

# Ecosystem Approach to the Formation of Goods Express Delivery Supply Chains in Aviation Logistics

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The article shows that in the context of accelerating the processes of economic integration in aviation logistics at the micro, meso and macro levels, complicating the forms of business organization, the emergence of new forms of cooperation between companies and new ways of jointly creating added value, many organizational boundaries in the economy are becoming more blurred and dynamic. The use of the concept of "ecosystem" in research is growing. An attempt is made to consider the possibility of using the "ecosystem" design for economic analysis at the aggregated level and to highlight the elements of the aviation logistics ecosystem on which the attention of researchers will be focused. From the authors' point of view, the aviation logistics ecosystem is a combination of aviation, logistics, transport and postal organizations, which provides goods express delivery supply chains with the system of interconnected technologies. In the framework of the article analysis of air cargo industry framework, synchronization and digitization of service operations in air cargo service supply chain, express delivery supply chains were represented. The authors proposed a mathematical model that allows logisticians to optimize the supply chain of special categories of goods, which is one of the priority tasks of the aviation logistics ecosystem.

**Keywords:** Ecosystem, goods express delivery, supply chain, aviation logistics.

## 1. INTRODUCTION: AIR CARGO INDUSTRY FRAMEWORK

Undoubtedly, air transport plays an extremely important role in servicing global supply chains, as it offers highly integrated, comprehensive and fast delivery with safe, reliable, convenient and highly efficient services. And although it carries only 1% of the total cargo, the value of these goods reaches, according to various estimates, 35-40% of world trades, as these are goods with a short life cycle, for the sale of which the key factor is time [1]. Worldwide air freight traffic from 2004 to 2021 is represented in Figure 1.

As it can be seen from the figure, in recent years the world volume of air freight has increased rapidly and reached 61.3 million tons. The main drivers of growth, industry experts believe, is the global growth of e-commerce, which increased demand for accelerated delivery, as well as falling fuel costs for airlines, which began in 2016. The biggest traffic is between East Asia and the United States.

According to the International Air Transport Organization (IATA), the demand for air transportation decreased slightly in 2019. Demand is also projected to decline in 2020 due to the global economic crisis and the corona virus COVID 19 pandemic. Many countries have closed the airspace for commercial flights or significantly

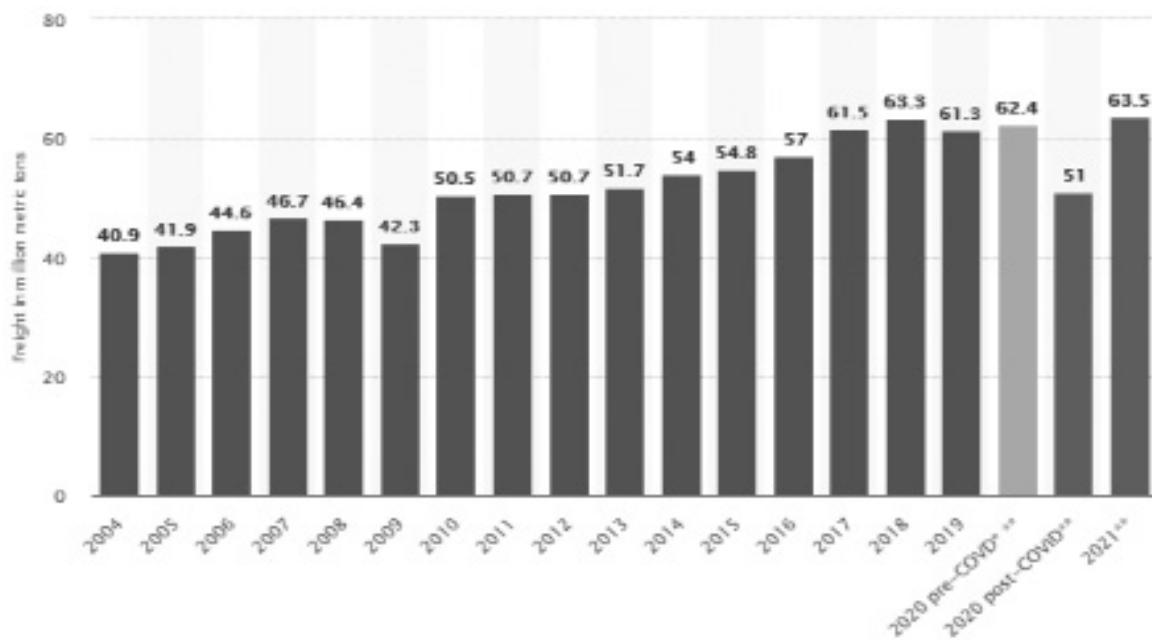


Fig. 1. Worldwide air freight traffic from 2004 to 2021(in million metric tons)

Source: Statista IATA 2020. Worldwide air freight traffic from 2004 to 2021 <https://www.statista.com/statistics/564668/worldwide-air-cargo-traffic>

reduced air travel. In this context, the European Commission considers that, in general, flight restrictions within the EU which prohibit air cargo flights in the absolute or which render the operation of such flights de facto impossible, for example as a result of unjustified restrictions on aircrew servicing air cargo flights, would be disproportionate. Third countries should also refrain from unnecessary restrictions on air cargo operations, in the common interest of supply chain continuity for essential goods, including highly specialized and critical products such as medical supplies [2].

At the same time, it is clear that the volume of air traffic will be restored within a year or two. Therefore, it is better to pay attention to the qualitative changes taking place in this market. In particular, the analysis of trends in the market of logistics services and global supply chains shows the growing competition between modes of transport, the main feature of which is not the volume of traffic, but the services provided and total added value for end users, an integral part of which is a quick response. However, it should be noted that in recent years the situation has been changed and now there is increasing talk about the need for interaction between modes of transport, which has led to the active implementation of the concepts of integration, co-modality and inter-modality. Airports are important multimodal interchange and central hubs of global supply networks [3 -4]. In this context, the role of 3PL providers is growing as they pay more attention to integrated services at lower cost. Studies by various scientists, in particular [4, 5], confirm the thesis of the growing role of logistics providers and logistics technologies in the aviation industry. In particular, it is noted that modern air transportation technologies are focused on reducing transit delivery time, accelerating capital turnover, ensuring end-to-end security in supply chains, which promotes the integration of goods, as well as financial, information and service flows.

The generalization of the different researchers' opinions, in particular, [8, 9, 10], allows to determine the following advantages of using air transport in global chains of freight traffic:

- expanding access to major markets and ensuring the internationalization of production of spare parts, components and finished products;

- increasing the productivity and efficiency of supply chains by timeliness and shortening the delivery time, which allows to significantly reduce inventories;
- being able to move goods quickly and reliably across borders, reducing the risk of losing goods. During air transportation the probability of damage to the cargo is minimized. Increased reliability is also provided by a system of continuous monitoring, which allows us to check the location and condition of the cargo, regardless of its current location;
- stimulating innovation, as air transport promotes effective cooperation of companies from different countries and uses the latest information and communication technologies;
- using the economies of scale in a better way, through efficient airline networks and consolidation of global and regional freight flows;
- providing better mobility and efficiency of contacts among sellers, buyers and consumers, which contributes to the growth of the level of logistics service.

However, in the field of freight transport involving air transport, there are many significant problems that create barriers to its effective use:

- The complexity and high duration of customs procedures in the registration of export-import trade flows related to the specifics of goods and cargo. It considers various factors, such as weight, dimensions and specifications of the cargo, customs relations between the buyer country and the seller country, and so on.
- The presence of various factors influencing the designing of logistics schemes for the movement of goods, the correct calculation of the delivery route, cost optimization and prevention of possible risks.
- High cost of air transportation, due to the high costs of air carriers for the maintenance and operation of aircrafts, as well as high airport fees for maintenance and support. The calculation of the cost of services in the carriage of goods has an interesting feature. On the one hand, more cargo on the board - more profit. On the other hand, the aircraft has a capacity limit, so the cost of air transportation is calculated as the ratio of weight to a certain volume [11]. It consists of several components: the cost of transportation (air freight); cost of surcharges (fuel, airport, security); the cost of cargo handling at airports (loading, unloading, paperwork). It should also be noted that deregulation of air traffic has increased freight rates, but has given shippers a greater choice among carriers in terms of fares, consequential losses and overcharged charges [12].
- The structure of the airline network, as air transport is strictly linked with the airport system. Since air transportation services are provided by airlines, for optimal operation these services need to be corrected and adjusted in accordance with the logistics requirements, such as to get into the popular "air flows". Freight airlines continuously monitor the current situation in major consumer markets, because it directly affects the fluctuations of freight flows - sources of income in the business of freight carriers. "Joining" regular freight flows between major consumer markets is one of the main prerequisites for the stable operation of the airline [13].

It is well known that the air freight market is directly affected by macroeconomic factors, in particular, the volume of gross production of goods and services, trade and international trade, income levels and price indices for services [14]. The main indicator of economic development is the gross domestic product. The impact of air transport development on the economy as a whole has been described by international scientists as a catalytic economic effect, which indicates a positive correlation between the development of air transportation and the level of economic activity for the long perspective.

In general, the air freight market is a global business, with more than 50% of international traffic. This means that the aviation business, like trade in general, depends on the economic activity not only of individual countries but also of trading partners. It can be argued that the demand for air freight has a greater connection with the volume of international trade than with the economic activity of countries and the world economy as a whole.

In this context, it is appropriate to draw attention to the IATA report "Value of Air Cargo: Air Transport and Global Value Chains", which proves that almost half of world trade occurs as part of global value chain [15]. The study was the first to quantify the relationship between air traffic volumes and participation in world trade and proposed two special measures - the Air Trade Facilitation Index (ATFI) and the e-Freight Friendliness Index (EFFI), which are used as a complement to existing the Air Connectivity Index (ACI). The greatest demand for aviation services is in high value-added industries (automotive, electronics, pharmacy, fashion, food, etc.), for which the time factor is critical in terms of meeting consumer needs or maintaining consumer quality (e.g., perishable goods). ACI was developed by Arvis and Shepherd [16] as the final indicator of the country's position in the global air transport network. It is calculated on the basis of data on bilateral scheduled air services, and takes values from 0 to 100. Scientists have shown that countries with a higher ACI score have stronger air connections to a wider range of destinations than countries with a lower ACI score, and, accordingly, have greater contribution to the formation of global added value. The disadvantage of this indicator is that it does not take into account non-scheduled flights and cargo flights operated by express operators.

ATFI is very important in terms of simplifying international trade procedures, in particular customs, for fast, reliable and competitive movement of goods across the borders. This indicator is a response to the implementation of the recommendations of the 9th WTO Ministerial Conference in 2013 and the adoption of the Multilateral Agreement on Trade Facilitation, aimed at implementing effective mechanisms to accelerate customs clearance of goods, reduce corruption and bureaucracy, increase trade and significantly reduce movement of flows. To calculate the ATFI, data from various sources are used, which are summarized according to the weighted average methodology as follows:

- Global Express Association's Customs Capability Database (25%).
- OECD's Trade Facilitation Indicators (25%).
- Signature of the 1999 Montreal Convention (30%), or equivalent domestic legislation.
- Signature of the Revised Kyoto Convention (10%).

It has been shown that the countries with the best values of this index trade more in intermediate resources, which is a major part of participation in global value chains [17].

EFFI reflects the ability to perform operations related to air transportation in electronic form. Electronic freight processing has clear time and cost savings for exporters and importers and is spreading around the world. The aim of EFFI is to capture the current state of the capacities as global value chains depend on the rapid and reliable movement of goods across borders, and the ability to use electronic processing to facilitate transportation can be a crucial determinant of efficiency. Electronic documentation and processing can lead to fewer border delays, reduced transaction costs, and increased security and reliability - all that can be beneficial to involved firms involved. ATFI reflects some aspects of the role of information technology that can contribute trade facilitation. The index is based on new data provided by IATA. One part concerns the use of an electronic invoice (eAWB). This data is compiled by country of origin and destination to provide an indicator of EAWB usage for total AWB transactions for a given period. The second part of the IATA dataset is information about eFreight transactions, namely, the total number of AWBs. This second indicator covers a wider range of information than just eAWB as it includes the ability to run the entire transaction electronically.

Thus, the two new indicators allow us to characterize the air transport environment in terms of participation in the creation of global value chains. The first captures efficiency at the country level in relation to the specific amounts of trade facilitation that are most important for air cargo. The second focuses on the problem of eFreight and covers the country's capabilities in this area. Quantitative analysis shows that both indicators are strongly related to increased integration in foreign trade and the importance of trade in intermediate products.

These indicators will undoubtedly be useful for comparative analysis of countries, as well as for analytics. In the table 1 Top Ten Air Trade Facilitation Index Scores are introduced.

Table 1. Top ten Air Trade Facilitation Index scores globally

Top Ten Air Trade Facilitation Index Scores Globally			Top Ten eFreight Friendliness Index scores Globally		
Rank	Country	ATFI Score	Rank	Country	EFFI Score
1	Austria	98.21%	1	United Arab Emirates	47.37%
2	Slovenia	97.09%	2	Denmark	41.60%
3	Republic of Korea	97.07%	3	Hong Kong	41.59%
4	Italy	96.70%	4	Singapore	40.18%
5	Sweden	96.49%	5	Sweden	39.77%
6	Netherlands	95.38%	6	Korea, Republic of	39.31%
7	Finland	94.58%	7	Canada	38.70%
8	Japan	94.15%	8	Netherlands	38.61%
9	Canada	94.09%	9	South Africa	37.71%
10	Denmark	93.96%	10	United States	37.70%

Source: Value of Air Cargo: Air Transport and Global Value Chains. Commissioned by IATA. Ben Shepherd, Principal Anirudh Shingal, Senior Consultant Anasuya Raj, Consultant December 6th, 2016 Commissioned by IATA Final Report <https://www.iata.org/contentassets/307646ccaf10488f9ee240c87d8f72dd/value-of-air-cargo-2016-report.pdf>

The data represented in the table 1 show that the leading countries consider air transport as an important link of the global value chains. Developing countries need to attract significant investment in infrastructure development and simplify international trade procedures. Development of international relations, promotion of aviation trade and e-Freight friendliness should be key policy priorities for governments around the world. Specifically, an increase of one percentage point in the ATFI is associated with an increase in trade by 2.30%, while an increase of one percentage point in the EFFI is associated with an increase in trade by 2.46%.

According to some experts, due to the globalization of trade and economic activity, the growth rate of air freight will increase faster than the passenger one [18]. They also emphasize that the physical movement of goods has become an extremely complex operation, involving the use of new technologies for transportation, storage and tracking of goods [19, 20]. This process involves a variety of players, the general structure of which and the relationships among them are presented in Figure 2.

Deregulation of air transportation has increased freight rates, but has given shippers more choice among carriers in terms of fares, consequential damages and overcharges. Integrated operators now offer multimodal services that take advantage of the distance, cost and time of different modes of transport. On the European and Asian markets, integrated carriers have recently increased the scale of their international operations. Indeed, within Europe, integrated carriers are now estimated to perform most of the overall intra-European RTK. In Europe, the competition of terrestrial modes is caused by the relatively low long-term growth rate of air traffic [21].

The ever-increasing need for various types of air transportation has led to the creation of a comprehensive air transport system of the new generation, which has sufficient flexibility and cost-effectiveness and provides maximum mobility in the airspace. This ecosystem includes airports, air traffic organizations that meet the demand for air cargo, resources, as well as participants in various global and regional chains of goods traffic (Figure 2.).

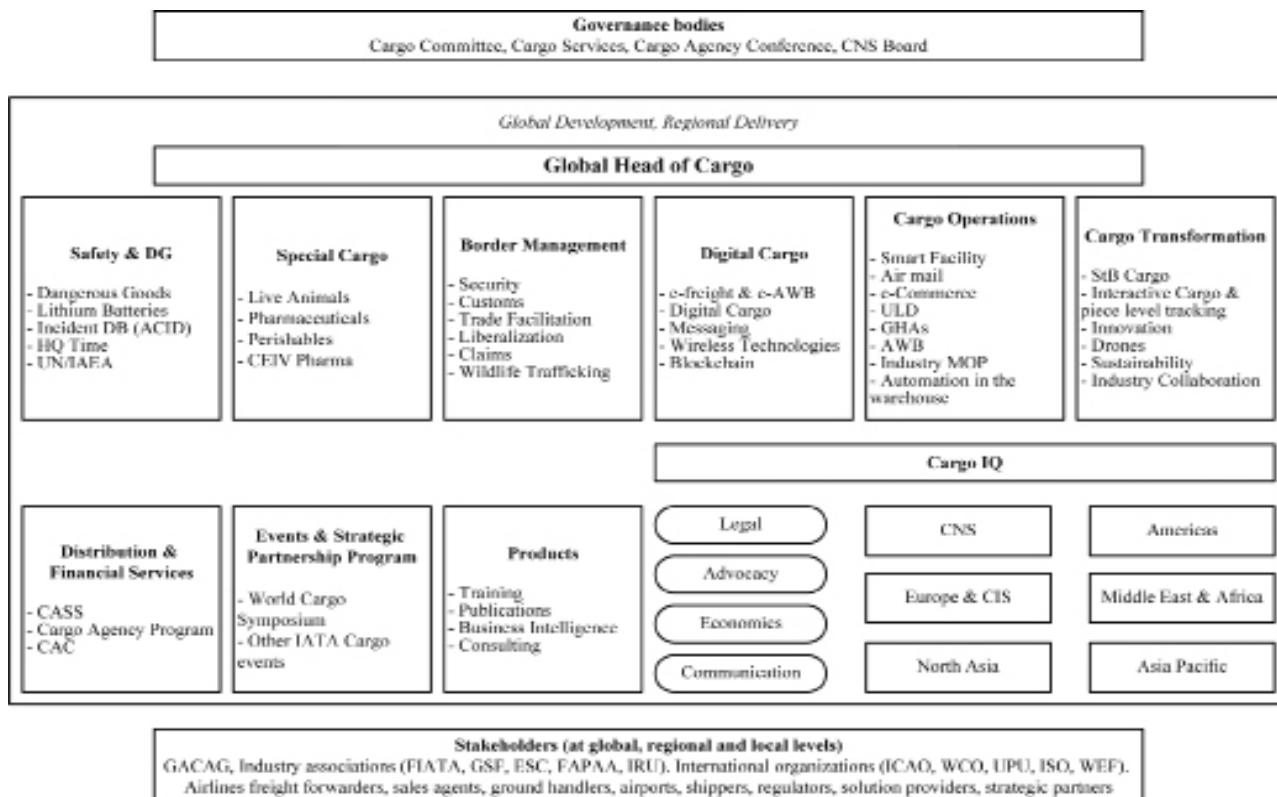


Fig. 2. The Structure of the Global Air Freight Ecosystem

In the presented ecosystem, ICAO plays an important role in regulating the freight market, which has identified the following priorities for market development:

- air cargo and mail security and facilitation,
- maintaining or improving all aspects of air cargo safety,
- evolving from paper-based to electronic solutions,
- minimizing the environmental footprint of air cargo,
- liberalizing market access for air cargo services.

According to the decisions of the 6th World Air Transport Conference and the 39th Assembly, ICAO has taken a leading role in further liberalizing air freight services and stimulating the development of global supply chains involving air transport. This organization has developed the document "ICAO-WCO Moving Air Cargo Globally", which should promote a better understanding of the supply chains of air cargo and mail, the introduction of effective standards for business continuity of air transport, which should contribute to sustainable socio-economic development of the world economy [22].

IATA, as the International Air Traffic Association, seeks to engage all stakeholders - airlines, freight forwarders, airports, governments and land carriers - through the network of offices so as to integrate and make extensive use of digital technologies to optimize global supply chains. To this end, the online booking platform *Cargo.one* has been created, which will have handled more than 10% of all airline bookings in Europe by the end of 2020. If in the past air transport companies focused on internal optimization, the active use of digital technologies lets them focus on building network processes and ensuring the transparency of supply chains, which will improve the quality of customer service. Because non-transparency creates inefficiency, which does not allow to fully realize the potential of available capacity in all participants in the supply chain. IATA research shows that shippers often wait 2-3 days to get the price of air transportation. Ordering can also take several hours. It should only be done during the airline's business hours and rarely provides a guaranteed seat for a particular

flight. According to the same organization, information for a typical booking is re-typed 97 times throughout the booking process, multiplying the chances of errors and delays.

## 2. SYNCHRONIZATION AND DIGITIZATION OF SERVICE OPERATIONS IN AIR CARGO SERVICE SUPPLY CHAIN

As mentioned above, the growth of consumer demands for the quality of air transport services is due to both the growing demand for fast delivery of various products and the desire of customers to minimize delivery times, ensure maximum safety and completeness of cargo. This, in turn, requires synchronization of flows and processes in supply chains. Also note that in the scientific literature, the term "synchronization" is often replaced by the terms "supply chain integration", "coordination in supply chains", "interaction in supply chains". For example, the interaction of companies in supply chains is discovering, and synchronization means a situation in which two or more independent companies work together to deliver products, use a single delivery plan, ensure joint fulfilment of logistics operations, which allows them to increase efficiency [23]. The main focus in this sense is on ensuring the confidential exchange between companies of private information, for instance information about the demand for specific products, as well as on ensuring joint decision-making of all participants in the supply chain. The in-depth and comprehensive analysis of synchronization from the point of view of the system approach is carried out in the work, and the system of indicators for its measurement is defined [24]. Moreover, the concept of cross-docking has recently become widespread, the core of which is to ensure a synchronous execution of all logistics operations in supply chains [25].

Most researchers consider the availability of information exchange during cyclical processes as a prerequisite for achieving synchronization of customer service operations in supply chains. Modern information technologies have opened the era of competition in real time, created an opportunity to increase the efficiency and accuracy of logistics operations and functions in the supply chain. They also provide a single electronic document management system for all participants in the supply chain. Figure 3 shows a general diagram of the movement of documents accompanying the cargo in the supply chain [22].

The presented scheme reflects the process in which a freight forwarder consolidates cargo flows from different shippers into a single batch at the airport of departure, and provides brokerage services and delivery to the destination. Throughout the delivery chain, 14 basic documents are used, as they are sequentially transferred from one link to another. The origin freight forwarder prepares the internal manifest (House Cargo Manifest) and the general consignment note on behalf of the consignor, and sends the information to customs for a preliminary risk assessment.

They may also send a Prior Notification to the freight forwarder at the destination, which allows the preparation of documents for customs clearance. It also transfers the cargo to the aircraft operator at the point of departure, who after inspection accepts the cargo for transportation. After arrival of the cargo at the destination airport, an aircraft operator submits a declaration to the customs of import and receives permission from the customs to release the cargo for delivery to the destination. The sequence of documentation of the air supply chain is presented in Figure 4 [22].

In order to reduce paperwork and speed up a document flow, IATA initiated in 2004 the transition to a paperless process of documenting of air transportation through the use of electronic data and messages between participants in the supply chain (B2B) and with representatives of regulatory authorities (B2G and G2G) at checkpoints on the route of transportation. Synchronization of information flow with the physical movement of goods allows us to track the movement of goods "door to door" regardless of mode of transport and the

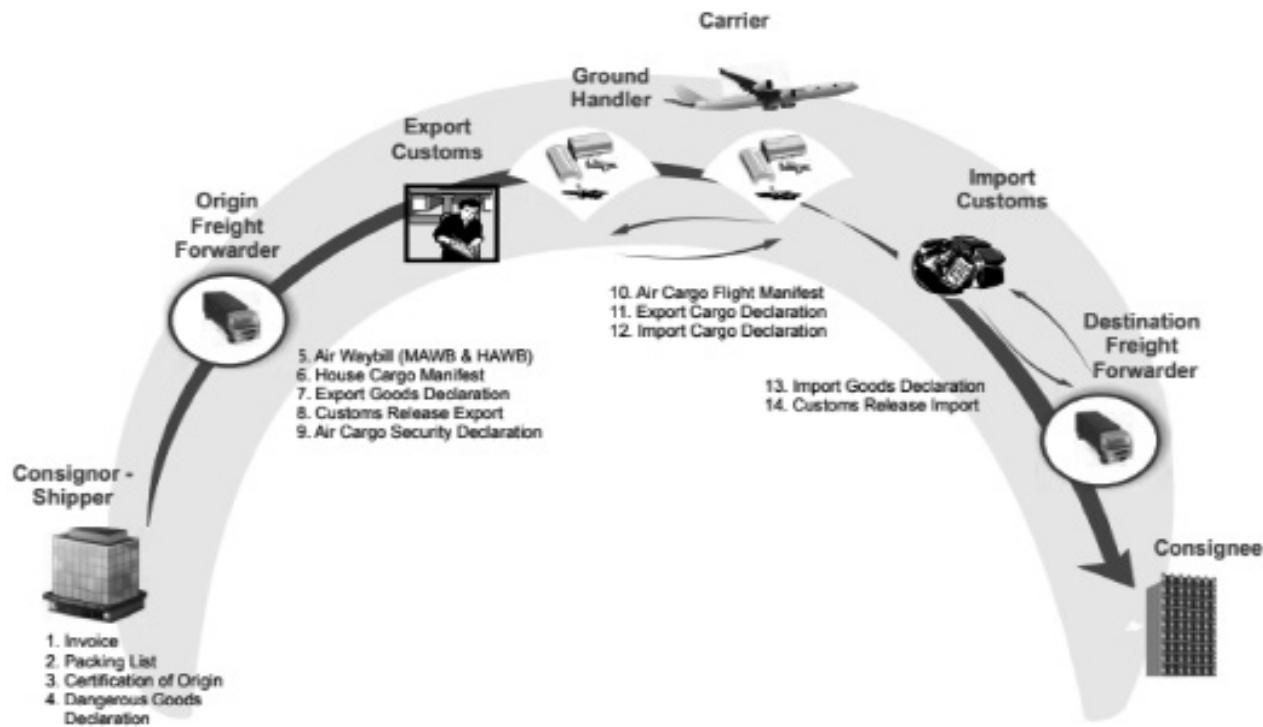


Fig. 3. General cargo: most common document flow for Customs

Source: ICAO – WCO. Moving Air Cargo Globally Air Cargo and Mail Secure Supply Chain and Facilitation. Guidelines <https://www.icao.int/Security/aircargo/Moving%20Air%20Cargo%20Globally/Forms/AllItems.aspx>

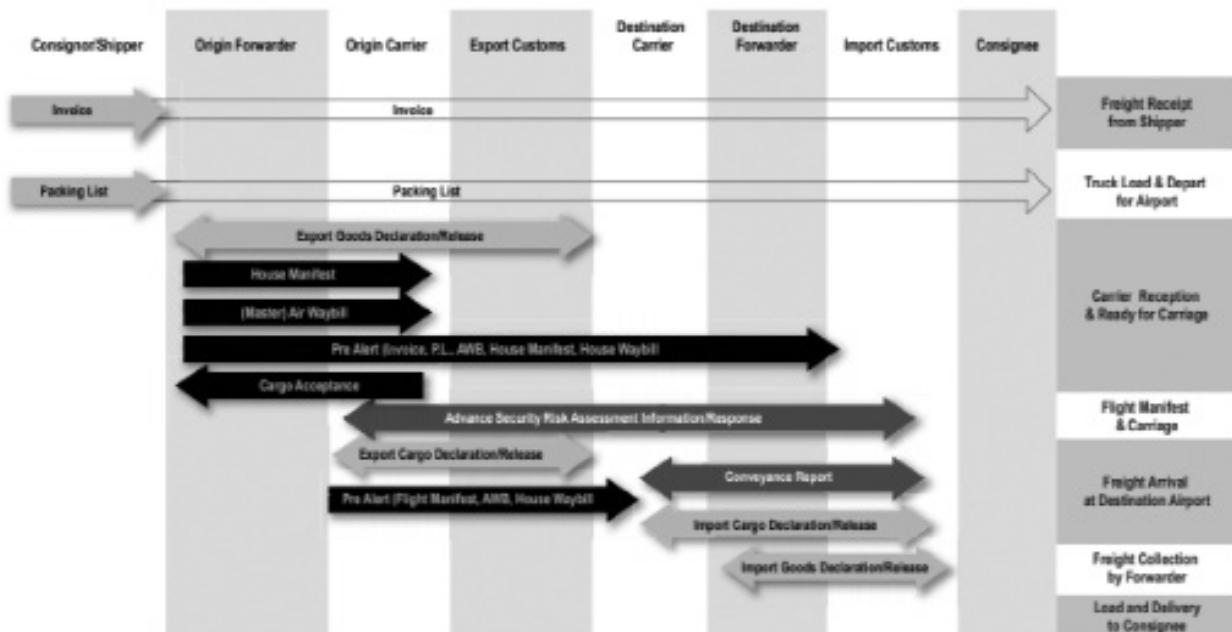


Fig. 4. Air cargo supply chain document sequence

Source: ICAO – WCO. Moving Air Cargo Globally Air Cargo and Mail Secure Supply Chain and Facilitation. Guidelines <https://www.icao.int/Security/aircargo/Moving%20Air%20Cargo%20Globally/Forms/AllItems.aspx>

number of trans-shipments. Currently, the e-Freight standard is used in more than 49 countries. It is based on the principles recommended by the United Nations Economic Commission for Europe and is used by the World Trade Organization and Customs organizations.

In 2012, the Global Air Cargo Advisory Group (GACAG) developed a roadmap for the transition to 100% e-freight, which defined the approach, structure and objectives for the program. The roadmap described the overall approach of the industry with a clear definition of the leadership role of the three main components:

- component I: interaction with regulators and governments around the world to create an e-Freight route network with fully electronic customs formalities and paperless support rules;
- component II: interaction in the logistics chain of freight, to digitize cargo documents, starting with AWB;
- component III: development of a plan for the digitization of commercial and special cargo documents, which usually accompany air cargo.

GACAG also has approved the plan to eliminate paper documentation on cargo transportation.

Step 1. Support network creation. Involvement of regulatory authorities to create a network where customs authorities are an electronic and regulatory environment that supports electronic documentation. An electronic customs environment involves the ability to develop electronic customs declarations (export and import), no requirements for presenting original documents (Invoice and packing Lists) during transit or after it. Electronic documents (Invoice / Packing List) must be accepted by customs in electronic format or as hard copies.

Step 2. Implementation of electronic workflow on the way “airport-airport”. Digitization of key transport documents (Air Waybill, House Manifest, Consignment Security Declaration (CSD), Flight Manifest). The goal is paperless acceptance and delivery of cargo from airport to airport. This stage involves the establishment of electronic interaction between freight forwarders, airlines and ground handling agents (FF-Airline-GHA), signing and implementation of agreements on the use of electronic air waybills, the possibility of exchanging electronic air waybills (FWB and FHL) between FF-Airline-GHA systems (or posting this information on the airline's web portal). Procedures are also defined between FF-Airline-GHA for acceptance of cargo at the point of origin and destination without original documents.

Step 3. Implementation of electronic workflow on the way “door to door”. Digitization of key commercial documents (Invoice / Packing List / HAWB) and Special Cargo Documents The goal is to eliminate “paper bags” from the shipper to the consignee. It is expected for the freight forwarder at the point of departure to exchange key documents with the freight forwarder at the destination, broker and shipper in electronic form (HAWB, Invoice, Packing List). In addition, electronic document archiving (e-Archiving) is becoming possible [26].

The first step towards the transition to e-Freight has already been made, that is the transition to the electronic Air Waybill (e-AWB). Statistics show that more than 70% of air waybills are currently used in an electronic form (e-AWB). Due to the introduction of e-AWB, the logistics industry has significantly increased efficiency. Eliminating necessity for paper workflow has shown its advantage in optimizing the process of handling air cargo. In addition, e-AWB allows the airline to provide some forwarders with information electronically before the actual delivery. In such a way they can book their cargo via smartphone directly at the carrier's warehouse, without having to stand in line at the reception. This process ensures the most efficient handling of freight, saving time and money.

The main platform for the implementation of electronic workflow is an airport, as an important link in the supply chain. That is why the UN Economic Commission for Europe recommends the implementation of a “single window” mechanism, and the simplification of all procedures for international trade in transport

terminals. The “single window” system at international airports provides the use of cargo handling procedure before the arrival of the aircraft for risk analysis, thereby reducing the waiting time and increasing the speed of cargo handling. “Single window” creates a platform for the exchange of information between all stakeholders, that can be united in two groups:

- stakeholders that are subjects of the cargo supply chain: airlines, freight forwarders, customs brokers, express carriers, shippers and consignees;
- stakeholders that are represent the bodies of state control over freight transportation: customs service, border service, health care, etc.

“Single electronic window” is an integrated database with full registration of all documents, which allows us to standardize and unify information flow. Different communication channels and data transmission methods can be used to transmit information between stakeholders. At the same time, models of information interaction of commercial structures with each other (business to business, B2B) and with state control bodies (business to government, B2G) are used.

Another constraint on the accelerated movement of goods in supply chains, and therefore requires synchronization, is the control of aviation safety. The ICAO regulatory framework for the protection of the entire air cargo chain has been developed step by step over time and is now fixed in the Standards and Recommended Practices (SARPS) of Annex 17 “Safety” to the Chicago Convention, supplemented by guidance material in the Aviation Security Manual (DOC 8973 - Restricted). These regulatory frameworks are constantly being revised and updated to best eliminate evolving threats. In particular, these documents introduce the concept of “secured cargo delivery chain”. This means that security controls can be carried out not only at the departure airport, but previously at the point of departure or at an intermediate point before delivery to the airport. This ensures that costs and responsibilities are shared between all stakeholders in order to reduce the burden of safety oversight by aircraft operators. To this end, the Standards provide for the Regimes of Registered Agents and Known Consignors, which are approved by the appropriate authority.

A regulated agent is a freight forwarder or any other legal entity (such as a ground handling agent) that does business with an aircraft operator and provides security controls that are recognized or required by the relevant authorities for cargo or mail. An organization that has received the status of a regulated agent has the right to take security controls on the cargo, including carrying out inspections. An aircraft operator can receive cargo already checked for safety by a regulated agent who is responsible for the safety status of freight (Figure 5) [22].

A legal entity may act as a known consignor when it send cargo or mail at its own expense, and when its procedures comply with general rules and safety standards sufficient to permit the delivery of cargo or mail on a commercial aircraft. Once the known consignor has reported the cargo safety status, it can be handed over to a regulated agent, another registered legal entity or directly to the aircraft operator, who is then responsible for its protection until the aircraft is loaded on board (Figure 6) [22].

It is essential that throughout the supply chain, including transfer points, participants in the process exchange information on the status of cargo and mail in terms of security, in order to ensure that everything that needs to be checked or re-inspected for security is properly identified and well-checked.

To ensure the transfer of such information, the organization responsible for the protection of air cargo must give the Consignment Security Declaration (CSD), which reflects the security status of cargo and mail, and contains other important information considering security. This declaration is passed to each subsequent member of the supply chain so that they can take appropriate security measures about the cargo and protect it from unauthorized access. Additional automation of processes related to air cargo transportation is provided



Fig. 5. Security controls applied by regulated agents

Source: ICAO – WCO. Moving Air Cargo Globally Air Cargo and Mail Secure Supply Chain and Facilitation. Guidelines <https://www.icao.int/Security/aircargo/Moving%20Air%20Cargo%20Globally/Forms/AllItems.aspx>

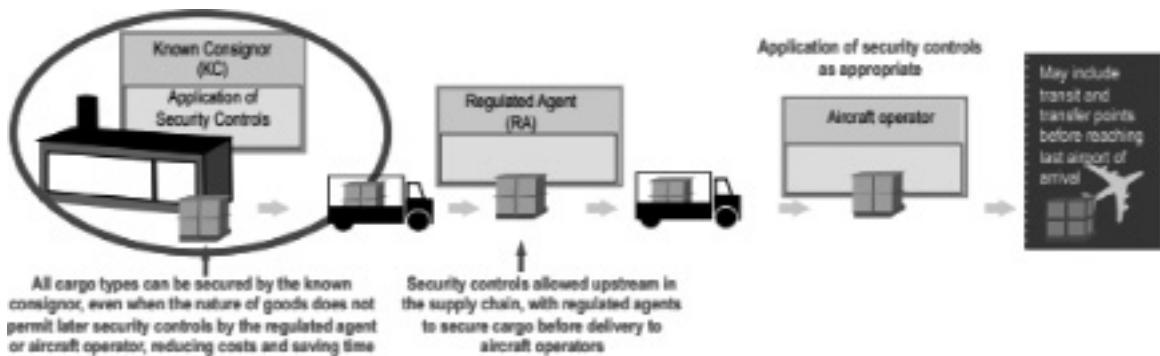


Fig. 6. Security controls applied by known consignors

Source: ICAO – WCO. Moving Air Cargo Globally Air Cargo and Mail Secure Supply Chain and Facilitation. Guidelines <https://www.icao.int/Security/aircargo/Moving%20Air%20Cargo%20Globally/Forms/AllItems.aspx>

by the use of an electronic version of the CSD (i.e. e-CSD), which allows operators to electronically exchange and store the information necessary to ensure security.

ICAO is also doing a lot of work to simplify formalities for air freight. The so-called SAFE package, adopted by the World Customs Organization, provides for integrated customs formalities. As part of the integrated control chain, the integrity of the goods accepted for carriage is ensured from the moment it leaves its place of origin until it arrives at the point of final destination. This process begins with a prior electronic message containing the standard information required of the exporter or his agent. It must arrive at customs before the goods are loaded on a vehicle, plane or ship (or in a container) for export. After that, another preliminary message may come in due time, from the operator [25].

For security reasons, the customs service usually limits its information to the requirements contained in the standard documentation of aircraft operators based on Annex II of the SAFE Framework Standards. Equally at the same time will receive a preliminary electronic message from the operator or his agent. Then, in due time, there will be an additional message from the importer. As part of an integrated chain of inter-customs control, customs services throughout the supply chain can exchange data, especially about the high-risk cargo.

In order to reduce risks, increase transparency and controllability of cargo delivery conditions, the use of blockchain technology is a promising avenue [27]. There are many publications on the possibilities and benefits of using this technology in air transport supply chains, in particular [28]. In 2017, British Airways conducted a study about the possibility of using blockchain technology jointly with Heathrow, Miami and Geneva airports. This study demonstrates the effectiveness of the use of the technology in aviation for the organization of secure information exchange [29]. Cathay Pacific Company is launching a blockchain platform for controlling container freight [30].

In 2018, SITA launched the Aviation Blockchain Sandbox platform, which encouraged collaboration between airlines to search for Distributed Ledger Technology (DLT) applications in accounting [31]. According to Lufthansa, a promising area of blockchain technology in the aviation industry is tracking the supply of aircraft components. Samsung also intends to use this technology to track its products through the aviation supply chains, which, according to their estimates, will add savings to logistics costs in the long run.

To work with the integrated blockchain platform, a system "smart contracts" was developed, which provides for the coding of the transaction only if it is approved by all its participants through the use of "signature share". In this case, to access the block, it is necessary to register all marked keys that have "signature shares" of this transaction [32]. "Smart contract" is a computer protocol designed to simplify the verification, negotiation, or execution of contracts in digital form without the involvement of third parties, such as a notary, broker, etc. In addition, a smart contract automatically ensures the fulfilment of obligations under the contract. For example, a smart contract can automatically send a payment to the supplier immediately after delivery [33, 34].

The advantages of using blockchain technologies in SCM are:

- autonomy - independence from third parties in concluding a contract and conducting negotiations;
- data validity - all transactions are encrypted with cryptographic code in the general distributed database; documents cannot be lost or edited;
- security - no possibility of hacking the database;
- data transfer rate - it is transmitted instantly when it is possible to automate the processing of electronic documents;
- reduction of the amount of transmitted information - by reducing the use of EDI (electronic data interchange) with replacing the encoded information in blocks;
- the possibility of multifaceted use of data in the supply chain / network - reduces the number of errors and allows us to synchronize changes.

Blockchain technology let us to record information about each movement of cargo in the cloud system by creating an appropriate record. This system simplifies the procedure of checking documents and detecting mistakes in them, mainly when checking markings, customs clearance, phytosanitary and veterinary control [35].

Thus, the digitization of the air transport business, the implementation of e-freight, Blockchain technologies and other innovations, will synchronize flows and processes in the air supply chains in real time, which will improve the quality of customer service.

### 3. EXPRESS DELIVERY SUPPLY CHAINS

The CEP market (Courier, Express & Parcel) is a specific segment of services that actively uses air transport for accelerated delivery of goods, especially in international traffic. CEP companies tend to increase supply chain efficiency by tackling the "last mile of their B2B and B2C customers." The general structure of the market is

presented on the Figure 7. *ResearchAndMarkets.com*'s experts believe that the volume of this market was US \$ 430bn in 2019 and forecast annual growth of 8-10%. The main driver of such growth is e-commerce.

Despite the large number of studies, the development of specific types of transportation, in particular, express delivery, and the interaction of enterprises in the process of express delivery of goods has not given enough attention. Let's clarify the basic concepts related to the CEP market:

- express shipments (ES) are letters, parcels, small packages, direct mail containers, small cargo units;
- express transportation - is the movement of ES with the participation of one or more modes of transport

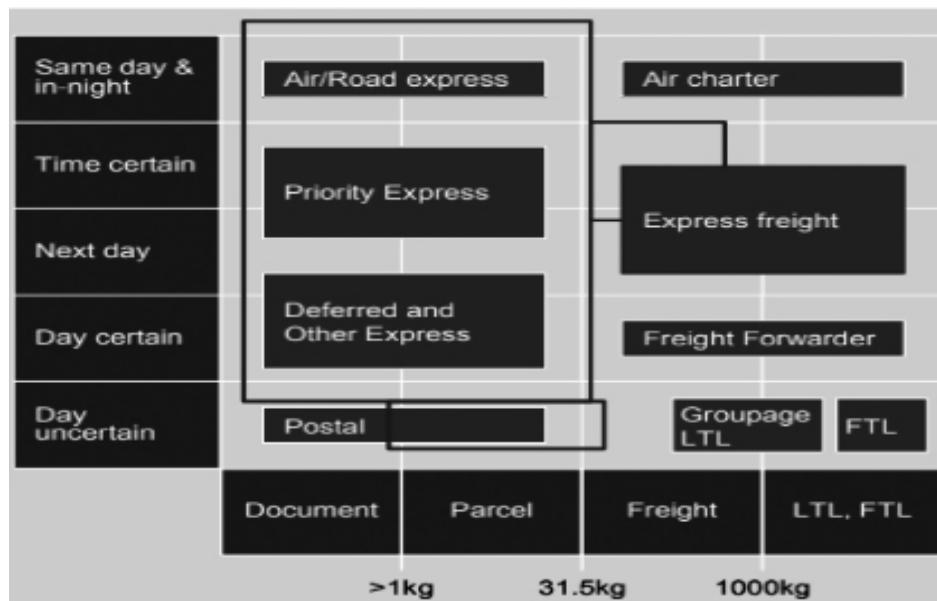


Fig. 7. Scope of Market = Courier, Express and Parcels

Source: Accenture 2015 Adding Value to Parcel Delivery Research. New delivery trends impacting post and parcel transformation. [https://www.accenture.com/t20170331T042236\\_w\\_us-en\\_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Dualpub\\_23/Accenture-Adding-Value-To-Parcel-Delivery-V2.pdf](https://www.accenture.com/t20170331T042236_w_us-en_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Dualpub_23/Accenture-Adding-Value-To-Parcel-Delivery-V2.pdf)

- for a strictly limited period (usually during the day or the next day);
- express delivery is a complex of services and works on acceptance of the goods, their sorting, transportation, address and courier delivery, as well as other related services that meet the needs of consumers in terms of delivery on a door-to-door basis.

The main features of express delivery of goods with the participation of air transport are:

- speed. Most express delivery companies offer their customers service overnight or the next day, often referring to delivery before 09.00, 12.00 or 17.00 the next business day or within 2-3 days;
- tracking and control. Having accurate information on the status of shipments in transit has allowed manufacturing firms to use modern business techniques such as "just in time" (JIT) and supply chain management, as well as reduce time to market, inventory costs and storage space savings;
- distribution system "Hub & Spoke". Under this system, the choice of a hub airport is vital, as it plays a central role in the operations of integrated express delivery companies. Hub airports are used to handle small cargo flows that cannot be sent directly from an economic point of view. The classic integrator, in order to successfully use its hub, needs a fairly wide market of origin and destination of goods. To meet customer requirements, classic integrators use night operations at hub airports to sort and distribute packages. This feature of night processing has very special consequences for the operated aircraft. Such aircraft should be quiet, and their use is very limited, sometimes up to only a few hours a day (Reinolds-Feighan,

- 2001). Demand zones, warehouses, points of collection, delivery and service centers reflect the spokes of the Hub & Spoke distribution network, which characterizes all operations of classic integrators.
- schedule. Integrated express delivery companies use a fixed schedule. Tight schedule and standardized service make integrated express services somewhat inflexible, as the service schedule is difficult to adjust to individual needs.
  - high standards of safety and preservation of ES.
  - financial guarantees - return up to 100% of the cost of transportation in violation of the stated terms and guaranteed delivery times.

The study of trends in the development of express delivery has revealed the following patterns:

- the structure of express shipments is changing by increasing the share of parcels and small loads, due to the growth of catalogue and electronic trade in consumer goods;
- the greatest demand is for mixed road and air transportation, which is due to the growing demand for door-to-door delivery;
- express delivery is carried out on a global scale, i.e. it is mainly international transportation of goods and mail in combination with courier or postal delivery at points of consumption of goods.

Taking into account these features, different players in the CEP market are established. Traditionally, these are express carriers, airlines, freight forwarders, postal and courier companies. Most of the classic freight market players are gradually transforming into logistics providers. Structural analysis shows the gradual blurring of boundaries between different players in the CEP market and the diversification of their logistics activities. This trend is confirmed by recent IATA studies on the impact of e-commerce on air freight [36]. In particular, e-commerce players can choose different options for delivery of goods purchased via the Internet. Air transport can provide speed, efficiency and reliability, which is ensured by the interaction of freight forwarders, airlines, postal operators and integrator companies. Table 2 shows there is a description of the strengths and weaknesses of these participants.

IATA concludes that IATA member airlines, together with their partners, need to prepare for the future growth of e-commerce and become modern service providers that exceed consumer expectations in online and offline formats. This means that express delivery chains must also change.

Consider specificity of the activities of integrating companies in the market of air express delivery. Their main difference from other freight market players is that they offer not only consolidated service "from airport to airport", but a range of door-to-door and "just in time" delivery services. Indeed, they are service providers responsible for combining different services (transport, forwarding, logistics, information, etc.) in different markets around the world.

Foreign scientists classify two groups of integrator companies:

- global players competing in all aspects of door-to-door services;
- niche players who specialize by the route or type of product.

The market of classic integrated express transportation is characterized by the movement of small packages with high frequency, scheduled delivery time, quality of service based on the cost of the package, door-to-door transportation around the world, individual solutions, value-added service, use of transport networks, spatial and timely availability of fast, reliable and flexible services (Baum, Hen, 2004).

The market of classic integrated express transportation is characterized by the movement of small parcels with high frequency, scheduled delivery time, quality of service based on the cost of the parcel, door-to-door

Table 2. SWOT-Analysis of Key Participants in the CEP Market and Express Delivery Chains

	<b>Traditional air cargo</b>	<b>Integrators</b>	<b>Postal operators</b>
<b>Strengths</b>	<ul style="list-style-type: none"> <li>All type of cargo</li> <li>• Security</li> <li>• Safety</li> <li>• Identification of dangerous goods</li> <li>• Airlines' network and schedule</li> <li>• Specialized supply chain partners</li> </ul>	<ul style="list-style-type: none"> <li>• Integrated supply chain solutions</li> <li>• Customs pre-clearance / speed</li> <li>• Security</li> <li>• Safety</li> <li>• Participants in trusted trader programs</li> <li>• Identification of dangerous goods</li> <li>• End-to-end tracking</li> <li>• First and last mile</li> <li>• Investments in new technologies</li> <li>• Airlines' network and schedule</li> </ul>	<ul style="list-style-type: none"> <li>• First and last mile</li> <li>• Pricing structure / chargeable principles (flat-rate convention from UPU)</li> <li>• Tracking on ground</li> <li>• Direct access to shippers and e-trailers</li> </ul>
<b>Weaknesses</b>	<ul style="list-style-type: none"> <li>• Fragmented</li> <li>• No end-to-end tracking</li> <li>• Slow adoption of digital</li> <li>• Limited investments in new technologies</li> <li>• No direct access to shippers and e-tailers</li> <li>• Undeveloped first-mile collection</li> </ul>	<ul style="list-style-type: none"> <li>• Costs</li> <li>• Reliant on traditional air cargo carriers for their enhanced network</li> </ul>	<ul style="list-style-type: none"> <li>• Fragmented</li> <li>• Security issues in airmail</li> <li>• Safety issues in airmail</li> <li>• Slow adoption of digital</li> <li>• No air/rail/sea network</li> </ul>
<b>Opportunities</b>	<ul style="list-style-type: none"> <li>• Airmail and cargo IT systems alignment</li> <li>• End-to-end optimization</li> <li>• Customs pre-clearance</li> <li>• End-to-end tracking and interactive cargo</li> <li>• Business diversification</li> <li>• Drones</li> <li>• Revised value model</li> <li>• Cooperation with other modes</li> <li>• Flexible final mile solutions</li> <li>• Inter-modality for blended supply chains</li> </ul>	<ul style="list-style-type: none"> <li>• Drones and other autonomous vehicles and robotics</li> <li>• Decrease in the taxation for online trade</li> </ul>	<ul style="list-style-type: none"> <li>• Alarm resolution concept</li> <li>• ACI &amp; e-CSD for airmail</li> <li>• Airmail and cargo IT systems alignment</li> <li>• End-to-end tracking and interactive cargo</li> <li>• Drones and other autonomous vehicles</li> </ul>
<b>Threats</b>	<ul style="list-style-type: none"> <li>• Competition from integrators and postal operators</li> <li>• E-tailers becoming their own logistics providers (Amazon)</li> <li>• Future competition from drones operators</li> <li>• Innovations in surface modes of transport</li> <li>• Too slow to adapt to necessary changes</li> <li>• Inefficient and cumbersome regulations increasing costs and/or release times</li> </ul>	<ul style="list-style-type: none"> <li>• Postal operators pricing model</li> <li>• E-tailers becoming their own logistics providers (Amazon)</li> <li>• Future competition from drones operators</li> <li>• Innovations in surface modes of transport</li> <li>• Inefficient and cumbersome regulations increasing costs and/or release times</li> </ul>	<ul style="list-style-type: none"> <li>• Competition from integrators/ express carriers</li> <li>• E-tailers becoming their own logistics providers (Amazon)</li> <li>• Future competition from drones operators</li> <li>• Lithium batteries in airmail</li> <li>• Too slow to adapt to necessary changes</li> <li>• Lack of control of what is being transported</li> <li>• Inefficient and cumbersome regulations</li> </ul>

Source: IATA. White paper. Air cargo and e-commerce enabling global trade March 2019.

transportation around the world, individual solutions, value-added service, use of transport networks, spatial and timely availability of fast, reliable and flexible services (Baum, Hen, 2004).

Over the past decade, traditional integrators have diversified from a simple express service to large transportation and logistics companies that offer much more than just express service. That is, some of them have become super-integrators that provide the following groups of services:

- classic integrated express delivery services, including courier or special services for urgent goods that cannot be transported by traditional carriers;
- progressive classic transport services, which include ship freight and maritime logistics (door-to-board, LCL, FCL and non-container cargo), standard transport of perishable or dangerous goods, multimodal transport services (such as sea-air transport);
- supply chain management and logistics services. Super-integrators can act as a leading logistics provider, distribution centre operator, offering logistics and distribution consulting services, project management, call centre management, billing services on behalf of clients, implementation of logistics projects and performance management of existing businesses.

Proof of the evolution of classic express carriers to super-integrators is a review of the websites of these companies to determine the mission and market competence:

- “DHL is the global market leader in international express, air and sea freight, ground transportation and logistics” ([dhl.com](http://dhl.com));
- “FedEx is a global provider of transportation, e-commerce and supply chain management services” ([fedex.com](http://fedex.com));
- “TNT is a global provider of postal, express and logistics services” ([tnt.com](http://tnt.com));
- “UPS has become the world’s largest package delivery company and a leading global provider of specialized transportation and logistics services” ([ups.com](http://ups.com)).

Integrator companies compete directly or indirectly with each of the participants in express delivery. They compete with freight forwarders for the process of consolidation and transportation of small packages, with terminal operators and ground handling agents for in-house processing processes, with airlines for air transportation both from airport to airport and from door to door. Moreover, they compete with each other for market share in the express air freight business.

However, researchers of air freight markets note the disadvantages and weaknesses of integrators:

- isolation in its own system. As mentioned above, integrators support the most efficient production systems because they focus on a single standard product (small parcels). About 90% of the integrator infrastructure is built to minimize costs through efficiency, mainly for small freights;

inability to differentiate services. Intense competition among integrators has led to a very important problem: it is extremely difficult for the sender to find a difference in the range and quality of services offered by any of the major integrators, namely UPS, FedEx, TNT and DHL. In order to compete in such conditions, all integrator companies move towards multimodal operations in order to further differentiate their market position. Consider in more detail the technological process of delivery of express shipments in international traffic with the participation of air transport on a door-to-door basis. Traditionally, this process contains sequential and parallel operations:

- collection of small shipments from senders or agents;
- delivery of goods to the regional or central sorting station;

- preparation of cargo for transportation (bringing into a transportable state, accumulation of shipments, etc.);
- loading the cargo and performance of secondary operations (registration of documents, load securing, etc.);
- transfer to the airport of departure;
- cargo, auxiliary and warehousing operations at the airport;
- transfer of cargo to the destination or transhipment airport (hub);
- transit operations in the transhipment port (transhipment, warehousing);
- cargo, auxiliary and warehousing operations at the destination airport;
- moving the cargo to the sorting station;
- loading, auxiliary and warehousing operations at the sorting station;
- delivery of goods to the consignee.

The general scheme of the express delivery chain with the participation of air transport is presented on the Figure 8 [22].

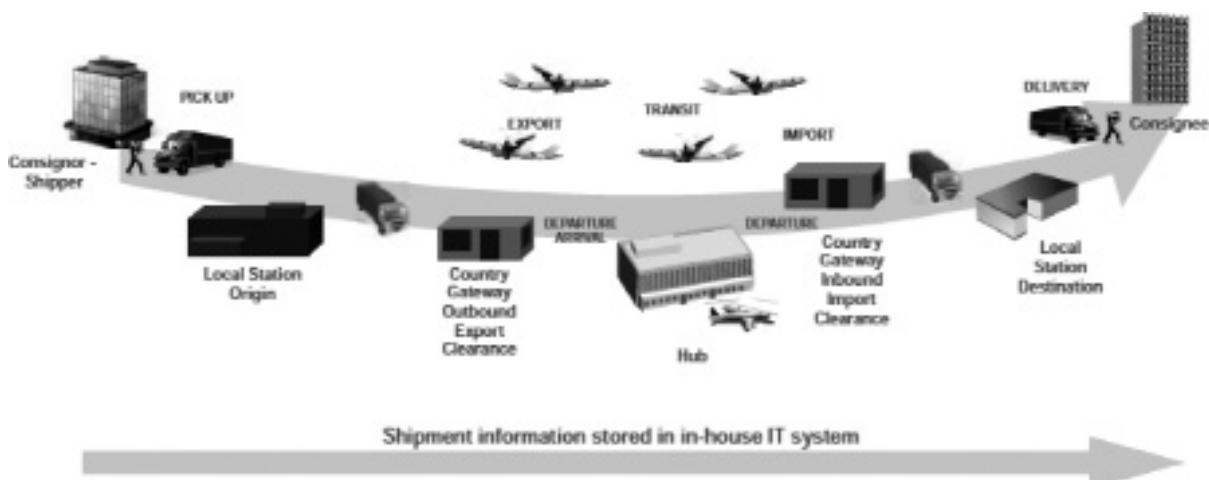


Fig. 8. The structure of the express delivery chain with the participation of air transport

Source: ICAO – WCO. Moving Air Cargo Globally Air Cargo and Mail Secure Supply Chain and Facilitation. Guidelines <https://www.icao.int/Security/aircargo/Moving%20Air%20Cargo%20Globally/Forms/AllItems.aspx>

Management of the express delivery chain involves the integration of information and communication systems and standardization of document flow. These specialized information and communication systems of companies-integrators for urgent cargo allow us to work in the paperless format which is necessary for services on urgent delivery. Companies engaged in this segment prefer to submit the necessary official documentation (such as manifestos and product declarations) in electronic way. Supporting documentation such as commercial invoices is digitized and can be provided electronically or is directly accessible when needed or requested. In cases where national law still requires the provision of paper documents, these documents may be printed on request in the prescribed form.

The key participants in the CEP market are postal operators whose activities are regulated by the Universal Postal Union (UPU). The structure of the postal supply chain is shown in Figure 9 [22].

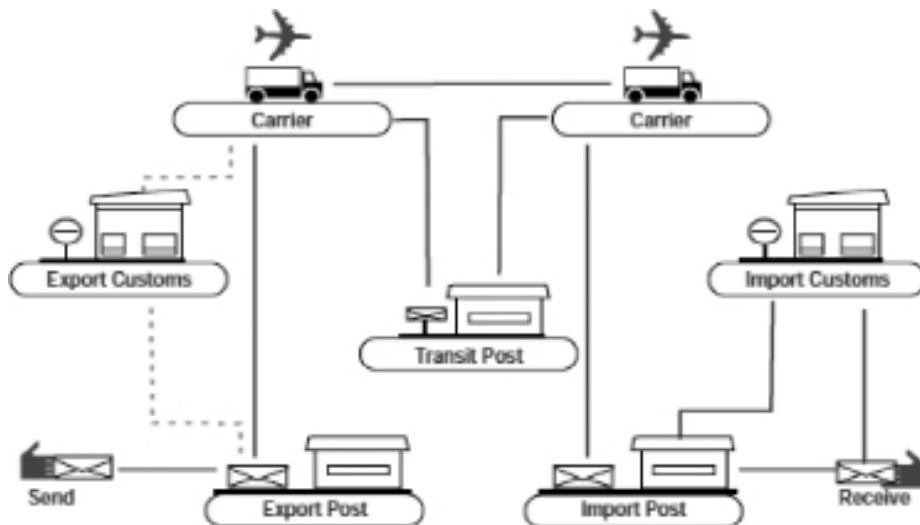


Fig. 9. Postal Supply Chain

Source: ICAO – WCO. Moving Air Cargo Globally Air Cargo and Mail Secure Supply Chain and Facilitation. Guidelines <https://www.icao.int/Security/aircargo/Moving%20Air%20Cargo%20Globally/Forms/AllItems.aspx>

The initial link of postal services is the reception of items in the post office, which takes export items. When making this service, the sender is asked to confirm that the shipment does not contain dangerous parts or items prohibited by postal law before shipment. After that, the customs declaration is attached to the shipment. After further processing of the shipment and possible verification by the customs export department, the point of dispatch addresses the shipment to the aircraft operator. Each postal item sent to the operator is accompanied by transport documentation, as well as operational documents for export purposes. Before loading on board the aircraft, a safety inspection has to be carried out. Article 9 of the Air Force Convention contains specific provisions on the responsibility of postal services for the security and protection of postal items. In addition, some postal employees are certified as registered agents who have the right to inspect mail. Some postal operators are also authorized economic operators. After that, the mail is delivered to the airport, which serves the post office - directly or through several transit stops. Here, the operator of the aircraft to whom the mail is entrusted passes it to the post office in the country of import. The import customs shall check all incoming shipments in order to determine their acceptability and, if necessary, determine the amount of the duty. After cleaning by the import customs, postal items are processed on the territory of the post office-importer. Finally, they arrive at the recipient.

A simplified diagram of the mail delivery chain introduced below [22].

The movement of international mail involves three stages of information exchange: between postal services, between postal services and aircraft operators, between postal services and customs. This process is increasingly happening via email. There is a standardized message format for each of these steps.

The presented description of express delivery and mail delivery processes allows us to synchronize flows and operations in supply chains, which involve several aspects. In general, synchronization is getting to a state of synchrony of two or more flow processes, when the processes in the interacting elements of the logistics system occur with a constant phase relative to each other. This idea allows you to select the following types of synchronization:

- by time - sets the exact time of appearance of the flow, harmonizes the movement of several flows and determines the moment of interaction of flows;

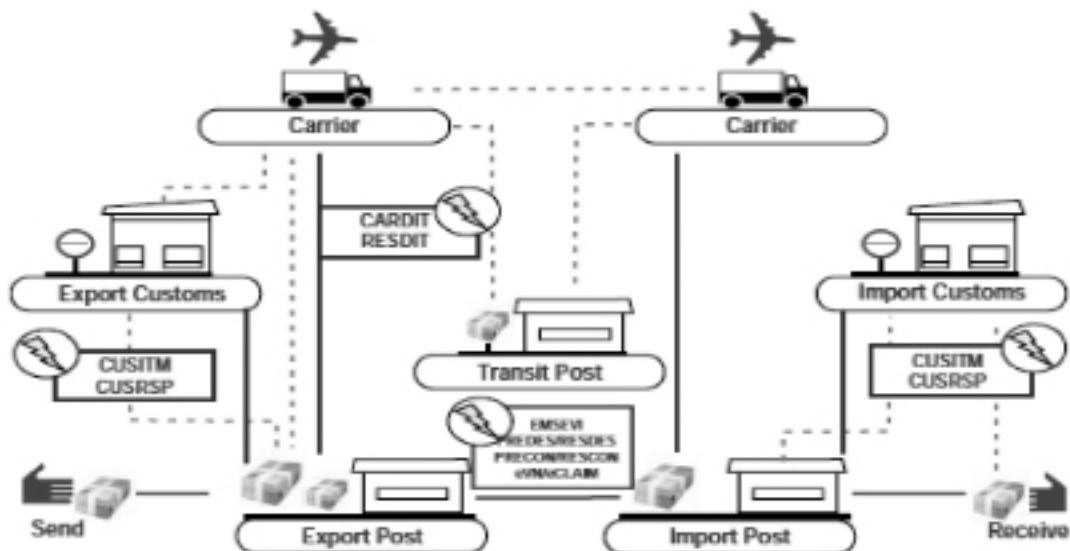


Fig. 10. Electronic information exchanges

Source: ICAO – WCO. Moving Air Cargo Globally Air Cargo and Mail Secure Supply Chain and Facilitation. Guidelines <https://www.icao.int/Security/aircargo/Moving%20Air%20Cargo%20Globally/Forms/AllItems.aspx>

- by volume - ensures compliance with the volumetric characteristics of interacting flows;
- by quality - determines that the incoming material flow (flow of express shipments) has the necessary quality characteristics and can interact with other flows;
- in space - ensures the appearance and reception of flows in the right place.

While functioning of such a complex system of maintenance of flow processes, conflict situations (differences in interests) are possible, due to the relationship between the links in the express delivery chain, and the contradictions between the elements of interacting processes. Avoidance of such conflict situations is possible provided that all goals, operations and resources are removed and contradictions between the elements of interacting processes in the chain are eliminated, namely:

- remove conflicting goals;
- remove the execution of parallel operations that use one available resource, and the available stock of this resource provides the execution of only one operation;
- the gap between the planned value for the respective operations and the actual one should not exceed the established limits.

#### 4. THE MATHEMATICAL MODEL OF THE OPTIMAL SCHEME FOR SPECIAL CATEGORIES GOODS DELIVERY

In our opinion, the integrator company determines the standards of customer service (senders and recipients of ES), as well as the list of services that should be outsourced to other participants in the CEP market. In determining the requirements for business partners, the integrator of the express delivery chain should focus on the quality of customer service both in terms of its own organization and in terms of the parameters of the supply chain. Then, taking into account the declared service and the state of development of infrastructure of various modes of transport, it identifies the main business partners (logistics intermediaries) in the service regions (postal and courier companies, car and air carriers, freight forwarders and customs brokers). The tools of synchronization of the flow process are the mechanisms of influencing the parameters of both the controlled and interdependent flows, as well as the processes occurring in different links of the chain.

Computer modelling and optimization methods are used to optimize processes in express delivery chains and enhance the effect of synchronization of flows, processes and economic interests of express delivery chain links. Given the fact that each operation in the express delivery chain is characterized by parameters: duration, cost of resources and funds, we can calculate the duration of express delivery and assess the reliability of the customer's order "just in time" fulfilment. However, in real time in any link of the cargo flow there may be delays or failures in operational processes, as well as a possible increase in delivery time due to uncoordinated actions of consequent links in the chain and the formation of queues. The mathematical model for choosing the optimal scheme for urgent goods delivery could be presented as:

where  $i$  - type of operation with cargo in the express delivery chain,  $i = \overline{1, n}$ , where  $n$  is the total number of operations for delivery of one express shipment on a door-to-door basis;  $k$  is the index of the enterprise that participates in the operations of the express delivery chain,  $k = \overline{1, m}$ , where  $m$  is the total number of enterprises that can perform operations in the express delivery chain,  $I_k$  - the set of enterprises that can perform

$$\sum_{i=1}^n \sum_{k \in I_k} (c_{ik} t_{ik} + \Delta_{ik}(\tau_{ik}) p_{ik} + r_{ik}) x_{ik} \rightarrow \min , \quad (1)$$

$$\text{MIL} = \sum_{i=1}^n \overline{t_{ik}} x_{ik} + \rho_p \sqrt{\sum_{i=1}^m \sigma_i^2 + 2 \sum_{i \leq j} r_{ij} \sigma_i \sigma_j} , \quad k \in I \quad (2)$$

$$P(\alpha < T_k^{MIL} < \beta) = \Phi \left( \frac{\beta - \sum_{i=1}^m \overline{t_{ik}}}{\sqrt{\sum_{i=1}^m \sigma_i^2 + 2 \sum_{i \leq j} r_{ij} \sigma_i \sigma_j}} \right) \Phi \left( \frac{\alpha - \sum_{i=1}^m \overline{t_{ik}}}{\sqrt{\sum_{i=1}^m \sigma_i^2 + 2 \sum_{i \leq j} r_{ij} \sigma_i \sigma_j}} \right) \geq 0,95 \quad (3)$$

$$\overline{t_{ik}} = t_{ik} + \tau_{ik} , \quad i = \overline{1, n} , \quad k \in I_k , \quad (4)$$

$$\sum_{k \in I} x_{ik} = 1 , \quad i = \overline{1, n} , \quad (5)$$

$$x_{ik} \geq 0 , \quad x_{ik} \in \{0, 1\} , \quad k \in I_k , \quad i = \overline{1, n} , \quad (6)$$

the operation  $i$ ,  $c_{ik}$  - the cost of execution of the operation  $i$  of the delivery cycle by the enterprise  $k$ ;  $\overline{t_{ik}}$  - the average duration of the operation  $i$  when performing by the enterprise  $k$ ,  $\Delta_{ik}(\tau_{ik})$  - monetary estimate of potential losses depending on the duration of the delay of the operation  $i$  by enterprise  $k$ ,  $r_{ik}$  - transaction costs for interaction with the counterparty when performing the operation  $i$  by enterprise  $m$ ;  $\sigma_{ik}$  - standard deviation of the operation  $i$  by the enterprise  $k$ ;  $p_{ik}$  - the probability of delay in the operation  $i$  by the enterprise  $k$ ;  $\rho_p$  - the parameter of the normal distribution, which corresponds to the probability  $p$ ,  $r_{ij}$  - the correlation coefficient between the operations  $i$  and  $j$  of the delivery cycle,  $\alpha$  and  $\beta$  - respectively the lower and upper limit of time delivery "just in time",  $\Phi$  - tabulated function of the normal distribution,  $x_{ik}$  - Boolean variable, which takes the value of 1 when performing the operation  $i$  by enterprise  $k$  and 0 otherwise.

The proposed model (1) - (5) allows us to find such schemes of movement and processing of goods, which will ensure the delivery of express shipments to the recipient within the specified time with minimal costs.

Studies of organizational and technological schemes of express shipments delivery show that delivery time depends on many factors, therefore, is a random variable that can be used to estimate statistical methods.

The total duration of express delivery can be determined by the formula:

where n is the number of stages of a specific transport-technological scheme of transportation of ES, j is the number of a separate stage,  $t_j$  is the normative duration of the stage j of cargo delivery (calculated without considering random delays);  $\tau_j$  - possible time delay when performing the stage j of delivery.

If there are no regulatory requirements for the duration of individual operations, it can be used the results of

$$T = \sum_{i=1}^n (t_i + \tau_i), \quad (7)$$

observations of individual operations, to determine the minimum and maximum duration of operations, as well as its mean values and standard deviations.

If the customer of express transportation makes a request for delivery of ES at a certain time or indicates a permissible deviation from the specified time or a permissible time range, the main parameters of the model "just in time" are calculated by the formula:

where  $T_n$  is the moment of the beginning of the delivery cycle,  $x_p$  is the parameter of the normal distribution, which corresponds to the probability  $p$ ;  $\sigma_T$  is the standard deviation of the delivery cycle duration, which can be calculated by the formula:

$$T_{TB} = T_n + \bar{T} + x_p \sigma_T, \quad (8)$$

where  $\sigma_i$  - standard deviations of the duration of the operation  $i$  of the technological scheme of delivery;  $r_{ij}$  is the correlation coefficient between the operations  $i$  and  $j$ .

$$\sigma_T = \sqrt{\sum_{i=1}^n \sigma_i^2 + 2 \sum_{i,j} r_{ij} \sigma_i \sigma_j}, \quad (9)$$

If the duration of the express delivery is given by a range of values, it is necessary to estimate the upper and lower limits of the duration of the delivery according to formula 8.

The probability of fulfilment "just in time" is calculated:

a) in case of the exact value of the delivery time - with formula 10.

where:  $\Phi(\dots)$  is a tabulated function of the normal distribution;

b) in case of the range of the moment of delivery - with formula 11.

$$P = \Phi\left(\frac{T - \bar{T}}{\sigma_T}\right), \quad (10)$$

The proposed mathematical model allows us to find such schemes of movement and processing of goods, which will ensure the express shipments delivery within the specified time with minimal cost. Both standard

$$P(\alpha < T < \beta) = \Phi\left(\frac{\beta - \bar{T}}{\sigma_T}\right) - \Phi\left(\frac{\alpha - \bar{T}}{\sigma_T}\right), \quad (11)$$

and modified methods can be used to solve the mathematical problem. Today, there are both universal simulation applications for discrete systems (e.g., Any Logic or Arena) and specialized, focused on supply chain modelling (e.g., Supply Chain Builder).

## 5. CONCLUSION

The article shows that in the context of accelerating the processes of economic integration in aviation logistics at the micro, meso and macro levels, complicating the forms of business organization, the emergence of new forms of cooperation between companies and new ways of jointly creating added value, many organizational boundaries in the economy are becoming more blurred and dynamic. The use of the concept of “ecosystem” in research is growing. An attempt is made to consider the possibility of using the “ecosystem” design for economic analysis at the aggregated level and to highlight the elements of the aviation logistics ecosystem on which the attention of researchers will be focused.

There are two approaches to the definition of this ecosystem. As part of the first approach to the ecosystem, interdependent organizations are involved in the production of products; in the second, as a system of interconnected technologies. From the authors point of view, the aviation logistics ecosystem is a combination of aviation, logistics, transport and postal organizations, which provide goods express delivery supply chains with a system of interconnected technologies use.

In the framework of article analysis of air cargo industry framework, synchronization and digitization of service operations in air cargo service supply chain, express delivery supply chains were represented. The authors proposed a mathematical model that allows logisticians to optimize the supply chain of special categories of goods, which is one of the priority tasks of the aviation logistics ecosystem.

Universities play a significant role in the development of training programmes, technology, and regulations of aviation logistics. National Aviation University and International University of Logistics and Transport in Wroclaw are paid special attention to the field of aviation and transport logistics and more than 10 years develop joint scientific and educational activity in this sphere. More than 30 joint international scientific-practical congresses and conferences, successful programs of mobility of professors and students, joint publications and innovation projects play a significant role for improvement of aviation logistics level [37].

Currently, the National Aviation University, Kiev, Ukraine and the International University of Logistics and Transport in Wroclaw, Poland, introduce new innovative joint educational programme “Aviation Logistics”. Scientific and education activity of the universities aims to develop a system of training of highly qualified aviation logistics specialists. This article is the next step on the way of fruitful scientific – educational cooperation of our institutions. Improvement of instruments and methodologies of aviation logistics system is the basis for its further development.

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