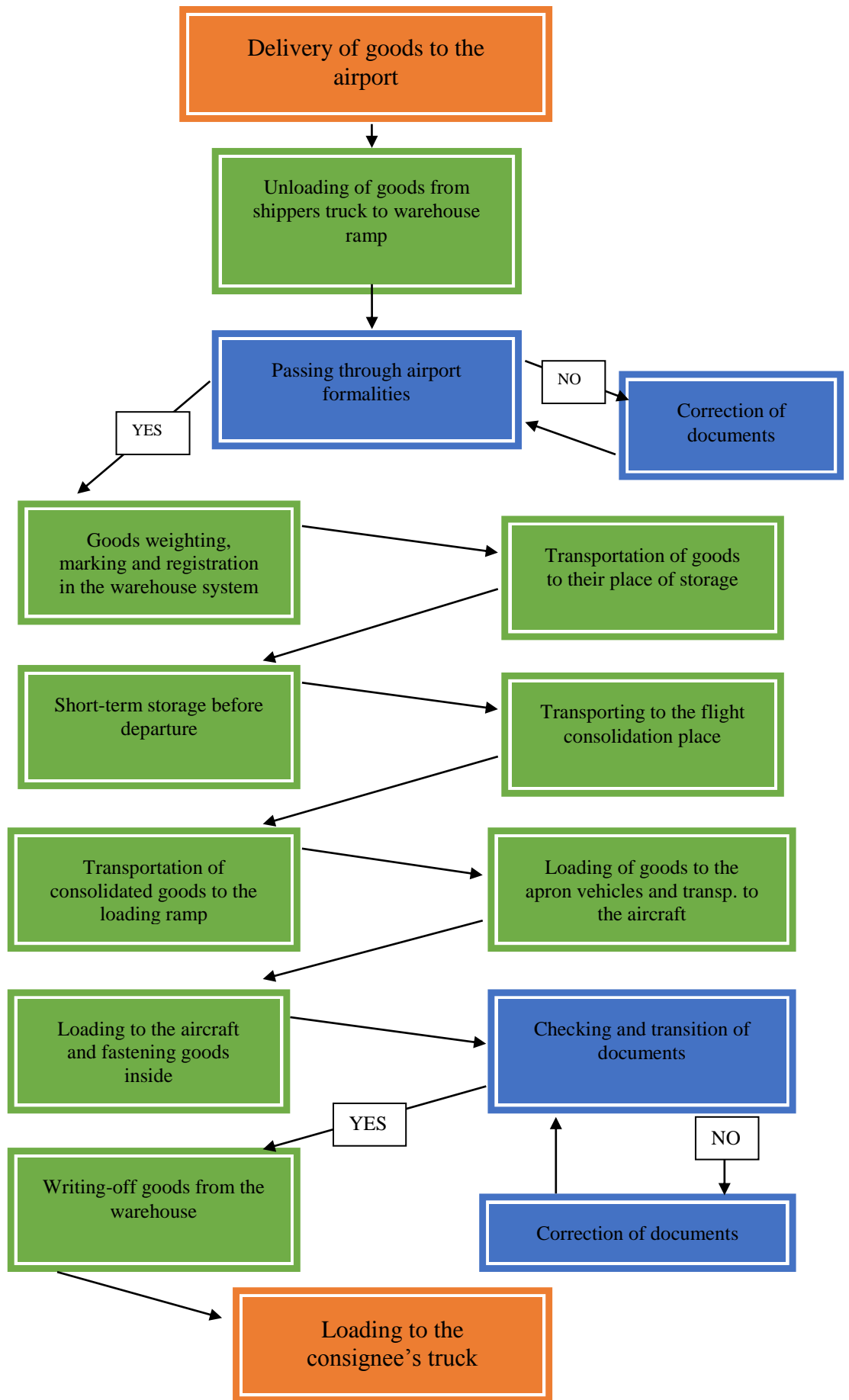

Fig. 3.15 Hierarchy of Air Cargo Terminal Personel

```
                    ┌─────────────────────────┐
                    │  Delivery of goods to   │
                    │       the airport       │
                    └─────────────────────────┘
                                │
                                ▼
                    ┌─────────────────────────┐
                    │ Unloading of goods from │
                    │ shippers truck to       │
                    │ warehouse ramp          │
                    └─────────────────────────┘
                                │
                                ▼
                    ┌─────────────────────────┐      ┌──────┐    ┌──────────────────┐
                    │  Passing through        │──────│  NO  │────│  Correction of   │
            ┌───────│  airport formalities    │      └──────┘    │  documents       │
            │       └─────────────────────────┘                 └──────────────────┘
         ┌──────┐
         │ YES  │
         └──────┘
            │
            ▼
  ┌─────────────────────────┐                      ┌──────────────────────────┐
  │  Goods weighting,       │─────────────────────▶│  Transportation of goods │
  │  marking and            │                      │  to their place of       │
  │  registration in the    │                      │  storage                 │
  │  warehouse system       │                      └──────────────────────────┘
  └─────────────────────────┘
  ┌─────────────────────────┐                      ┌──────────────────────────┐
  │  Short-term storage     │─────────────────────▶│  Transporting to the     │
  │  before departure       │                      │  flight consolidation    │
  │                         │                      │  place                   │
  └─────────────────────────┘                      └──────────────────────────┘
  ┌─────────────────────────┐                      ┌──────────────────────────┐
  │  Transportation of      │─────────────────────▶│  Loading of goods to the │
  │  consolidated goods to  │                      │  apron vehicles and      │
  │  the loading ramp       │                      │  transp. to the aircraft │
  └─────────────────────────┘                      └──────────────────────────┘
  ┌─────────────────────────┐                      ┌──────────────────────────┐
  │  Loading to the         │─────────────────────▶│  Checking and transition │
  │  aircraft and fastening │                      │  of documents            │
  │  goods inside           │         ┌──────┐     └──────────────────────────┘
  └─────────────────────────┘         │ YES  │          ▲            │
            │                         └──────┘          │         ┌──────┐
            ▼                                           │         │  NO  │
  ┌─────────────────────────┐                           │         └──────┘
  │  Writing-off goods      │                  ┌──────────────────────────┐
  │  from the warehouse     │                  │  Correction of documents │
  └─────────────────────────┘                  └──────────────────────────┘
            │
            ▼
  ┌─────────────────────────┐
  │  Loading to the         │
  │  consignee's truck      │
  └─────────────────────────┘
```

Fig. 3.16 Departure bulk cargo handling on domestic warehouse
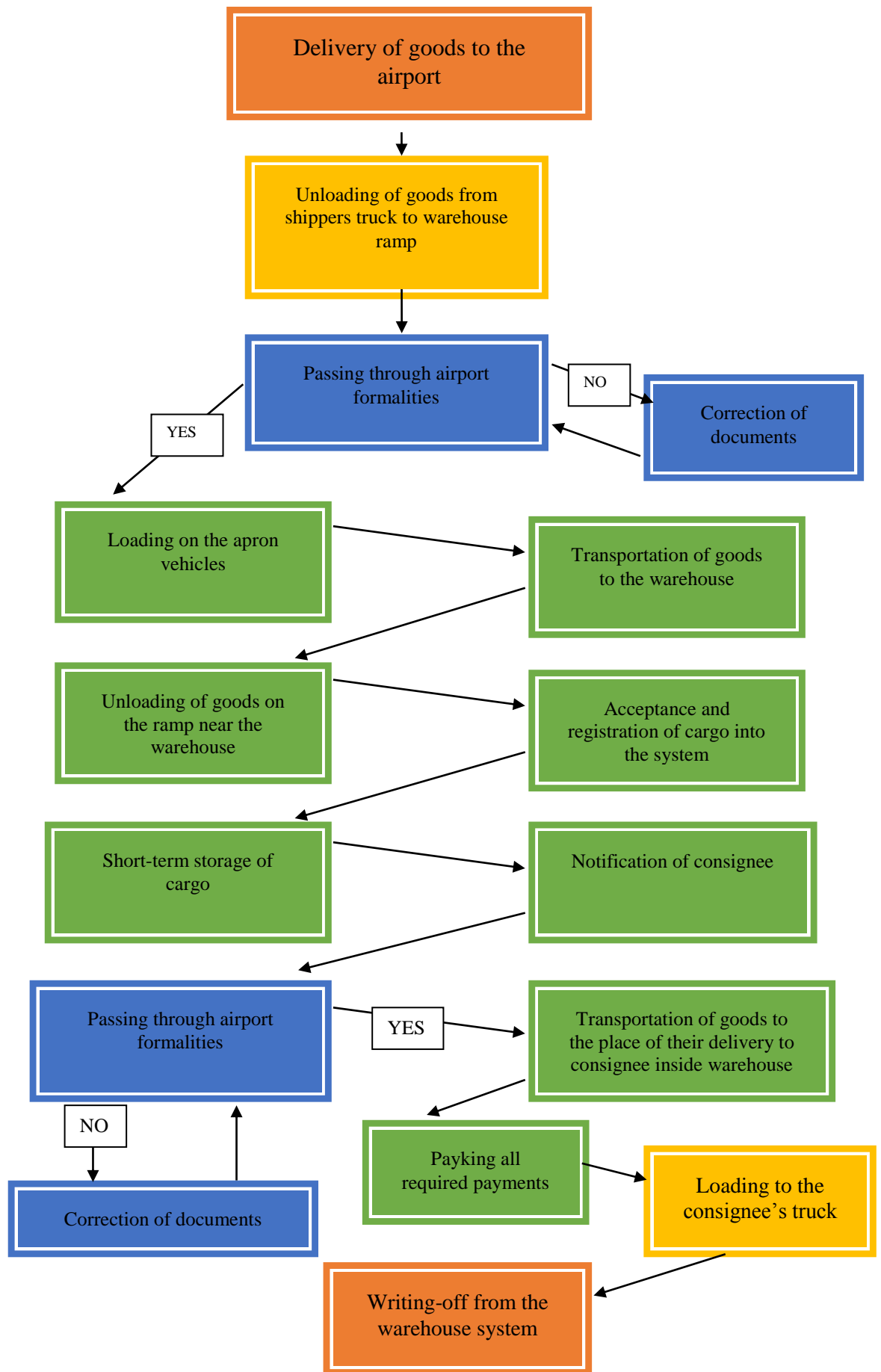
100

Fig. 3.17 Technological process of arriving bulk cargo handling in the domestic warehouse
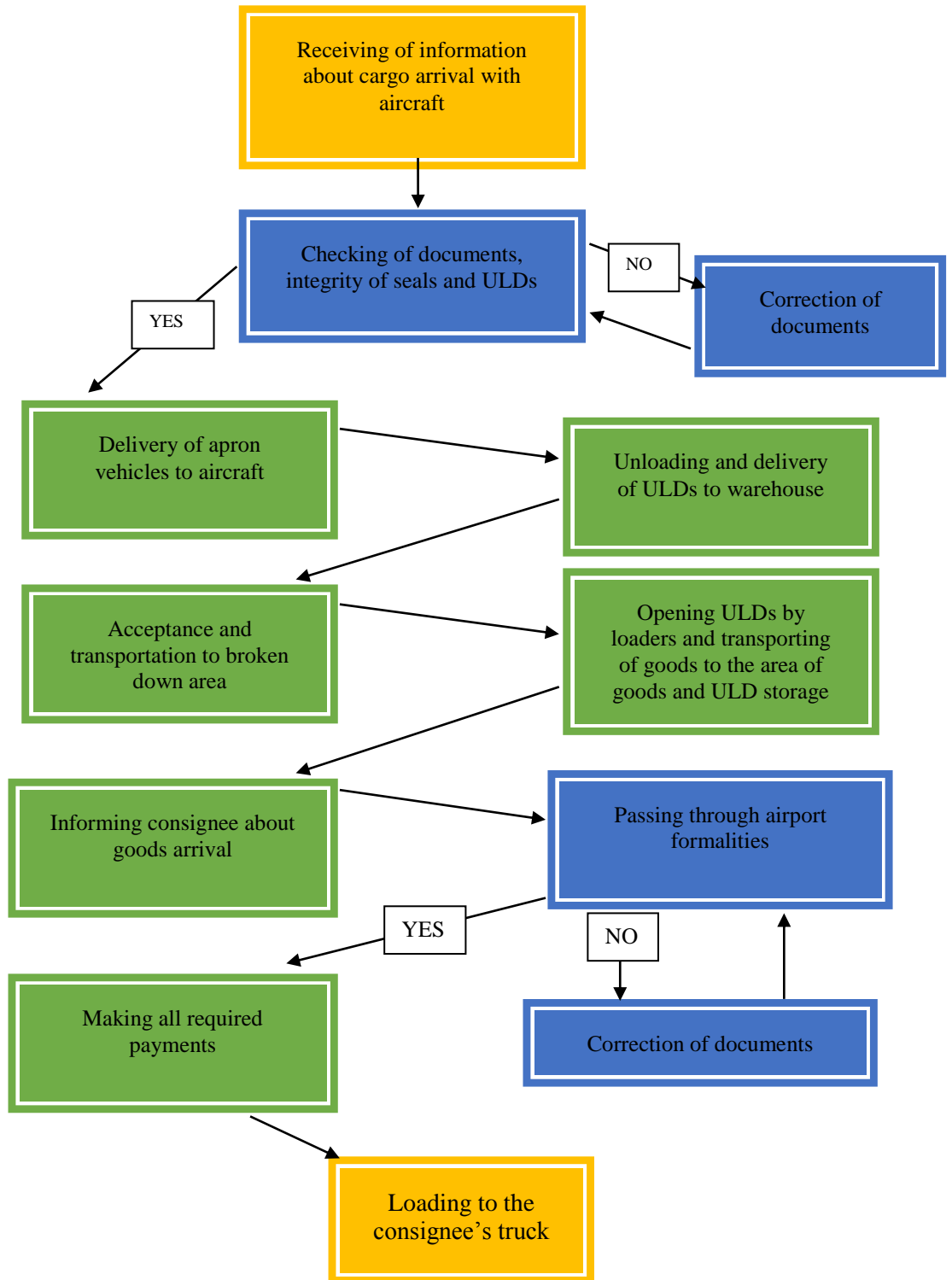
Fig. 3.18 Technological process of export goods handling in ULD in the international warehouse
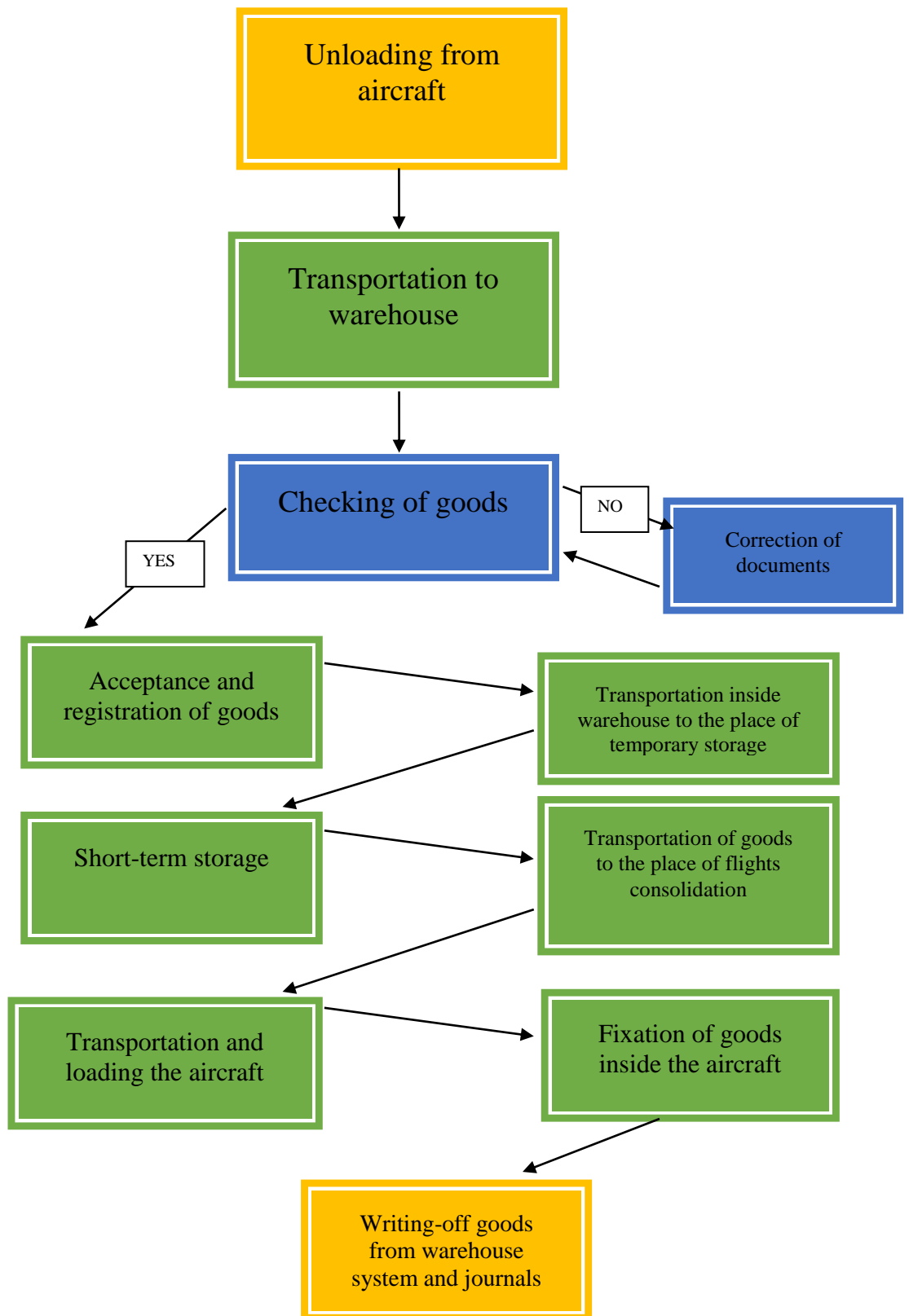
Fig. 3.19 Technological process of transit or transferred goods handling in international warehouse
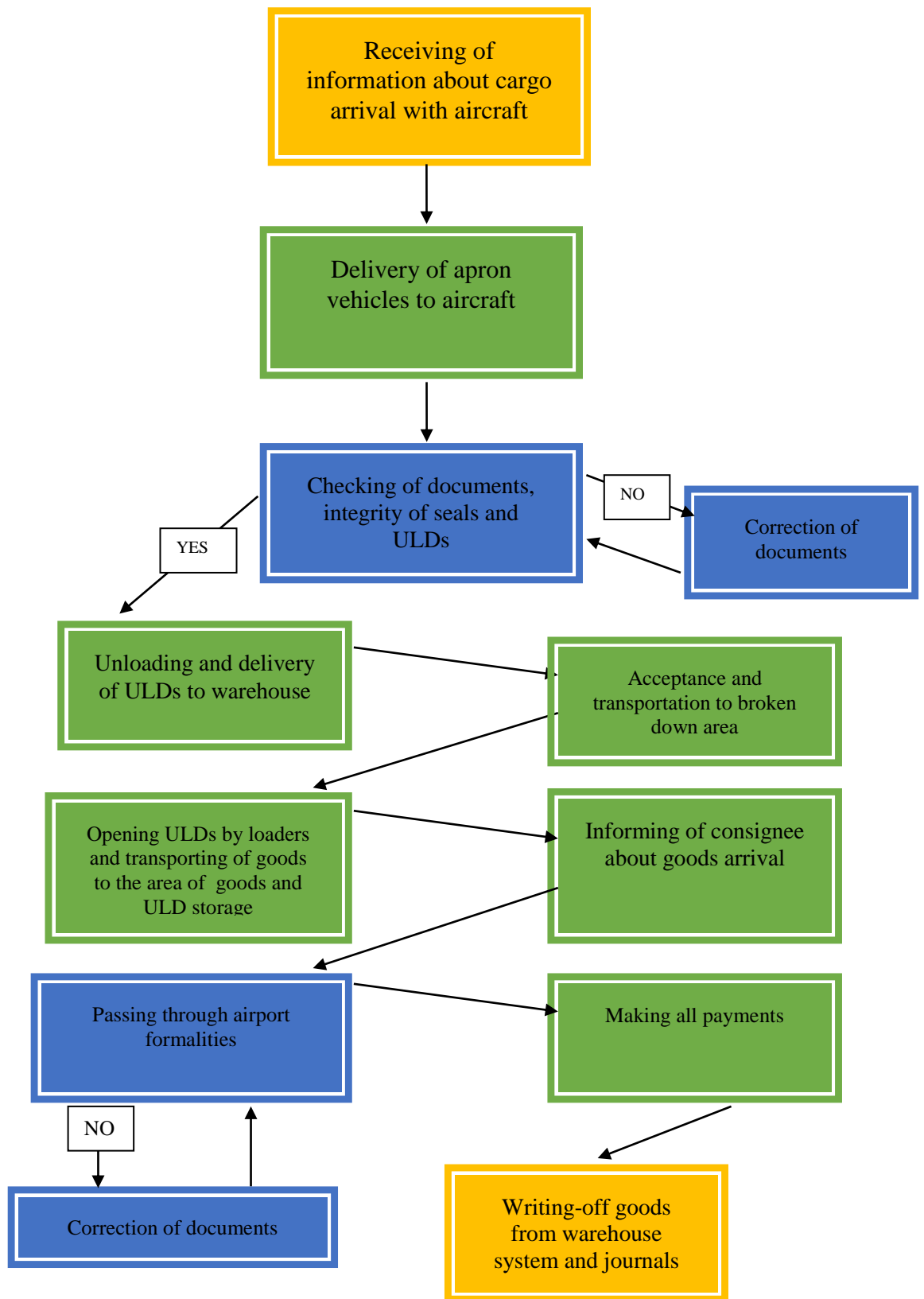
Fig. 3.20 Technological process of import goods handling in ULD in international warehouse

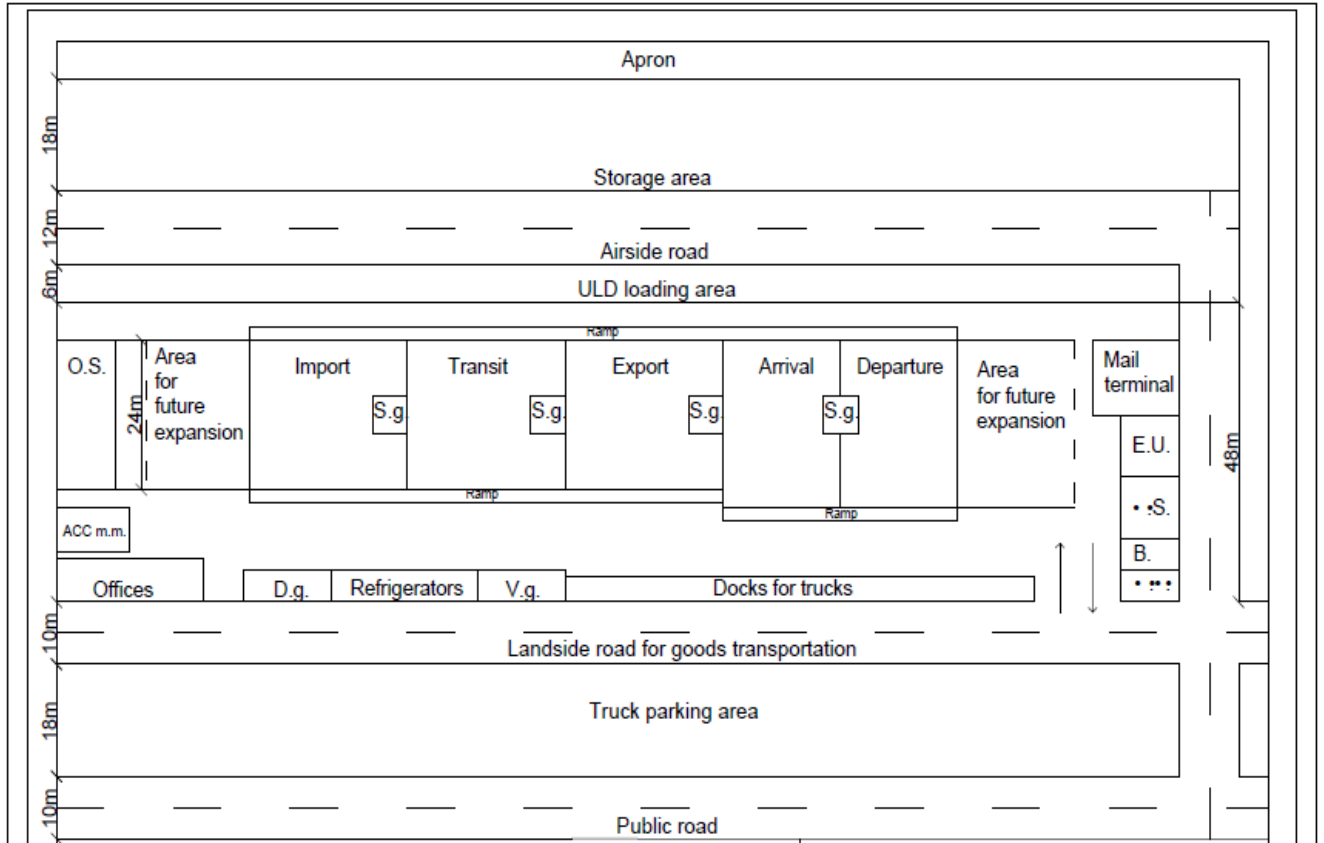# 3.5. PLANNING DECISIONS OF AIR CARGO TERMINAL SPECIFICATION IN BORYSPIL AIRPORT

International Warehouse



Fig. 3.24 The Scheme of International Warehouse in Scale 1:10 m

Domestic Warehouse

Table 3.2

Number	Designation	Meaning
1	**1**	Arrival cargo storage area
2	**2**	Departure cargo storage area
3	**3**	Freezers
4	**4**	Loading/unloading area
5	◯	Component table
6	**6**	Racks for bulk cargo
7	**7**	Ramp
8	△	Electric forklift loader
9	▭	Diesel tractor with 2 trolleys
10	▱	Vehicle with lifting body
11	**11**	Stack
12	▫	Usual technical good
13	**13**	Transit cargo storage area
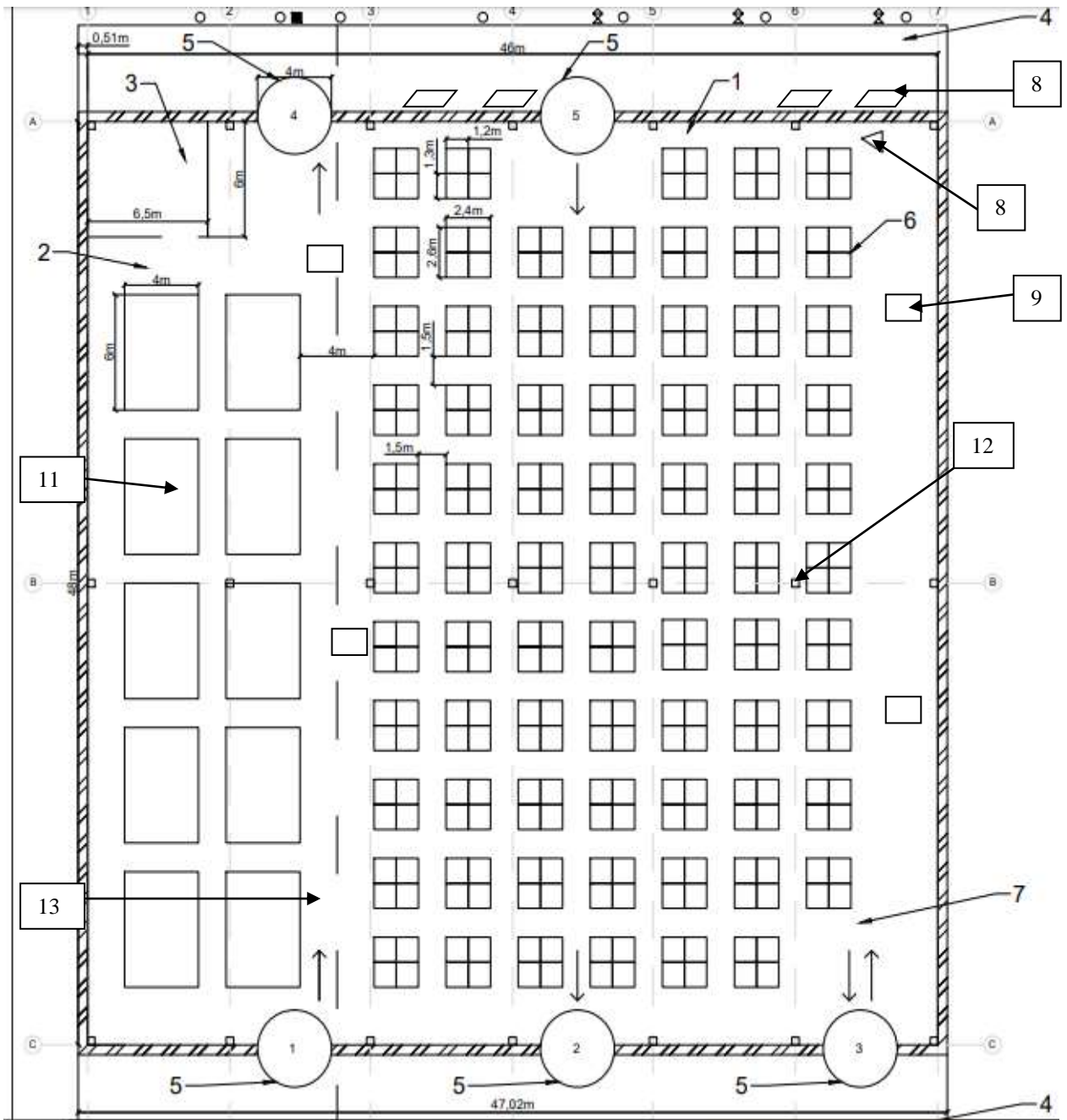
Fig. 3.24 The Scheme of Domestic Warehouse in Scale 1:2 m

SUMMARY

Air cargo plays a crucial role in today's world. Whether it's through express shipments providing expedited service, cargo carried in the holds of passenger aircraft linking together businesses across the globe, freighters delivering cargo on high volume trade lanes, or chartered flights providing needed supplies on special service schedules, the air cargo industry serves as a key engine of economic growth and development. It supports trade and investment, promotes connectivity, and improves efficiency and competitiveness.

There are some problems in today's Boryspil airport that have to be managed and solved. The problems are the following:

1. Today's airport infrastructure is limited to simultaneous storage of 800 tons and unloading of 200 tons per day; excess volume is forced to pile up outside the warehouse (outdoor);

2. Weak links in airport operations are the low quality of cheap machinery and equipment operating at airports, and low wages for loaders;

3. In the short term (2020), plan to approve new cargo and mail handling technologies in existing infrastructure:

• Rebuilding some storage facilities (to increase the quantity and improve the quality of handling special goods such as valuable goods and animals);

• Introduced a temporary platform for transferring goods from the platform to a warehouse outside the warehouse (which has been ongoing since the end of 2017);

• There are also plans to increase salaries for warehouse staff and purchase additional equipment.

In this thesis we have made Master Plan of Air Cargo Terminal and decision for planning of cargo warehouses construction (DAL and IAL) on the basis of calculations. The original (according to circumstances) technological process of cargo handling was invented for ACT for all cargo flows. Schemes-algorithms of technological process operations carriage out were also designed. Following calculations were done:

- technological parameters of cargo warehouses (area, capacity, amount of goods turnover, etc.);
- number of stacks and racks;
- length of loading/unloading works front and optimal number of goods acceptance points;
- number of mechanization means (electric loaders) inside the warehouse for inside- warehouse goods transportation and consolidation;
- number of apron mechanization means (vehicles with lifting body).

As e-commerce continues to drive air cargo volumes to the highest level seen in years, a growing middle class of consumers is benefiting from automated rapid fulfillment and quick delivery. Most of these shipments, however, consist of small packages delivered to the consumer's door by postal authorities that are struggling to maintain workable margins. The overshadowing concern of both postal services and integrators is that their primary customers could one day become their fiercest competitors.

Automation also provides forwarders with benefits – maybe not as much in small-package consumer delivery, but in serving the large cargo delivery needs of e-commerce-related companies.

The primary question for forwarders and freight transportation providers is whether technology is a support tool or an end unto itself. While those forwarders who ignore the benefits of automation in the shipping process may do so at their peril, no electronic panacea exists, and even the most advanced technological tool has its limitations. Just think of the time when you needed product or service assistance only to get stuck in the frustrating, endless loop of an automated phone attendant that failed to provide the customer service as envisioned. Is that our vision for the future of airfreight?

The strength of forwarding has always been its interaction with shippers while it enables technology to perform rudimentary tasks and deliver data as requested for analytics and shipment status information. Digitalization itself must not be

feared, but solely relying on automation as the primary customer service interface should be frightening to forwarders.

Many important factors explain the need to develop new production plans for cargo aviation, such as high oil prices.

The main process for improving the operation of airport cargo terminals is the introduction of international standards for electronic registration of air cargo and support for the international standard-electronic freight. It is developed and recommended by the International Air Transport Association (IATA). The point of departure on the cargo route for electronic exchange of air cargo documents between agency representatives.

The use of electronic air cargo standards is a qualitative breakthrough in air cargo organizations and is considered an international standard for international cargo clearance, which is guided by leading international industry players.

In this article, we draw conclusions about the possibility of introducing the IATA "e-freight" standard at Borispol Airport, as this does not require a large investment, and therefore proposes a document processing technology for importing and exporting goods in the e-freight environment implementation.

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